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Green Quantitative Easing as Intergenerational Climate Justice:

On Political Theory and Pareto Efficiency in Reversing Now Human-Caused Environmental Damage

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Green Quantitative Easing as Intergenerational Climate Justice: On Political Theory and Pareto Efficiency in Reversing Now Human-Caused Environmental Damage

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Abstract

The present paper endorses an interdisciplinary approach to the complex and urgent issue of intergenerational climate justice, and proposes a rich menu of policy options, in particular some novel and unconventional ones, to resolve it immediately but flexibly. We incorporate the realistic features of economic growth, nominal interest, expected inflation, and the option for nonrepayment or partial repayment of public debt across generations as well as a central bank institution, or rather the global network of central banks, to implement climate mitigation policy in the stylized model proposed by Sachs (2015). Similarly, but even without repayment, we find such kind of policy, which we label 'green quantitative easing', or 'green QE', to be Pareto-efficient across generations. Differently, we argue that neither the present, nor future generations need to repay the novel greening compensatory transfers (GCTs) to households and firms we envisage to serve as a main financial instrument of central banks in triggering a decisive reversal in environmental deterioration right now, without further delay, given the emergency of the situation. Moreover, and in support of the economic considerations and incentives, we argue from philosophical, legal and political-theory grounds that such a financial scheme intermediated by central banks worldwide serves two types of principles of intergenerational climate justice: (i) principles that tell us to mitigate climate change now and avoid harm for future generations; and (ii) principles that tell us how to share mitigation costs fairly across generations. Our spectrum of suggested pragmatic green QE initiatives includes potential issuance by firms and households of super-long-term coupon bonds to be held by central banks over up to a century, possibly GCT-based only, and allows for much flexibility and complementarity in the practical solutions to be potentially chosen, with voluntary partial repayment or not of the mitigation costs across generations.

Keywords: green quantitative easing, greening compensatory transfers, central banks, public finance, climate change mitigation policy, intergenerational climate justice, intergenerational social welfare

JEL Classification Codes: D61, D63, D78, E21, E58, F55, G28, H23, O44, Q54

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1 Introduction

The risks of global warming and environmental deterioration for human health and life on the planet have been steadily increasing over the past few decades. They have also been acknowledged widely by scientists, and more recently have culminated into an international political effort, mobilized under the United Nations, to legally bind and enforce coordinated actions to reverse this trend. In effect, the Paris Agreement, a far-reaching international treaty on climate change, was concluded in December 2015 by 196 signatories and entered into force in November 2016.[1] This achievement is unprecedented: for the first time in the history of mankind, a binding agreement unites all nations under the common threat, with the ambitious goal "to combat climate change and adapt to its effects".[2] In numerical expression, the goal that was set is "to limit global warming to well below 2, preferably to 1.5 degrees Celsius compared to preindustrial levels." This long-term temperature goal is consistent with the nationally determined contributions (NDCs) submitted by 2020 by each country. "Countries aim to reach global peaking of greenhouse gas (GHG) emissions as soon as possible to achieve a climate neutral world by mid-century." The implementation of the Paris Agreement "requires economic and social transformation, based on the best available science", that is, a transition of the global society to sustainable ecological environment, and "works in 5-year cycles of increasingly ambitious climate action carried out by the countries."

The G20 Green Finance Study Group (2016) defines 'green finance' as the financing of investments that provide environmental benefits. In a narrower sense, Ehler *et al.* (2020), p. 31, describe 'green bonds' as "debt instruments whose proceeds finance projects with various environmental benefits – including climate change mitigation". Over the past decade or so, such financial instruments have been growing in popularity as well as in traded volumes across the world. Ehler *et al.* (2020), p. 31, calculate that the global issuance of green bonds surpassed $250 billion in 2019, which accounts for about 3.5% of total global bond issuance ($7.15 trillion).[3] These authors also note (*ibid.*, p. 31) that private institutions have accordingly developed "green bond certifications and standards that grant issuers a green label if individual projects are deemed sufficiently in line with the Green Bond Principles (GBPs) of the International Capital Market Association (ICMA), and the use of proceeds can be ascertained."

Mark Carney (2019), former Governor of the Bank of England and Special Envoy of the United Nations on Climate Action and Finance, stressed that – contrary to the pledge in the Paris Agreement – the global financial system is currently funding a 4°C rise in the temperature of the planet. This conclusion is disappointing, bearing in mind the key role of the financial system in the economy and society, namely, to facilitate the necessary financing and liquidity for human and economic activity to thrive. Because financial markets enable investment in fossil fuel resources, some researchers (e.g., Fisher and Alexander, 2019) have suggested that the financial system should share in the responsibility to mitigate climate change, by undergoing a reform to reduce the emissions of GHG that derive from human and economic activity. This reform, to be undertaken by regulators and central banks, needs to influence investment and consumption choices in a way that incentivizes economic agents to quickly switch to forms of sustainable energy.

Academic research in economics (see, e.g., Manne and Richels, 2005; Nordhaus, 2008; Acemoglu *et al.,* 2012; Golosov *et al.*, 2014) has generally agreed that the 'first-

[1] See the webpages of the United Nations on climate change: https://www.unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

[2] This and the remaining few quotes in the first paragraph here are from the same website source cited in footnote 1.

[3] This amounts to 0.28% of (nominal) world GDP for 2019, estimated at $88.1 trillion by the International Monetary Fund (IMF) in its *World Economic Outlook* (October 2018), a value available online via StatisticsTimes.com.

best' approach to mitigating climate change would be a carbon tax, in the case of Acemoglu *et al.* (2012) combined with research subsidies, to avoid its excessive use. In a setting where the optimal carbon pricing focuses on the climate externality as the only distortion in the economy, Barrage (2020) interprets the carbon tax as Pigouvian, in the sense that it internalizes the full environmental damage costs of carbon emissions. He further claims that "analyses of this benchmark setting do not account for potential interactions between carbon levies and other taxes" and argues that "[c]arbon pricing, if implemented, will interact with fiscal policy. On the one hand, carbon taxes raise revenues directly. On the other hand, they may decrease revenues indirectly by shrinking the bases of other taxes" (*ibid.*, p. 2). Barrage (2020) then studies the optimal design of carbon taxes both as an instrument to control climate change and as a part of fiscal policy. A major concern to us here, in this paper, is that the carbon tax 'first-best' policy has not yet been implemented in the real world we live in, due to various costs and tradeoffs. This plain fact naturally moves the attention of researchers to a 'second-best' solution, possibly cheaper to enforce, as the one implied by the menu of options for immediate climate change mitigation proposed in the present paper and some related literature we cite.

An optimal policy for a transition to a low-carbon economy requires, further, the coordination of fiscal authorities – in implementing a carbon tax and/or adopting other measures to 'green' economic activity – with monetary authorities (e.g., Schoenmaker, 2019), in their more recent and complementary effort to 'green' the financial system too. We aim to focus here on monetary policy, where our main novel proposals are targeted at, even if indeed embedded within a more profound monetary-fiscal-financial-social coordination effort. One reason is that monetary policy seems to have been less discussed, except very recently, with view to its potential to help mitigate climate change. Another reason is the indirect control of monetary policy, via banking and financial regulation, over the financial system, in addition to its direct effect, via interest rate setting, on decisions of households and firms with regard to saving, consumption, investment, borrowing and lending. Given the continuing absence of a carbon tax first-best solution, we would argue that what we broadly discuss as 'green' quantitative easing ('green QE', for short), even if remaining second-best policy for greening the economy (see also Volz, 2017, among others), needs to be