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Climateflation and Monetary Policy in an Environmental OLG Growth Model

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Abstract
Central banks are gradually acknowledging that climate change can potentially impact price stability, and the term *climateflation* has entered the vocabulary of policymakers. The present paper contributes to the emerging literature around this concept. We develop an Overlapping Generations (OLG) model to study the interplay between conventional monetary policy and the environment when the so-called "independence hypothesis" does not hold, i.e. money is not neutral in the long run. We aim to provide some initial insights on the macroeconomic and environmental implications of using a Taylor rule to manage interest rates under two critical assumptions. First, environmental quality (degradation) has a positive (negative) externality on production through a damage function. Second, we innovate by linking the environment to inflation through expectations in a modified Phillips curve. Central banks shape wealth composition via the individual's intertemporal optimisation problem, breaking the "independence hypothesis". Numerical experiments allow us to assess the relationship between environmental quality and economic activity when (i) expectations are more responsive to *climateflation*, (ii) the monetary authority responds strongly to inflation deviations from its target, (iii) there is an increase in the inflation target, and (iv) whether fiscal policy is green expansionary.

Keywords Monetary policy · Inflation targeting · Green transition · OLG

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1 Introduction

The assumption that productive capacity is independent of monetary policy remains the dominant paradigm in macroeconomics. It lies at the basis of the inflation-targeting framework used by most central banks (see Blanchard 2018). While such a consensus was never unanimous—and there have always been some dissent voices outside more mainstream circles (Minsky 1993)—recent empirical evidence is challenging the view that money is neutral in the long run (e.g. Jordà et al. 2023; Ma and Zimmermann 2023). The topic is increasingly receiving attention as data seems to support the relevance of hysteresis effects on economic performance (see, for example, Summers 2015; Girardi et al. 2020; Furlanetto et al. 2023; Fazzari and Gonzales 2025).

On the other hand, central banks are gradually realising that climate change can potentially impact prices and financial stability. As a result, scholars and policymakers have started to explore different channels through which monetary policy and environmental targets interact. For example, climate transition expenditures require large upfront costs, making them susceptible to changes in credit accessibility. Variations in interest rates have measurably contributed to the cost of renewable energies (Schnabel 2023). There has been a special concern on transmission mechanisms related to physical and transition risks (see NGFS 2019; ECB 2021). Recent efforts include the pioneering proposal of a climate-augmented monetary policy rule (Chen et al. 2021; Bacchiocchi et al. 2024) and how quantitative instruments, as well as credit allocation programmes, could minimise climate change-related financial distress (e.g. Campiglio 2016; Dafermos et al. 2018).

Our research question lies in the intersection between these two major themes. We are interested in the interplay between conventional monetary policy and the environment in a context where the so-called "independence hypothesis" does not hold, i.e. money is not neutral in the long run. More specifically, we develop a model that allows us to study the environmental and macroeconomic implications, both in terms of output and inflation, of linking mechanically the level of the baseline interest rate to deviations of inflation from its target under two crucial assumptions. First, environmental quality (degradation) has a positive (negative) externality on production. Second, as the adverse consequences of climate change materialise and agents become more aware of them, they influence inflationary expectations. Our goal is not to derive an optimal rule but rather to study the side effects of a specific type of policy.

For this purpose, we rely on an Overlapping Generations (OLG) framework.[1] It stands as a popular tool among scholars interested in green-growth dynamics (e.g. John and Pecchenino 1994; Zhang 1999; de la Croix and Gosseries 2012; Wei and Aadland 2022; Jaimes 2023), providing a useful structure that permits analysis of situations where agents' actions have consequences that outlive them. Moreover, OLG models have the realist feature of

[1] A suitable alternative would be to rely on a New Keynesian model with endogenous growth (e.g. Garga and Singh 2021). While future research in that direction is to be encouraged, we refrain from going in that direction for two main reasons. First, we want to bring climateflation and monetary policy into the discussion using a framework that is somehow consolidated among environmental economics, allowing agents' actions to have consequences that outlive them. Second, our toy model permits us to keep a somehow more parsimonious structure.

treating government debt as net wealth. This well-known attribute creates a natural set-up in which monetary policy has real consequences because it determines the composition of the public's portfolio between government debt and other assets (for a comprehensive discussion, see Hu et al. 2023). Despite not being the main workhorse model to deal with monetary policy, OLGs have been used to study inflation and savings dynamics (see Bernasconi and Kirchkamp 2000; Sterk and Tenreyro 2018), optimal monetary policy rules (Crettez et al. 2002; von Thadden 2012; Hiraguchi 2014), rational asset price bubbles (as in Gali 2014), and the non-neutrality of monetary policy (e.g. Braun and Ikeda 2021; Hu et al. 2023).

We assume agents live for only two periods: young and old. They work during the first phase and save all income in capital or government bonds. In the second period, they consume their previous savings. Building on John and Pecchenino (1994), individuals derive utility from consumption and environmental quality (see also Caravaggio and Sodini 2023). The former harms the environment, which feeds a damage function that reduces economic activity. Firms operate in a competitive market, so wages correspond to the marginal productivity of labour weighted by the externality from ecological conditions (as in Brock and Taylor 2010). We innovate by linking ecological degradation to inflation through a modified Phillips curve. It is argued that people incorporate *climateflation* resulting from physical and transition risks into their expectations. Central banks set the nominal interest rate using a generalised Taylor rule that responds to such price pressures. Finally, interest rates shape wealth composition through individuals' intertemporal optimisation problem.

We perform a set of numerical experiments under four main scenarios. In the first, we assume agents become more responsive to *climateflation*. Thus, the monetary authority needs to increase the interest rate to keep expectations anchored. Its action raises the share of wealth going to public debt and reduces capital accumulation, decreasing output. A reduction in economic activity diminishes pollution but also harms conservation efforts; this last effect prevails, deteriorating environmental quality. Therefore, inflation expectations remain above the baseline case. The second scenario corresponds to a situation where the central bank responds strongly to deviations of inflation from its target. Despite such a sharp reaction, if inflationary pressures from environmental degradation are relatively small, the monetary authority actually implements a less stringent monetary policy. People respond by saving less in the form of bonds and physical assets. Less capital implies a reduced output. On the other hand, lower accumulated wealth results in less consumption, the net outcome being an improvement in environmental quality. Thus, we document the possibility of a trade-off between economic activity and the environment.

In the third scenario, we assume the central bank understands *climateflation* as a "fact" and adopts, as a response, a more lenient monetary policy by increasing the inflation target. Not surprisingly, agents get away from public bonds. However, capital accumulation is sustained in this case, leaving output unchanged. Resources allocated to environmental conservation are not harmed. Moreover, a reduction in overall wealth leads to lower consumption. Combined, these two effects allow for a marginal improvement in environmental quality. Still, it is insufficient to curb inflation, which remains unchanged. Finally, we examine the model's response to a more flexible fiscal policy. We show the most dangerous scenario arises when the government increases its deficit without addressing environmental quality. This leads to a robust switch towards public bonds, bringing capital accumulation down. Consequently, output is also strongly reduced. The contraction in economic activity is so large that it reduces the pool of resources available for conservation purposes, creat-

ing a lose-lose situation. Alternatively, adopting an expansive *green* fiscal policy lowers inflationary expectations by increasing (reducing) the positive (negative) externality from environmental quality (degradation). Moreover, the mitigation of climate-related risks also directly benefits economic activity. Therefore, it is shown that a green fiscal program can create win-win gains.

The remainder of the paper is organised as follows. Section 2 brings a general overview of the phenomenon of *climateflation*, including definitions and reactions from policymakers to the concept. Section 3 presents our OLG growth model with a detailed explanation of its main transmission channels. It will be calibrated in Sect. 4 in line with the four main scenarios previously discussed. Some final considerations follow.

2 Main Notions and Stylized Facts

Climateflation is a term increasingly being used to describe price increases directly resulting from climate change. It has gained attention from central banks as they acknowledge the potential negative impact of global warming on economic stability. It has become a central issue addressed by the ECB's Governing Council. They have identified five main transmission mechanisms connecting monetary policy and climate-related risks: The interest rate, as uncertainty about policy responses increases risk premia and affects the natural rate of interest; a credit channel, given that delinquent loans restrict the supply of credit; an asset price channel, since they generate capital destruction and lower company valuations; the exchange rate, considering that the adjustment of the carbon frontier can interrupt global value chains in terms of prices; and expectations, as less predictable transition policies that are inconsistent over time reduce the credibility of monetary policy.

Indeed, the relatively large upfront costs incurred in green capital-intensive expenditures make them particularly susceptible to changes in the cost of credit. For example, low and declining interest rates have measurably contributed to the fall in the LCOE of renewable energies (see Schnabel 2022, 2023). While price stability is a prerequisite for a sustainable transition, recent inflation dynamics threaten it. Central banks usually tighten monetary policy to keep inflation under control, and consequently, financing conditions become more restrictive. Since fossil fuel-based power plants have comparably low upfront costs, a persistent rise in the cost of capital may discourage efforts toward rapid decarbonisation.

Moreover, unless GHG emissions are cut rapidly, the economic system will likely remain exposed to the risks of "climateflation".[2] The main idea is directly linked to the cost of climate change: As climate-related risks rise, such as severe weather events, so does their impact on economic activity and prices. While the evidence is still preliminary, authors such as Parker (2018) find that natural disasters may have had substantial and persistent upward effects on the price levels of developing countries. Applying panel local projections for 48 advanced and emerging market economies, Faccia et al. (2021) suggest that very hot seasons have a marked impact on prices over the near term, though the impact across the various

[2] Related categories are "fossilflation" and "greenflation". The former is a simple portmanteau for inflation in fossil fuel prices. The latter is related to the fact that green technologies require large amounts of metals and minerals, such as copper, lithium and cobalt, especially during the transition period. Thus, there is a push in the demand for most metals and minerals, increasing their prices and ultimately affecting overall inflation. This paper focuses on the concept of *Climateflation* as a supply-side climate-change-related inflation pressure.

price indices tends to disappear. Using data on 173 countries from 1970 to 2020, Cevik and Jalles (2023) conclude that inflation and growth respond significantly to disasters caused by climate change, but the impact varies in terms of direction and magnitude. Output is normally negatively impacted, while droughts and storms lead to higher inflation. Exploiting a global dataset of monthly consumer prices, Kotz et al. (2023) show that increased average temperatures cause non-linear upward inflationary pressures, which persist over 12 months in both higher- and lower-income countries.

Climate change is related to various supply shocks threatening inflation stability. Insights on how successfully different countries have been in improving environmental conditions can be obtained from the Environmental Performance Index (EPI), which is a composite indicator developed by the Yale Center for Environmental Law & Policy and the Center for International Earth Science Information Network Earth Institute. It is a measure at the national level of how close countries are to the established environmental policy objectives. The EPI ranks up to 180 countries regarding climate change performance, environmental health, and ecosystem vitality. Its range goes from 0 to 100, the highest possible performance.

We report in Fig. 1(a) the scatterplot of the EPI in 2020 against expected 2024 inflation, as reported by the OECD. The dotted line marks the trend controlled by 2020 per capita Gross Domestic Product (GDP) using 2017 Purchasing Power Parity (PPP) international

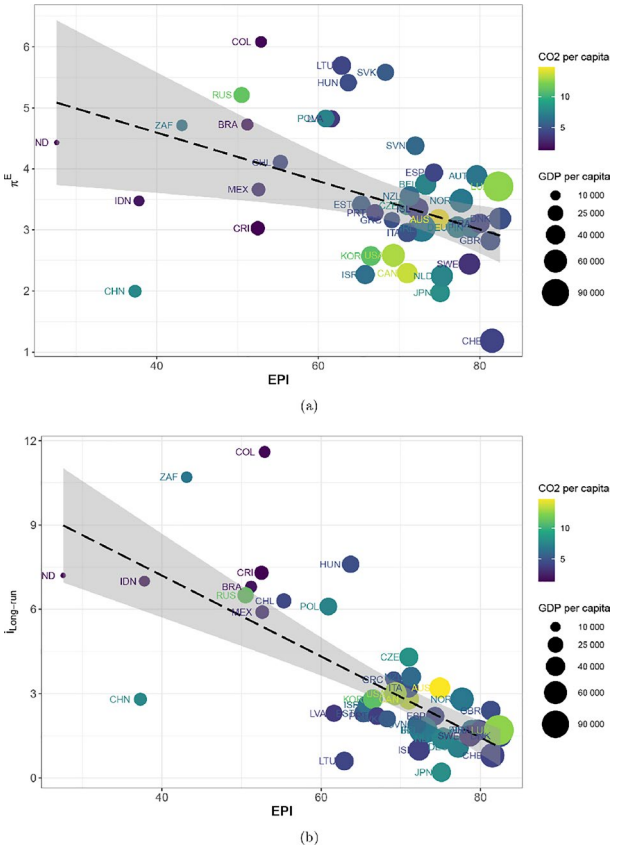

Fig. 1 EPI, expected inflation, and long-run interest rates

dollars. The colour of the circles is related to the CO2 per capita emissions in kilotons. We plot in grey the region corresponding to the 95% confidence interval. The curve's downward slope suggests a negative correspondence between the two variables.[3] Figure. 1(b) plots the EPI versus the OECD-provided long-term interest rate, showing a negative correlation between them again. In the context of climate-related price pressures, inflation expectations and long-run interest rates are connected by environmental conditions and monetary policy. While both diagrams are only correlations, causality will likely run in both directions, reinforcing each other. The model developed in the next section aims to provide some insights into the mechanisms behind them.

In a recent document, the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) concludes that the impact of natural disasters might imply a potential long-term adverse effect on the global activity of up to minus 15 per cent (NGFS 2022). Such uncertainty also harms economic growth, as global warming-related repercussions increase risk aversion and lead to unstable investment demand. Economic growth may be directly affected as innovation resources are diverted to rebuilding and adaptation to climate risks (as in Letta and Tol 2019). This raises additional concerns regarding the divide between Global North and South, given that developed economies have lower inflation rates and somehow better environmental performance, while countries like India, Indonesia, and South Africa register the lowest EPI and highest inflation rates.

Whereas climate change may complicate the conduct of monetary policy to guarantee price stability (Coenen et al. 2018), central banks are discussing whether to intervene by applying instruments that favour green production and investment (see Acemoglu et al. 2012; Schnabel 2020, 2021). How monetary policy is carried out can influence the effectiveness of the transition. Scholarship assessing this nexus is still relatively scant (e.g. Adjemian and Darracq Pariès 2008; Annicchiarico et al. 2018; Annicchiarico and Diluiso 2019; Solana 2019). Authors such as Annicchiarico and Di Dio (2015) have explored what would be the optimal monetary policy response to climate change, pointing out that environmental degradation generates additional economic shocks that will affect the optimal conduct of the former (see also Economides and Xepapadeas 2018, 2019).

The bottom line of the evidence surveyed in this Section is that if climate change and environmental quality are intrinsically related, a deterioration in ecological conditions leads to higher climate risks. They are increasingly disrupting production, damaging output and creating inflationary pressures. As central banks are responsible for price stability and use monetary policy to achieve this goal, intuitively, managing interest rates might have long-lasting effects. While existing studies provide important insights regarding the problem at hand, our reading of the relevant literature is that most of it continues to fundamentally rely on the so-called "independence hypothesis", i.e. money is neutral in the long run. Considering the increasing evidence pointing out this might not be the case (e.g. Jordà et al. 2023; Ma and Zimmermann 2023), we aim at developing a model that allows us to study the environmental, inflationary, and output consequences of conventional monetary policy in a context where it has real consequences. As shown by Hu et al. (2023), OLGs offer a convenient framework for such a task because they treat government debt as net wealth.

[3] Of course, the scatter plots presented here aim only to provide a glance at how the variables correlate, having no causal meaning. In fact, the main purpose of the model developed in the present paper is to show that environmental conditions impact the macroeconomy and vice-versa so that both are simultaneously determined.

3 The Model

We consider an OLG economy where agents live for two periods: young and old. They work during the first phase and save all income in capital or government bonds. In the second period, they consume their previous savings. Our study builds on Caravaggio and Sodini's (2023) revisitation of the baseline environmental OLG growth model by John and Pecchenino's (1994) that has recently become quite popular among scholars interested in green-growth dynamics (e.g. Antoci and Sodini 2009; Caravaggio and Sodini 2022; Wei and Aadland 2022; Jaimes 2023). The present paper extends its framework in two different ways. First, we incorporate a damage function from emission externalities to output (see Brock and Taylor 2010). Second, we link ecological degradation to inflation through a modified Phillips curve, allowing us to assess conventional monetary policy's environmental implications.[4] It is argued that people incorporate *climateflation* resulting from physical and transition risks into their inflationary expectations. The monetary side of the economy is developed along similar lines to von Thadden (2012) and Hu et al. (2023). Our model joins recent efforts assessing the implications of including environmental goals into the monetary policy (for example Dafermos et al. 2018; Chen et al. 2021 pioneering proposed a climate-augmented monetary policy rule).

The OLG framework offers a natural setup where money is not neutral in the long run. As shown by Hu et al. (2023), even in the absence of any frictions, monetary policy has real effects because it determines the return on government debt, thus influencing the composition of the public's portfolio between government bonds and other assets. The "trick" consists in treating public debt as net wealth. Figure 2 provides a summarising diagram of our environmental OLG model, which is divided in four main blocks of equations:

1. Production technology
2. Government's budget constraint
3. Lifetime choice problem
4. Inflation and monetary policy

Agents get utility from consumption and environmental quality. Consumption harms the environment, but as the public values the latter, people also devote resources to ecological conservation and recovery. Still, for each level of environmental quality, there is an externality on production in the form of a damage function. Environmental degradation is reflected in such a function, which further embodies physical and transition risks associated with climate change. As those climate-related risks accumulate, they constitute a sort of permanent supply shock. Agents respond by adjusting the inflation expectations. On the other hand, the monetary authority uses the interest rate to achieve price stability. We know there is an ongoing debate on the best instrument available to central banks to assess this kind of shock. However, given that there is no consensus on the matter yet, we limit the analysis to a traditional Taylor rule. The choice of the interest rate feedbacks to the intertemporal optimisation problem of the agent, affecting her/his wealth composition. The amount of output produced depends on how much capital is accumulated.

[4] By introducing monetary policy and public debt into this framework, our results are not directly comparable to John and Pecchenino (1994) or Caravaggio and Sodini (2023). Both studies are purely specified in real terms without touching the money element. Zorner and Kubin (2024) have monetary considerations in an OLG model a la Matsuyama et al. (2016). However, they assume a balanced fiscal budget at all times, a clear distinction with respect to our model.

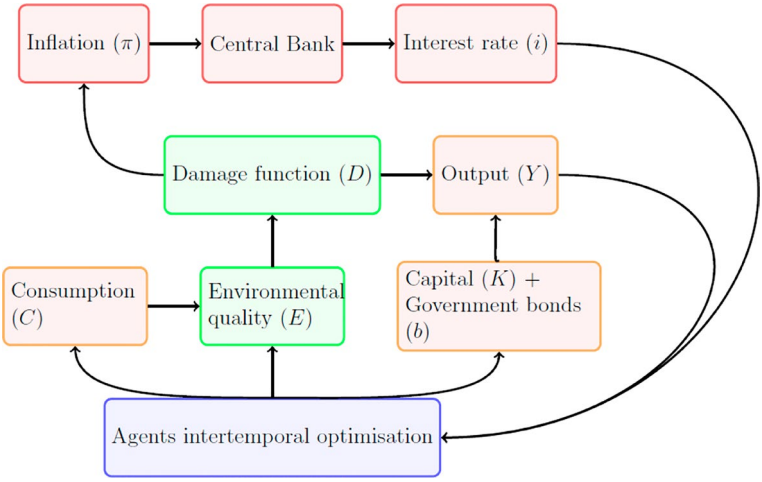

Fig. 2 A summarising diagram of our environmental OLG model

3.1 Production Technology

Firms adopt a production technology that combines capital (K) and labour (N), the latter corresponding to a constant number of identical two-period lived young agents. Climate change enters the picture as a negative externality on factors of production. Global warming damages the capital stock directly through natural disasters or indirectly through the fear that extreme events might happen, increasing investment risk and reducing its profitability. Moreover, the workforce is also affected by heat waves and other climate-change-related health problems. Such effects are represented by the function $D(\cdot) \in [0, 1]$. If we assume they equally affect K and N, it follows from the property of constant returns:

$$\begin{gathered} Y_t = [1 - D(E_t)]F(K_t, N) \\ D_E < 0, F_K > 0, F_N > 0, F_{KK} < 0, F_{NN} < 0 \end{gathered} \tag{1}$$

where Y denotes output, $F(\cdot)$ is the standard neoclassical production function with constant returns to scale. Physical capital fully depreciates within the production process of one period. Climate-change-related externalities are an inverse function of an environmental quality index (E) such that high carbon emissions are associated with more ecological degradation, leading to lower output.

We adopt a functional form for the damage function that comes with a smooth nonlinearity:

$$D(E_t) = \frac{1}{1 + \eta E_t} \tag{2}$$

where η is a parameter that intermediates the relationship between E and y, and captures the positive (negative) externality of environmental quality (degradation) on economic activity. The lower η is, the higher the damage $D(E_t)$ on output y_t will be. This specification has some similarities with Dafermos et al. (2018), which build on previous work by Weitzman

(2012). The main difference is that $D(\cdot)$ responds to an environmental quality index instead of global average temperatures in our setup (for considerations on environmental externalities evoking some sort of damage function see also Rezai et al. 2012; Antoci et al. 2014; Dao et al. 2017; Borghesi et al. 2019, among others).

Figure 3 provides a more concrete view of its format, taking the EPI as a reference point, and measuring the output loss.[5] The blue, orange, and yellow lines indicate the sensitivity of the damage function to different values of η. The black dotted line marks the index value for Denmark (DNK), a country with one of the highest EPI scores, South Africa (ZAF), at the other extreme, and the United States (USA), as an intermediate case. It is shown that when the η value is low, in blue, the output loss is relatively high. In this situation, countries with the same production technology might experience large differences in output due to discrepancies in their environmental performance. Alternatively, when η is large, in yellow, countries with a similar $F(\cdot)$ encounter small differences in output even under large EPI gaps. Put differently, economies characterised by sectors with a high sensitivity to environmental quality experience the largest damage. Overall Fig. 3 delivers output losses similar to those reported by Dynamic Integrated Climate-Economy (DICE) models (for an overview, see Nordhaus 2019).

From Eq. (1), output per young agent (y) can be written as:

$$y_t = [1 - D(E_t)]F(k_t, 1) = [1 - D(E_t)]f(k_t) \tag{3}$$

where $y = Y/N$, capital per unit of labour is $k = K/N$ and $f(\cdot)$ corresponds to the production technology in percapita terms. As before, improving environmental conditions reduces the negative impact of the damage function, resulting in higher economic performance.

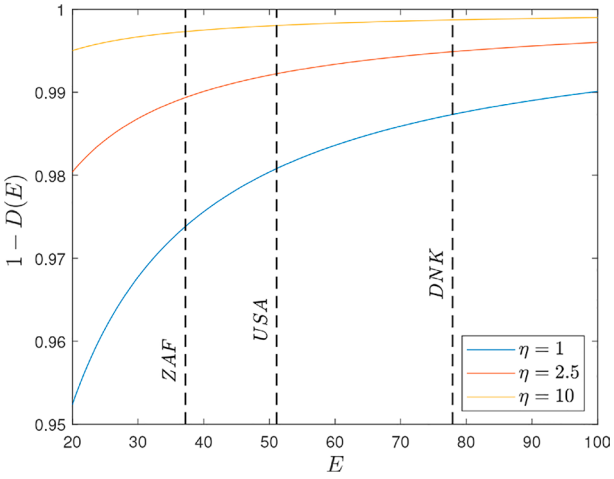

Fig. 3 Sensitiveness of the damage function to different values of η. Environmental quality is *proxied* by the EPI that ranges between [0,100]

[5] While the EPI provides an interesting statistic to position leaders and laggards in terms of their environmental performance, its main problem lies in the positive relationship with Gross Domestic Product (GDP). Such a correlation is an issue because richer countries happen to be those that pollute more in per capita terms, creating an awkward situation where high carbon emitters present better environmental performance. They have also historically led the process of environmental degradation after the Industrial Revolution. Our results should be interpreted in the light of this limitation.

We assume a Cobb-Douglas technology to keep the exercise simple and tractable from an algebraic point of view. This implies:

$$f\left(k_t\right) = Ak_t^{\alpha} \tag{4}$$

where $\alpha \in [0, 1]$ is the correspondent technical coefficient and A is a scaling parameter capturing the so-called total factor productivity. Therefore, it immediately follows that the share of wages on income is $1 - \alpha$. Given that production factors are remunerated according to their marginal productivity, from the profit-maximisation problem of the firm, we have that:

$$\begin{aligned} w_t &= [1 - D(E_t)]\left[f\left(k_t\right) - f_k\left(k_t\right) k_t\right] \\ &= (1 - \alpha)[1 - D(E_t)]Ak_t^{\alpha} \end{aligned} \tag{5}$$

and

$$\begin{aligned} r_t &= [1 - D(E_t)]f_k\left(k_t\right) \\ &= \alpha[1 - D(E_t)]Ak_t^{\alpha-1} \end{aligned} \tag{6}$$

where w and r are the wage and profit rates in real terms. We would like to stress that it is assumed that capital fully depreciates within the production process of one period. Notice that the damage function implies that a deterioration of the environment due to carbon emissions reduces the remuneration of both production factors.

3.2 Government's Budget Constraint

The government consumes a share of nominal per capita output in each period without affecting households' utility. In this way, we abstract for the moment from the possibility of the public sector directly fighting climate change, for example, through carbon taxes or permits (for an application related to demography, see de la Croix and Gosseries 2012; Cafferata and Davila-Fernandez 2024). Of course, this does not mean such channels are not important, and we will come back to them later on. The primary balance (g) plus interest payments are financed through the emission of government bonds (b). Thus, the public sector budget constraint can be summarised as follows:

$$g_t + \left(\frac{i_{t-1}}{1 + \mathbb{E}[\pi_t]}\right) b_{t-1} = b_t \tag{7}$$

where i is the one-period interest factor on government bonds per young agent and the operator $\mathbb{E}[\cdot]$ stands for expectations. Therefore, the real expected value of public bonds issued in $t - 1$ is given by $b_{t-1}/(1 + \mathbb{E}[\pi_t])$ with π as the inflation rate. All government spending, including its debt service net of taxes, must be financed by issuing new bonds. They are supposed to mature within one period. Hence, b should be understood as a one-period debt constantly being rolled over.

Debt targets can serve as a fiscal policy anchor to ensure the sustainability of fiscal policy and that there is sufficient policy room to cope with adverse shocks (e.g. von Thadden 2012; Fall and Fournier 2015). They provide a commitment tool that reassures markets, thereby

diminishing risk premiums. To guarantee the stability of public debt, the fiscal agent is assumed to follow a rule that keeps the primary balance as a proportion to output (θ) constant. Considering that our goal here is not to derive the best fiscal policy but to study the side effects of a given type of policy, we take θ as exogenously determined. Making use of Eqs. (3) and (4), we have that bonds in a certain period are such that:

$$\frac{g_t}{y_{t-1}} = \theta$$

i.e.

$$g_t = \theta[1 - D(E_{t-1})]Ak_{t-1}^{\alpha} \tag{8}$$

In this way, public debt becomes a function of environmental quality. By fuelling the damage function, high emissions reduce output. Thus, the primary balance compatible with the fiscal target will also be lower. This result is an immediate consequence of our simple, yet realistic, fiscal rule.

Substituting Eq. (8) into (7) and leading the resulting expression by one period, we obtain the dynamics of public debt as:

$$b_{t+1} = \theta[1 - D(E_t)]Ak_t^{\alpha} + \left(\frac{i_t}{1 + \mathbb{E}[\pi_{t+1}]}\right) b_t \tag{9}$$

such that the evolution of public debt responds to the environment, capital stock, and monetary policy. The latter matters in the form of interest and inflation rates.

3.3 Lifetime Choice Problem

We assume agents derive utility only from consumption (c) and environmental quality. Each representative individual born at time t has preferences defined over c and E at $t+1$, i.e. old age. To keep the algebraic steps as simple as possible, suppose an additively separable logarithmic utility function represents them. The lifetime choice problem consists in:

$$\begin{gathered} \max_{c_{t+1}, E_{t+1}} U\left(c_{t+1}, E_{t+1}\right) \\ U\left(c_{t+1}, E_{t+1}\right) = \ln c_{t+1} + \ln E_{t+1} \end{gathered} \tag{10}$$

subject to

$$\text{Portfolio constraint: } w_t = (1 + \mathbb{E}[\pi_{t+1}])(k_{t+1} + b_{t+1}) + n_t \tag{11}$$

$$\text{Budget constraint: } c_{t+1} = k_{t+1} + b_{t+1} \tag{12}$$

$$\text{Environmental quality: } E_{t+1} = (1-d)E_t - \beta c_t + \gamma n_t \tag{13}$$

where $0 < d < 1$ measures the speed of reversion of environmental quality to this level, while β and γ capture the sensitivity of our environmental index to consumption and con-

servation efforts (n). From the portfolio constraint, all wage income young agents receive is saved or used to improve the environment. They can supply their savings to firms or acquire public bonds. On the other hand, the budget constraint indicates that the old generation consumes all previous savings. This is a simplification introduced by Caravaggio and Sodini (2023) and substitutes the original specification in which the old generation only consumed income derivated from previously saved assets. Finally, the last expression recalls the evolution of environmental conditions (see John and Pecchenino 1994; Antoci and Sodini 2009; Caravaggio and Sodini 2022, among others). It shows that consumption negatively affects green performance while it positively depends on conservation efforts.

Combining Eqs. (11) and (12), consumption in $t+1$ can be written as the difference between wages and resources devoted to preserving and recovering the environment adjusted by inflation:

$$c_{t+1} = \frac{w_t - n_t}{1 + \mathbb{E}[\pi_{t+1}]} \tag{14}$$

Following John and Pecchenino (1994), we assume agents take wages, the profit rate, and the environmental index at the beginning of period t as given. Substituting Eqs. (13) and (14) into (10), the optimisation problem can be rewritten as:

$$\max_{n_t} \ \ln\left(\frac{w_t - n_t}{1 + \mathbb{E}[\pi_{t+1}]}\right) + \ln\left[(1-d)E_t - \beta c_t + \gamma n_t\right] \tag{15}$$

A competitive equilibrium is characterised by agents maximising (15) satisfying firms maximising profits and markets clearing. Along the dynamic equilibrium path, the First Order Conditions (FOC) imply:

$$E_{t+1} = \gamma\left(1 + \mathbb{E}[\pi_{t+1}]\right) c_{t+1} \tag{16}$$

which establishes the optimal correspondence between the environment, consumption, and inflation. The expression above lets us gather intuition on how monetary policy will enter the picture. Agents save in t to consume in $t+1$. So, ceteris paribus, higher expected inflation requires either an improvement in environmental quality or a reduction in consumption. If Central banks increase the baseline interest rate when confronted with an increase in expected inflation, such a contractionary monetary policy shifts wealth from capital to public bonds, potentially damaging output. This last effect means less consumption but also fewer resources for conservation activities. The two mechanisms play in opposite directions in terms of environmental impact.

From the concavity of the objective function concerning n, Eq. (16) allows us to obtain the optimal internal solution as:

$$n_t = \frac{1}{2}\left[w_t + \frac{\beta c_t - (1-d)E_t}{\gamma}\right] \tag{17}$$

Recall that agents get utility from consuming but also value environmental quality. More of the former negatively impacts the latter. Still, as the FOC indicates, agents choose the funds

allocated to preserve the environment to equal marginal utilities. Thus, higher consumption requires more resources dedicated to conservation efforts for a given environmental quality index, as shown in Eq. (17). The relationship between them in the equilibrium path is intermediated by $beta/\gamma$. This ratio captures the relative importance of both elements to E in $t+1$; see Eq. (13).

3.4 Inflation and Monetary Policy

We refer to Gordon's (1977) triangle model, which proposes a Phillips curve depending on inertia, demand, and supply factors. The first element includes wage and price contracts. The second captures demand-side-driven inflation sources in terms of the output gap. Referring to our discussion in Sect. 2, we include *climateflation* among the supply factors. The accumulation of climate-related physical and transition risks that follow from the deterioration of environmental quality is interpreted as a supply shock that affects agents' expectations about inflation ($\mathbb{E}[\cdot]$). Assuming a separable equation, we write:

$$\pi_t = P(\pi_{t-1}, z_t - y_t) + \mathbb{E}[\pi_{t+1}]$$

where

$$\mathbb{E}[\pi_{t+1}] = \rho D(E_t) + \varepsilon_t$$

such that

$$\varepsilon_t \sim N(0, \sigma)$$

Function $P(\cdot)$ groups inertia and demand effects, z stands for per capita aggregate demand, and $\rho > 0$ intermediates the response of inflation to supply shocks related to global warming. Stochastic shocks ε are i.i.d. with σ corresponding to the standard error. They capture the fundamental uncertainty surrounding the formation of expectations, especially regarding climate-related inflationary pressures.

The study of the macroeconomic effects of supply disruptions, such as energy price shocks or the pandemic emergency, has gained momentum in the profession (e.g. Gordon 2013; Fornaro and Wolf 2023). In the present paper, we are specifically interested in price variations related to the environmental crisis, thus motivating our choice to take them as a function of $D(\cdot)$. Moreover, precisely because the role of inflation inertia goes beyond the scope of our main narrative, and we are assuming $z = y$ for all t, we silence that channel and simplify the expression above to:

$$\pi_t = \mathbb{E}[\pi_{t+1}] = \rho D(E_t) + \varepsilon_t \tag{18}$$

such that an improvement in the environmental index reduces the pressure on π. Considering the functional specification proposed in Eq. (2) and that $E \in [0, 100]$, an index close to the upper boundary means inflation fluctuates around a zero mean. On the contrary, low environmental performance results in an augmented damage function. Thus, one should expect more production disruptions through natural disasters, harming factories and infra-

structure, as well as labour suffering the effects of e.g. heat waves. In both cases, the net outcome is higher inflation.

The monetary authority has its primary role in maintaining price stability, defined by a specific level of inflation. A common framework to describe the behaviour of Central Banks is Taylor's (1993) rule. It describes that interest rates should respond to divergences of actual from target inflation and the output gap:

$$i_t = R(\mathbb{E}[\pi_{t+1}] - \bar{\pi}, z_t - y_t)$$

where $R(\cdot)$ is an increasing function in both arguments and $\bar{\pi}$ corresponds to the inflation target. Taylor rules provide a simple mechanical link between the baseline interest rate and deviations of inflation from its target. Taylor rules have become a popular gauge for assessments of the monetary policy stance in advanced and emerging market economies. Our goal is not to derive an optimal rule but rather to study the side effects of this specific type of policy.

As before, we recall that our model does not account for an output gap. Thus, we assume the Central Bank commits to a sequence of nominal interest rates which only react to deviations of expected inflation from the target rate:

$$i_t = \bar{r} + \phi(\mathbb{E}[\pi_{t+1}] - \bar{\pi}) \tag{19}$$

where $\bar{r}$ describes the "neutral" interest rate while $\phi > 0$ is a policy reaction parameter. The nominal rate will equal $\bar{r}$ conditional to actual inflation matching $\bar{\pi}$. In this case, monetary policy is neither accommodative nor restrictive.

Substituting Eq. (18) into (19), the nominal interest rate becomes endogenous to environmental conditions:

$$i_t = \bar{r} + \phi\left[\rho D(E_t) - \bar{\pi}\right] + \phi\varepsilon_t \tag{20}$$

This concludes the presentation of the two main channels connecting the environment to the macroeconomy. Our damage function $D(\cdot)$ has a direct negative effect on the production technology as in Eq. (1) and creates inflationary pressures through expectations. By leading to a deterioration of the environment, higher CO2 emissions are ceteris paribus related to higher inflation and, consequently, to a more stringent monetary policy. The possible consequences of such a policy framework will be studied under different scenarios.

3.5 Dynamic System

The basic structure of the dynamic system comes from the government's budget constraint (9), our representative agent portfolio constraint (11) provided that the budget constraint (12) is also satisfied, and the dynamics of the environmental quality index in Eq. (13). After some rearrangements, we obtain:

$$\begin{aligned} b_{t+1} &= \theta\left[1 - D\left(E_t\right)\right] A k_t^{\alpha} + \left(\frac{i_t}{1 + \mathbb{E}[\pi_{t+1}]}\right) b_t \\ k_{t+1} &= \frac{w_t - n_t}{1 + \mathbb{E}[\pi_{t+1}]} - \theta\left[1 - D\left(E_t\right)\right] A k_t^{\alpha} - \left(\frac{i_t}{1 + \mathbb{E}[\pi_{t+1}]}\right) b_t \\ E_{t+1} &= (1 - d)\, E_t - \beta c_t + \gamma n_t \end{aligned} \tag{21}$$

Substituting Eqs. (5), (14), (17), (18), and (20) into the system (21) while abstracting from the stochastic component to focus on the deterministic skeleton of the model, our 3-dimension nonlinear map is defined and given by:

$$\begin{aligned} b_{t+1} &= \theta\left[1 - D\left(E_t\right)\right] A k_t^{\alpha} + \left\{\frac{\bar{r} + \phi[\rho D(E_t) - \bar{\pi}]}{1 + \rho D(E_t)}\right\} b_t \\ k_{t+1} &= \left(\tfrac{1-\alpha}{2}\right) \tfrac{[1 - D(E_t)] A k_t^{\alpha}}{1 + \rho D(E_t)} - \tfrac{1}{2\gamma}\left[\tfrac{\beta(k_t + b_t) - (1-d)E_t}{1 + \rho D(E_t)}\right] \\ &\quad - \theta\left[1 - D\left(E_t\right)\right] A k_t^{\alpha} - \left\{\tfrac{\bar{r} + \phi[\rho D(E_t) - \bar{\pi}]}{1 + \rho D(E_t)}\right\} b_t \\ E_{t+1} &= \left(\tfrac{1-d}{2}\right) E_t - \tfrac{\beta}{2}\left(k_t + b_t\right) + \gamma\left(\tfrac{1-\alpha}{2}\right)\left[1 - D\left(E_t\right)\right] A k_t^{\alpha} \end{aligned} \tag{22}$$

where the functional form of the damage function is defined in Eq. (2).

In steady state, $b_t = b_{t+1} = b^*$, $k_t = k_{t+1} = k^*$, and $E_t = E_{t+1} = E^*$. Thus, the equilibrium conditions are defined and given by the intersection of the nullclines:

$$b^* - \theta\left(1 - \frac{1}{1 + \eta E^*}\right) A k^{*\alpha} - \left[\frac{\bar{r} + \phi\left(\frac{\rho}{1+\eta E^*} - \bar{\pi}\right)}{1 + \frac{\rho}{1+\eta E^*}}\right] b^* = 0 \tag{23}$$

$$\left(\frac{1-\alpha}{2}\right)\left(\frac{1 - \frac{1}{1+\eta E^*}}{1 + \frac{\rho}{1+\eta E^*}}\right) A k^{*\alpha} - \frac{1}{2\gamma}\left[\frac{\beta\left(k^* + b^*\right) - (1-d)\, E^*}{1 + \frac{\rho}{1+\eta E^*}}\right] - b^* - k^* = 0 \tag{24}$$

$$\left(\frac{1-d}{2}\right) E^* - \frac{\beta}{2}\left(k^* + b^*\right) + \gamma\left(\frac{1-\alpha}{2}\right)\left(1 - \frac{1}{1 + \eta E^*}\right) A k^{*\alpha} - E^* = 0 \tag{25}$$

The system (22) does not have a closed-form solution. Appendix A.1. provides an additional assessment of the issue. Still, we would like to have more to say about the existence of one or more equilibrium points before moving on to our numerical exercise to provide the reader with further intuition of what might be going on. Thus, we state and prove the following Propositions, showing which parameters are critical to generating a non-trivial equilibrium solution. Given our interest in the interplay between fiscal and monetary policy under climateflation, we begin by studying the model's response when these two channels are momentarily muted. This means to assume the government enforces a balanced budget every period, $\theta = 0$, and agents do not incorporate environmental degradation in their inflationary expectations, $\rho = 0$. Notice that in such a scenario, monetary policy becomes neutral again, and environmental conditions influence economic performance only through the damage function.

Proposition 1 *Provided that the government maintains a balanced budget and there is*

no climateflation, i.e. $theta = \rho = 0$*, the dynamic system* (22) *admits the trivial solution* $(0, 0, 0)$ *and an additional unique nontrivial one defined by the triplet* $(0, k^*, E^*)$*, such that:*

$$k^* - \frac{\gamma(1-\alpha)}{\beta + \gamma(1+d)} k^{*\alpha} + \frac{1}{\gamma\eta} = 0$$

and

$$E^* = \gamma k^*$$

are simultaneously satisfied.

Proof. See Appendix A.2. ∎

In the absence of public debt and climateflation, the environmental quality index and capital stock exhibit a positive relationship, mediated by the parameter γ, which reflects the sensitivity of E in $t+1$ to conservation efforts in t. This result is quite straightforward, but it might be worth spending time on. Given that $\theta = 0$, there is no public debt, and the budget constraint indicates that wealth can only exist in the form of physical capital that must be consumed when agents are old, $c_{t+1} = k_{t+1}$. Since $\rho = 0$, prices are constant, and the condition for the equality between the marginal utilities of consumption and environment implies that $E_{t+1} = \gamma c_{t+1}$. Combining them, we have that $E_{t+1} = \gamma k_{t+1}$ so that in steady state $E^* = \gamma k^*$.

We proceed by showing the importance of the damage function in allowing for the existence of the non-trivial equilibrium. Let us return to our full setup and only impose $eta = 0$. The equilibrium conditions are now given by:

$$\begin{array}{c} b^* - \left[\frac{\bar{r}+\phi(\rho-\bar{\pi})}{1+\rho}\right] b^* = 0 \\ -\frac{1}{2\gamma}\left[\frac{\beta(k^*+b^*)-(1-d)E}{1+\rho}\right] - b^* - k^* = 0 \\ \left(\frac{1-d}{2}\right) E^* - \frac{\beta}{2}(k^*+b^*) - E^* = 0 \end{array} \tag{26}$$

From the public sector point of view, the absence of a positive (negative) externality from environmental quality (degradation) to production is equivalent to setting $\theta = 0$. To see this, notice that from Eq. (2), fixing $\eta = 0$ implies the damage function is such that $D(E) = 1 \quad \forall \quad E$. Thus, there will be no production in the first place. As the fiscal rule fixes the deficit g as a proportion of output, see Eq. (8), we have $g = 0$. Thus, new bonds are only issued for interest payments, as seen from Eq. (7). Still, old agents continue to consume, deteriorating the environment and depleting the previously accumulated wealth until the economic system collapses, a result summarised in the following Proposition.

Proposition 2 *In the absence of a damaging effect from climate change on economic activity, i.e.* $eta = 0$*, the dynamic system* (22) *only admits the trivial equilibrium solution* $(0, 0, 0)$.

Proof. See Appendix A.3. ∎

Despite its simplicity, this is an important economic result. It shows that such feedback from the environment to economic activity damages economic activity but still makes it viable.

If production does not respond to environmental conditions, business as usual will continue until both economic and environmental resources are depleted. This happens despite the fact agents value environmental quality.

4 Numerical Experiments

To provide a more concrete view of the main transmission mechanisms of the model, we present a numerical exercise based on a broad choice of parameters for our dynamic system. We do not aim to represent a specific country or region but rather to assess the forces that might be at play in our environmental OLG setup. Table 1 reports our calibration strategy. Some values, for example, those related to the Taylor rule and estimates of the natural interest rate, were chosen following the conventional macro literature (e.g. Laubach and Williams 2003; Hamilton et al. 2011; Holston et al. 2017; Carvalho et al. 2021). Others, such as the government deficit and the production function technical coefficient, were selected to match general macroeconomic stylised facts. Finally, we adopt a conservative approach for parameters related to *climateflation* and the damage function, allowing for relatively small effects.

Using the parameter values in Table 1, the deterministic part of our system admits a unique stable equilibrium:

$$P_1 = (b^*, k^*, E^*) = (5.1, 23.5, 72)$$

which is consistent with a level of output per young agent ≈ 100. Still, we would like to rule out more confidently, at least numerically, the existence of other stable solutions. Thus, we plot in Fig. 4 the basin of attraction of P_1 in the interval:

$$b \in [-50, 50], \quad k \in [0, 50], \quad E \in [0, 100]$$

Table 1 Calibration strategy

Parameter	Value	Source
θ	0.05	Consistent with a government deficit to GDP of 5%
η	7.5	Consistent with a $D(E) \in (0.005, 0.01)$
A	28.5	Consistent with $y^* \approx 100$
α	0.4	Consistent with a labour income to GDP of 60%
ϕ	1.5	Hamilton et al. (2011) & Carvalho et al. (2021)
$\bar{r}$	0.025	Laubach and Williams (2003) & Holston et al. (2017)
$\bar{\pi}$	0.02	Consistent with a 2% inflation target
γ	2.5	Caravaggio and Sodini (2022, 2023)
d	0.1	Consistent with a natural recovery rate of 10%
β	2.5	Caravaggio and Sodini (2022, 2023)
ρ	4.5	Consistent with climateflation $\in (0.005, 0.02)$
σ	0.02	Conrad et al. (2022) & Falc et al. (2021)

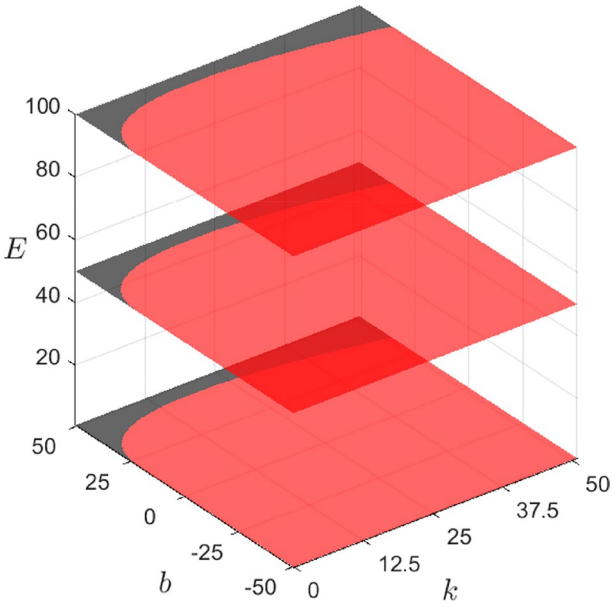

Fig. 4 Basins of attraction of the numerically obtained unique stable equilibrium point P_1. The red region indicates initial conditions converging to P_1 while, in black, we have those diverging from it

While most likely $b > 0$, we consider initial conditions for which the government is a lender instead of a net borrower. We allow the capital stock to vary at similar intervals. Finally, by definition, the environmental quality indicator lies between zero and 100. The red region in Fig. 4 indicates all initial conditions converging to P_1 while, in black, we show those diverging from it. Notice that you need excessively high debt to escape the attracting region around P_1. Therefore, we feel comfortable treating P_1 as the system's unique stable (relevant) equilibrium point.

We proceed by performing a series of experiments for the stochastic version of the system. Exogenous shocks from inflation expectations interact with monetary policy, further reverberating in the rest of the economy. We assume $\sigma = 0.02$ following evidence discussed by Falck et al. (2021) and Conrad et al. (2022). The model was run 1000 times in each scenario to report the average with the respective confidence interval. We study four scenarios, three regarding monetary policy and the last comparing neutral and green expansive fiscal policy.

4.1 Monetary Policy

We evaluate the response of the model to changes in three crucial parameters. First, we study what happens when there is an increase in the expectations response to *climateflation*. We augment the value of rho from 4.5 to 12, equivalent to raising expected climate-related inflation from $\approx 1\%$ to 2.25% so that $\pi > \bar{\pi}$. In a second scenario, we explore the implications of an increase in the central bank's response to inflation deviations from its target. To illustrate it, we doubled the respective coefficient from 1.5 to 3. A last monetary policy experiment consists in raising the inflation target. One could interpret this setting as a recognition by the policymaker that climate change-related physical and transition risks

are somehow part of the new reality that should be incorporated into the targets adopted to pursue price stability.

Figure 5 reports, in blue, our baseline case and, in orange, the model's response to increasing ρ. The first result is an apparent deterioration of both economic and environmental conditions. As agents strongly incorporate climate change into their inflation expectations, there is an increase in inflationary pressures, to which the monetary authority responds by adopting a contractionary monetary policy, i.e. higher i. Its motivation lies in the need to keep expectations anchored. An increase in interest rates makes savings in public bonds more desirable than physical capital, raising the share of public debt and reducing capital accumulation, bringing output down. As there is a reduction in overall wealth, consumption also falls. A reduction in production and consumption creates two opposing forces. There is less environmental pressure because consumption is smaller. However, fewer resources are available to fight climate change. The last effect prevails, leading to a marginal deteriora-

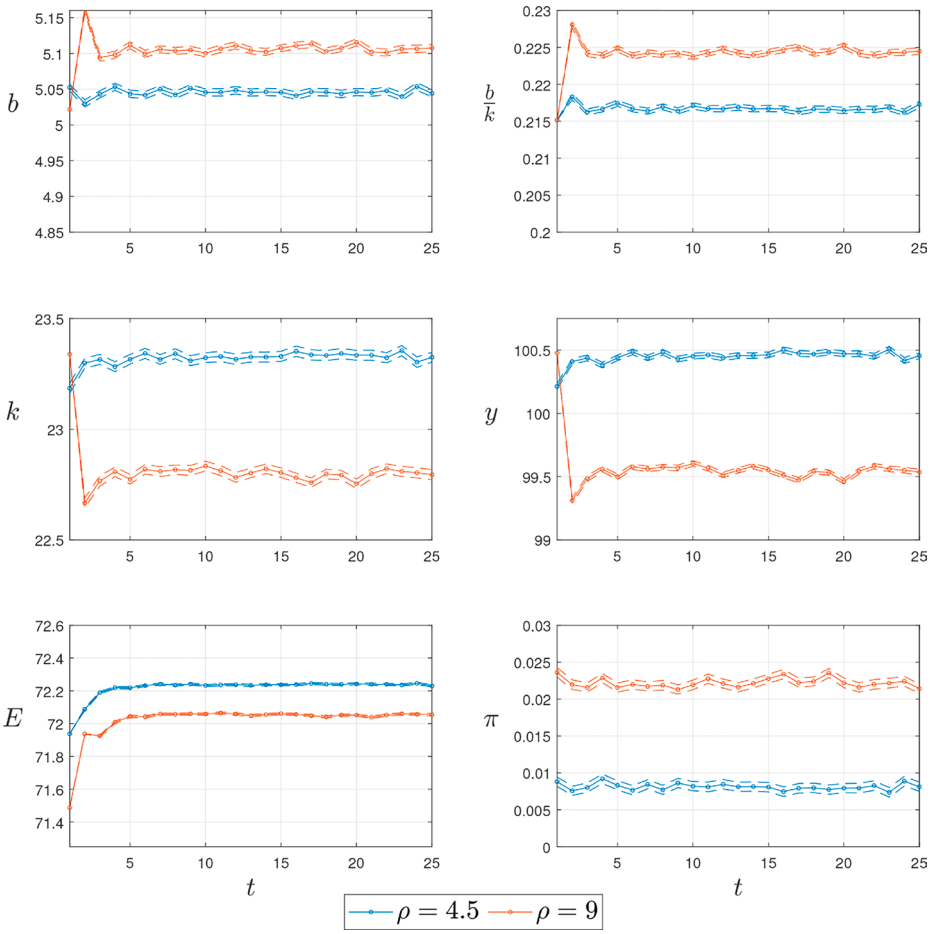

Fig. 5 Response to a negative shock under different scenarios of climate-change-related inflation. The dotted lines mark the 95% confidence interval. For comparability reasons, we use the same scale for the respective diagrams in Fig. 5 to 7

tion in E. It further reinforces the initial pressure on $\mathbb{E}[\pi_{t+1}]$, leaving inflation above the baseline scenario.

Using similar colours, we depict in Fig. 6 the system's response to a Central Bank that is more responsive to deviations of inflation from the target. This time, we document a trade-off between y and E. Climateflation exists but is stable and relatively weak so that $\pi < \bar{\pi}$ at the beginning of the period. Without worrying about inflationary pressures, monetary policy will be less stringent despite the higher reaction coefficient. People respond by saving less. There is a contraction in wealth, slightly stronger from the side of b rather than k because the former is directly linked to i. Lower savings during the young phase result in lower consumption in the old stage. Even though reducing capital accumulation implies less output and fewer resources to E, the consumption effect prevails. Thus, environmental quality marginally improves, but not enough to significantly change inflationary expectations. This explains the overlapping blue and orange colours for π.

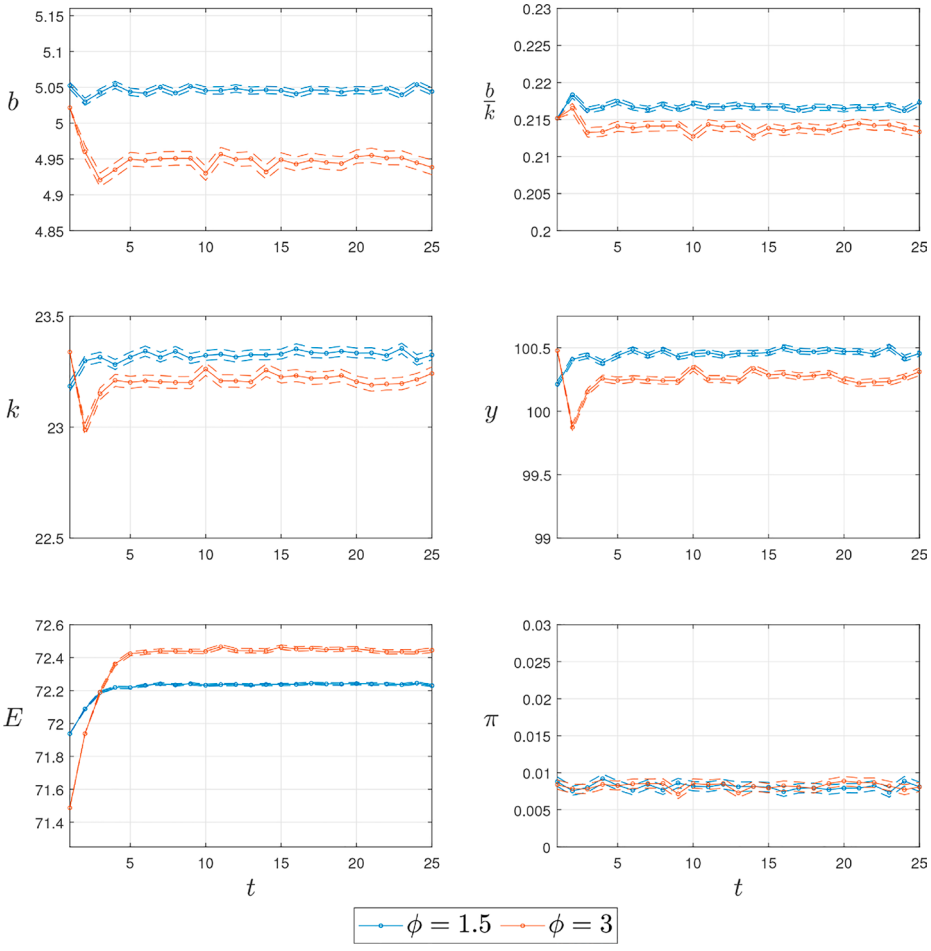

Fig. 6 Response to a negative shock under different scenarios of inflation aversion by the Central Bank. The dotted lines mark the 95% confidence interval. For comparability reasons, we use the same scale for the respective diagrams in Figs. 5 to 7

Our third experiment investigates the consequences of increasing the inflation target. There is at least one good reason the monetary authority might pursue such a strategy. If climate change implies a sequence of cumulative supply shocks associated with physical and transition risks that are part of the new reality, policymakers might want to accommodate monetary policy accordingly. Figure 7 shows the system's response to doubling $\bar{\pi}$ to 4%. Notice that the diagrams in Figs. 6 and 7 are relatively similar. Under a more relaxed monetary policy, we document agents turning away from public bonds. However, as the increase in $\bar{\pi}$ is quite strong, interest rates fall more than in the previous case. Agents turn away from public bonds, and the amount of physical capital remains unchanged, reducing the b/k ratio without damaging economic activity. Given that overall wealth has fallen, consumption will be reduced. But as production remains stable, so will conservation efforts. The net effect is an improvement of E. As before, such a marginal impact on environmental quality is not enough to modify the behaviour of inflation.

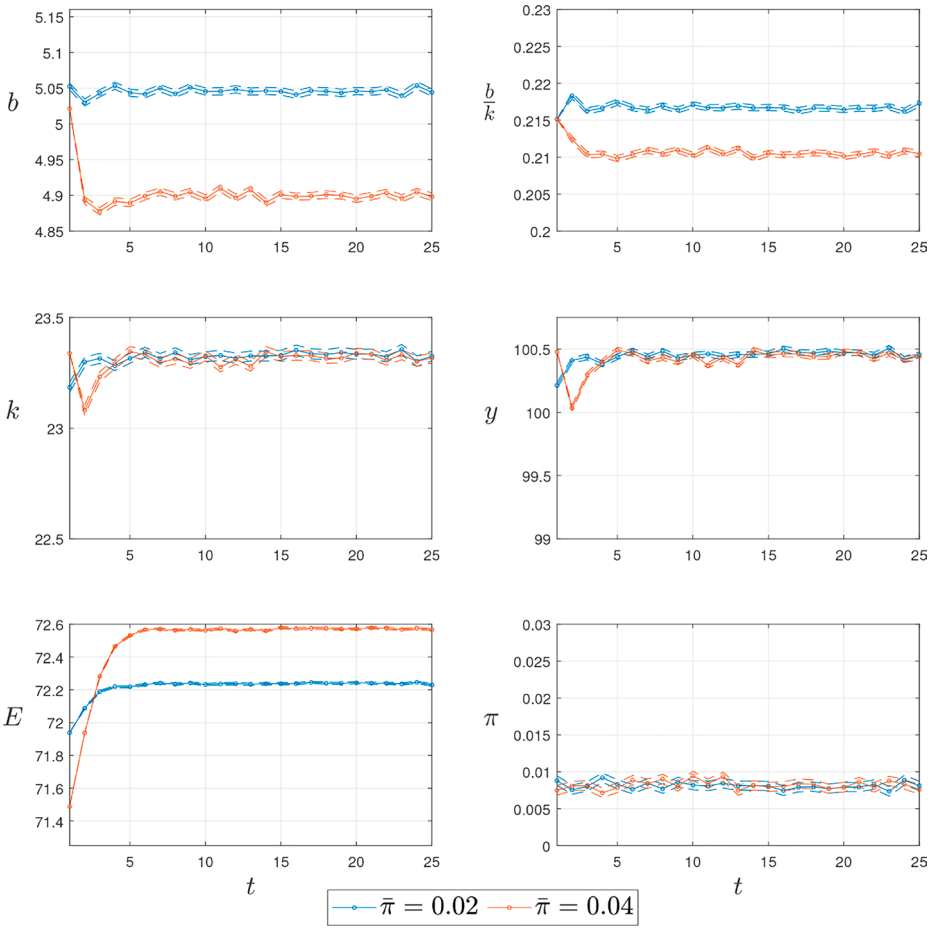

Fig. 7 Response to a negative shock under different inflation targets. The dotted lines mark the 95% confidence interval. For comparability reasons, we use the same scale for the respective diagrams in Figs. 5 to 7

A natural question arises: What inflation target and environmental quality index deliver a nominal interest equal to the neutral rate? Figure 8 provides some insights into that direction, taking Denmark, South Africa, and the United States as reference points.[6] In blue and orange, the panel on the left reports the curves corresponding to $\rho = 4.5$ and 9, respectively. In both cases, we have a negative relationship between $\bar{\pi}$ and E, reflecting the intrinsic nature of *climateflation*. Improving environmental conditions is associated with reduced emissions that limit climate-related supply shocks. Thus, the inflation target compatible with $i = \bar{r}$ decreases. A higher ρ means inflationary expectations respond strongly to the damage function, explaining why the orange curve lies above the blue one. The panel on the right refers to a similar situation, but we now change the shape of the $D(\cdot)$ function. Again, the higher the damage related to a lower E, the higher $\bar{\pi}$ would have to be. For example, in the case of the USA—which has an EPI score close to 50—the hypothetical inflation target is between 1%, see the orange line in the right diagram, and 7.5%, as depicted by the orange line in the left panel.

This environmental OLG model suggests that monetary policy has non-neglectable economic and environmental performance implications. The main transmission channel lies in conventional monetary policy having real effects because it determines the composition of the public's portfolio between productive capital and government bonds; a desirable feature of the OLG framework. *Climateflation* generates inflationary pressures, and the central

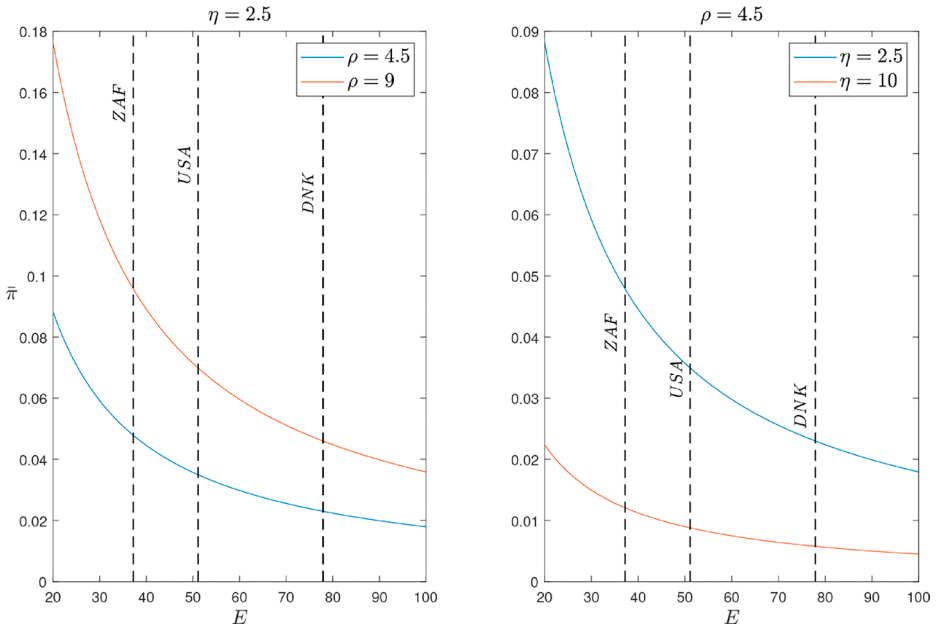

Fig. 8 Inflation target and environmental quality index combination delivering a nominal interest rate equal to the neutral rate

[6] As indicated the first time we referred to the EPI, it ranks 180 countries on climate change performance. most of them are in the interval [20,80]. The choice of plotting DNK, ZAF and the USA was mainly motivated to provide a visualisation of the spectrum where developed and developing countries lie according to this indicator. Moreover, it allows us somehow to compare the environmental performance of a leading European country with the United States.

bank's response could further damage the economy and the environment. Furthermore, an expansionary policy can potentially create trade-offs between the y and E.

4.2 Fiscal Policy

Our last experiment regards the adoption of a more lenient fiscal policy. In the model, the government has a passive role regarding climate change. It does not actively engage in improving environmental quality. Figure 9 shows that, in this case, raising θ is dangerous. Monetary policy guarantees a positive rate of return to government debt. Therefore, an expansionary fiscal policy leads to a strong switch towards that asset, significantly reducing capital accumulation. Per capita output depends on physical capital; thus, economic activity is also reduced. Moreover, as such a contraction is the strongest reported in our simulations, the pool of resources available for conservation purposes is harmed.

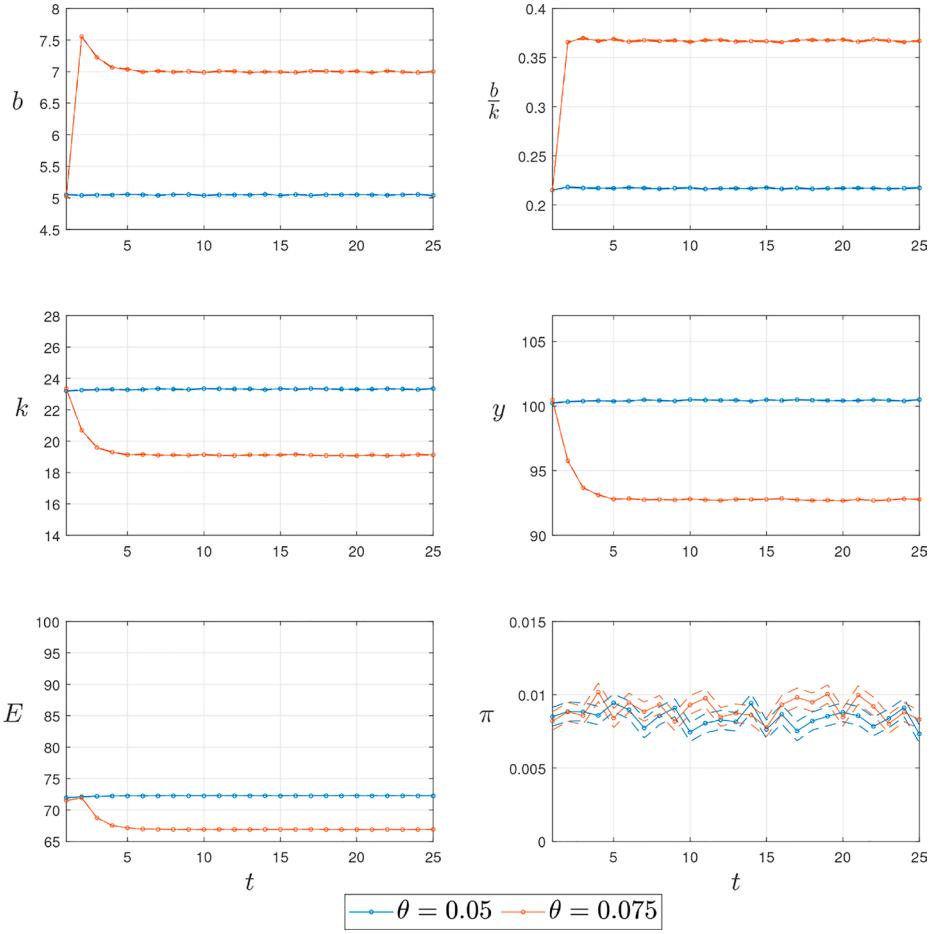

Fig. 9 Response to a negative shock under different deficits. The dotted lines mark the 95% confidence interval. For comparability reasons, we use the same scale as in Fig. 10

While an expansive fiscal policy appears to have strong negative implications for economic activity, this only occurs when the government does not engage in conservation activities. For instance, suppose all the deficit is used to improve environmental quality. We could think about this scenario as the government keeping a balanced budget and incurring debt only to promote a green-transition agenda. Adjusting Eq. (13) accordingly:

$$E_{t+1} = (1-d)E_t - \beta c_t + \gamma(n_t + \theta y_t) \tag{27}$$

where $theta$ is the target deficit embodied in the fiscal rule, see Eq. (8), lead by one period. Equation (27) implies that private and public action have the same impact on E, intermediated by parameter γ.

The modified 3-dimension deterministic skeleton of our nonlinear map is defined and given by:

$$\begin{aligned}
b_{t+1} &= \theta\left[1 - D\left(E_t\right)\right] A k_t^{\alpha} + \left\{\frac{\bar{r} + \phi\left[\rho D(E_t) - \bar{\pi}\right]}{1 + \rho D\left(E_t\right)}\right\} b_t \\
k_{t+1} &= \left(\frac{1-\alpha}{2}\right)\frac{\left[1 - D\left(E_t\right)\right] A k_t^{\alpha}}{1 + \rho D\left(E_t\right)} - \frac{1}{2\gamma}\left[\frac{\beta\left(k_t + b_t\right) - (1-d)\,E_t}{1 + \rho D\left(E_t\right)}\right] \\
&\quad - \theta\left[1 - D\left(E_t\right)\right] A k_t^{\alpha} - \left\{\frac{\bar{r} + \phi\left[\rho D(E_t) - \bar{\pi}\right]}{1 + \rho D\left(E_t\right)}\right\} b_t \\
E_{t+1} &= \left(\frac{1-d}{2}\right) E_t - \frac{\beta}{2}\left(k_t + b_t\right) + \gamma\left(\frac{1-\alpha}{2} + \theta\right)\left[1 - D\left(E_t\right)\right] A k_t^{\alpha}
\end{aligned} \tag{28}$$

where the main difference with the baseline model is that θ also appears in the last dynamic relation, reflecting the positive impact of the government on environmental quality.

Figure 10 plots, in blue, time series under the standard calibration used in Table 1. We refer to it as a zero-green government deficit because public debt is used to finance activities unrelated to climate change or sustainability. In orange, we report the opposite situation: All deficit is directed to the environment. The bottom left diagram shows a strong improvement in the environmental quality index. An immediate implication is reducing inflation, as the government lowers inflationary expectations by mitigating climate-related risks. We document a certain increase in public debt, but the strong reduction in the negative externality from the damage function guarantees agents prefer physical assets. Together, these two effects are related to higher production. There is no environment-production trade-off, with both variables improving together. We conclude that expansive fiscal policy should be avoided unless the government engages—directly or indirectly—in green activities. Such a result is in line with the recent literature highlighting the importance of the public sector in tackling climate change among more conventional approaches (Brock and Taylor 2010; Nordhaus 2019), including OLG models (Jaimes 2023), but also behavioural macroeconomics (e.g. Sordi and Davila-Fernandez 2023; Campiglio et al. 2024).

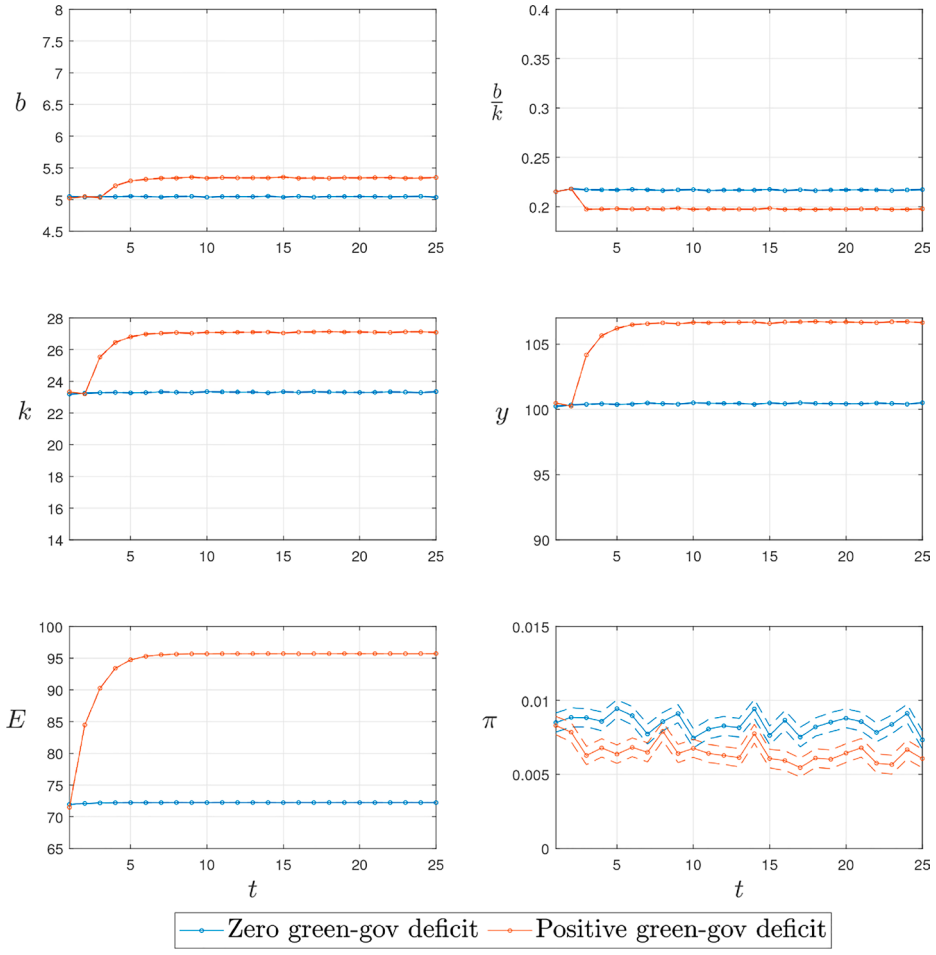

Fig. 10 Response to a negative shock when the government finances environmental conservation. Zero green-gov deficit indicates $\theta > 0$, but fiscal policy is not used to improve environmental quality. A positive green-gov deficit corresponds to the alternative case. The dotted lines mark the 95% confidence interval. For comparability reasons, we use the same scale as in Fig. 9

5 Final Considerations

The so-called "independence" hypothesis lies at the core of the current macroeconomics paradigm and is at the basis of the inflation-targeting framework. Still, recent empirical evidence is challenging the view that productive capacity does not respond to monetary policy. This is happening in a context in which central banks increasingly realise that climate change can potentially impact prices, and they should do something about it. The present paper aims to contribute to the intersection of these two major themes. We studied the interplay between conventional monetary policy and the environment when money is not neutral in the long run. More specifically, we develop a macrodynamic model to study the implications in terms of output and inflation of using Taylor rules in a context where

(i) environmental quality (degradation) has a positive (negative) externality on production, and (ii) the adverse consequences of climate change materialise influencing inflationary expectations.

Using an environmental OLG framework treating government debt as net wealth, 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 lifetime choice problem. Numerical experiments allow us to assess the response of environmental quality and economic activity when (i) expectations are more responsive to *climateflation*, (ii) the monetary authority strongly responds to inflation deviations from its target, (iii) the central bank increases the inflation target, and (iv) fiscal policy is less stringent.

A more stringent monetary policy in response to *climateflation* leads to lower output and a deterioration of environmental conditions. The main transmission channel was the composition of the public's portfolio between government bonds and other assets, recently highlighted in a different context by Hu et al. (2023). Under relatively small environment-related inflationary pressures, a strong Central Bank reaction might be related to the emergence of a trade-off between economic activity and the environment. Finally, we showed that expansive fiscal policies could be counterproductive if the government does not improve environmental conditions. Our last set of simulations suggests as a policy recommendation that the government needs to be directly or indirectly involved in financing the climate transition. Without such actions, increases in the public deficit divert wealth accumulation from physical assets to pure government debt. A green expansionary fiscal policy avoids an economy-environment trade-off, making the improvement of both possible.

A Mathematical Appendix

A.1 Additional Considerations on Equilibrium Determination

From the nullcline (23), we get $b^*\left(k^*, E^*\right)$, which is the equilibrium value of the public debt, b^*, as a function of the equilibrium values of capital per unit of labour k^* and environmental quality E^*, that is:

$$b^* = -\frac{A\eta k^{*\alpha} E^* \theta (1 + nE^* + \rho)}{(1 + nE^*)\{r(1 + nE^*) - \rho(1 - \theta) - \pi\theta - n[E^*(1 + \pi\theta)] - 1\}}$$

Analogously from the nullcline (24) we may also get $b^*\left(k^*, E^*\right)$, i.e.

$$b^* = \frac{(1-d)\eta E^{*2} - \beta k^* - E^*\left[d - 1 + \eta k^*(\beta - 2\gamma) - A\eta k^*(\alpha - 1)\gamma\right] + (1+\rho)2\gamma k^*}{\beta(1 + \eta E^*) - 2\gamma(1 + \eta E^* + \rho)}$$

and as well from the nullcline (25), we get $b^*\left(k^*, E^*\right)$, i.e.

$$b^* = -\frac{(1 + \eta E^*)\left[E^*(1 + d) + \beta k^*\right] + A\eta k^{*\alpha} E^* \gamma\,(\alpha - 1)}{\beta\,(1 + \eta E^*)}$$

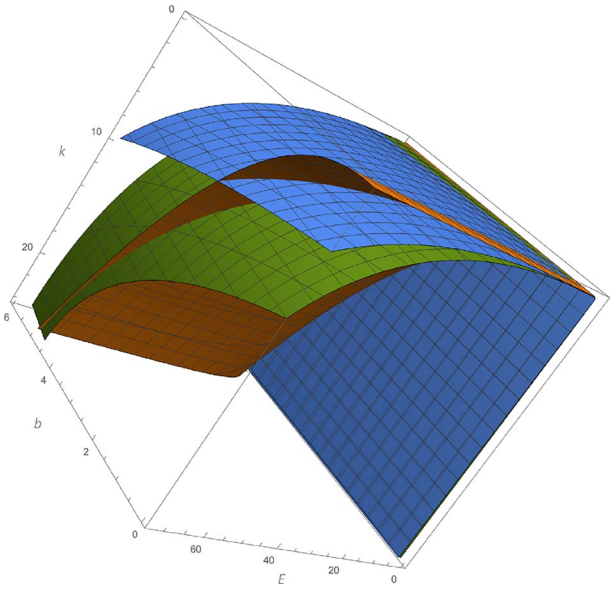

Fig. A.1 The 3D nullcline plot for the system (23)–(25). Green, burnt orange and blue surfaces show b, k and E nullclines, respectively. Solution curves must cross the nullclines in all directions. Plotting the nullclines helps to see where solutions lie

Fig. A.1 helps us understand the nullcline map in Eqs. (23)–(25). We use the set of parameters defined in Table 1. An equilibrium point is located at the intersection of the three coloured nullclines. However, to find the solutions for the given equation, we need to select the positive solution. Unfortunately, it is not possible to obtain an explicit function for b^*, k^*, and E^* since, for example, we have the term k^α and the terms b and k satisfy a fourth-degree polynomial.

A.2 Proof of Proposition 1

The equilibrium condition (23) becomes:

$$(1 - \bar{r} + \phi\bar{\pi})\, b^* = 0 \tag{29}$$

from which steady-state government bonds will equal zero, an expected result as we are assuming $theta = 0$. Conditions (24) and (25) are now equal to:

$$\left(\frac{1-\alpha}{2}\right)\left(1 - \frac{1}{1+\eta E^*}\right) k^{*\alpha} - \frac{1}{2\gamma}\left[\beta k^* - (1-d)\, E^*\right] - k^* = 0 \tag{30}$$

$$\left(\frac{1-d}{2}\right) E^* - \frac{\beta}{2} k^* + \gamma\left(\frac{1-\alpha}{2}\right)\left(1 - \frac{1}{1+\eta E^*}\right) k^{*\alpha} - E^* = 0$$

The two expressions in (A.2) continue to embed significant nonlinearities and require further work. From Eq. (29), it is evident in equilibrium $b^* = 0$. Rearranging the nullclines in (30) and omitting the superscript * for convenience, we can rewrite both as

$$\left(\frac{1-\alpha}{2}\right)\left(1-\frac{1}{1+\eta E}\right)k^{\alpha}=\left(\frac{1}{2\gamma}\right)\left[\beta k-(1-d)\,E\right]+k$$

$$\left(\frac{1-\alpha}{2}\right)\left(1-\frac{1}{1+\eta E}\right)k^{\alpha}=\frac{E}{\gamma}-\left(\frac{1-d}{2\gamma}\right)E+\frac{\beta}{2\gamma}k$$

It is easy to see that $(k, E) = (0, 0)$ simultaneously satisfies both equilibrium conditions. Thus, the system admits the trivial solution.

Furthermore, from (30), we also have that:

$$-\frac{(1-d)\,E}{2\gamma}+\frac{\beta k}{2\gamma}+k=\frac{E}{\gamma}-\frac{(1-d)\,E}{2\gamma}+\frac{\beta}{2\gamma}k$$

which results in a linear relationship between our environmental index and the capital stock:

$$E=\gamma k \tag{31}$$

Substituting Eq. (31) into the second expression in (30), we obtain:

$$\begin{gathered}\gamma\left(\tfrac{1-\alpha}{2}\right)k^{\alpha}-\gamma\left(\tfrac{1-\alpha}{2}\right)\tfrac{k^{\alpha}}{1+\eta E}=\left(\tfrac{1+d}{2}\right)E+\tfrac{\beta}{2}k\\ \gamma\left(\tfrac{1-\alpha}{2}\right)k^{\alpha}-\tfrac{\beta}{2}k=\left(\tfrac{1+d}{2}\right)E+\gamma\left(\tfrac{1-\alpha}{2}\right)\tfrac{k^{\alpha}}{1+\eta E}\\ \gamma\left(\tfrac{1-\alpha}{2}\right)k^{\alpha}-\tfrac{\beta}{2}k=\left(\tfrac{1+d}{2}\right)\gamma k+\gamma\left(\tfrac{1-\alpha}{2}\right)\tfrac{k^{\alpha}}{1+\eta\gamma k}\end{gathered}$$

$$\begin{gathered}\gamma\left(\tfrac{1-\alpha}{2}\right)k^{\alpha}-\tfrac{\beta}{2}k-\left(\tfrac{1+d}{2}\right)\gamma k-\gamma\left(\tfrac{1-\alpha}{2}\right)\tfrac{k^{\alpha}}{1+\eta\gamma k}=0\\ \gamma\left(\tfrac{1-\alpha}{2}\right)k^{\alpha}-\left[\tfrac{\beta}{2}+\left(\tfrac{1+d}{2}\right)\gamma\right]k-\gamma\left(\tfrac{1-\alpha}{2}\right)\tfrac{k^{\alpha}}{1+\eta\gamma k}=0\\ \gamma\left(\tfrac{1-\alpha}{2}\right)(1+\eta\gamma k)\,k^{\alpha}-\left[\tfrac{\beta}{2}+\left(\tfrac{1+d}{2}\right)\gamma\right](1+\eta\gamma k)\,k-\gamma\left(\tfrac{1-\alpha}{2}\right)k^{\alpha}=0\end{gathered}$$

so that, provided that $k \neq 0$, we can write:

$$\begin{gathered}1-\tfrac{\left[\frac{\beta}{2}+\left(\frac{1+d}{2}\right)\gamma\right]k}{\gamma\left(\frac{1-\alpha}{2}\right)k^{\alpha}}-\tfrac{\gamma\left(\frac{1-\alpha}{2}\right)}{\gamma\left(\frac{1-\alpha}{2}\right)(1+\eta\gamma k)}=0\\ 1-\tfrac{\left[\frac{\beta}{2}+\left(\frac{1+d}{2}\right)\gamma\right]k}{\gamma\left(\frac{1-\alpha}{2}\right)k^{\alpha}}-\tfrac{1}{1+\eta\gamma k}=0\\ \tfrac{\left[\frac{\beta}{2}+\left(\frac{1+d}{2}\right)\gamma\right]k}{\gamma\left(\frac{1-\alpha}{2}\right)k^{*\alpha}}+\tfrac{1}{1+\eta\gamma k}=1\\ \tfrac{\left[\frac{\beta}{2}+\left(\frac{1+d}{2}\right)\gamma\right]}{\gamma\left(\frac{1-\alpha}{2}\right)}k^{1-\alpha}+\tfrac{1}{1+\eta\gamma k}=1\\ \tfrac{\left[\frac{\beta}{2}+\left(\frac{1+d}{2}\right)\gamma\right]}{\gamma\left(\frac{1-\alpha}{2}\right)}k^{1-\alpha}=\tfrac{\eta\gamma k}{1+\eta\gamma k}\end{gathered}$$

Rearranging,

$$\begin{gathered}\frac{\left[\frac{\beta}{2}+\left(\frac{1+d}{2}\right)\gamma\right]}{\gamma\left(\frac{1-\alpha}{2}\right)}=\frac{\eta\gamma k^{\alpha}}{1+\eta\gamma k}\\ \left[\frac{\beta}{2}+\left(\frac{1+d}{2}\right)\gamma\right](1+\eta\gamma k)=\gamma\left(\frac{1-\alpha}{2}\right)\eta\gamma k^{\alpha}\\ \frac{1+\eta\gamma k}{\eta\gamma k^{\alpha}}=\frac{\gamma(1-\alpha)}{\beta+(1+d)\gamma}\\ k^{1-\alpha}+\frac{1}{\eta\gamma k^{\alpha}}-\frac{\gamma(1-\alpha)}{\beta+(1+d)\gamma}=0\end{gathered}$$

finally resulting in

$$k-\frac{\gamma\left(1-\alpha\right)}{\beta+\left(1+d\right)\gamma}k^{\alpha}+\frac{1}{\eta\gamma}=0 \tag{32}$$

Therefore, a second equilibrium solution exists when (31) and (32) are simultaneously satisfied.

A.3 Proof of Proposition 2

In the special case with no damage function, $/eta = 0$, the equilibrium conditions are given by:

$$\begin{gathered}b^{*}-\left[\frac{\bar{r}+\phi(\rho-\bar{\pi})}{1+\rho}\right]b^{*}=0\\ -\frac{1}{2\gamma}\left[\frac{\beta(k^{*}+b^{*})-(1-d)E^{*}}{1+\rho}\right]-b^{*}-k^{*}=0\\ \left(\frac{1-d}{2}\right)E^{*}-\frac{\beta}{2}\left(k^{*}+b^{*}\right)-E^{*}=0\end{gathered} \tag{33}$$

From the first expression in (33), in steady-state, there is no public debt, $b^{*}=0$, so that:

$$\left\{1-\left[\frac{\bar{r}+\phi\left(\rho-\bar{\pi}\right)}{1+\rho}\right]\right\}b^{*}=0\Rightarrow b^{*}=0$$

Substituting into the other two relations:

$$\begin{gathered}\left(\frac{1-d}{2\gamma}\right)E^{*}=\left(1+\rho+\frac{\beta}{2\gamma}\right)k^{*}\Rightarrow k^{*}=\left(\frac{\frac{1-d}{2\gamma}}{1+\rho+\frac{\beta}{2\gamma}}\right)E^{*}\\ \left(\frac{1-d}{2}-1\right)E^{*}=\frac{\beta}{2}k^{*}\Rightarrow k^{*}=-\left(\frac{1+d}{\beta}\right)E^{*}\end{gathered} \tag{34}$$

from which it follows:

$$\begin{gathered}-\left(\frac{1+d}{\beta}\right)E^{*}=\left(\frac{\frac{1-d}{2\gamma}}{1+\rho+\frac{\beta}{2\gamma}}\right)E^{*}\\ 0=\left(\frac{\frac{1-d}{2\gamma}}{1+\rho+\frac{\beta}{2\gamma}}+\frac{1+d}{\beta}\right)E^{*}\\ E^{*}=0\end{gathered}$$

Thus, substituting into (34), we also obtain $k^{*}=0$.

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Declarations

Competing of interest None.

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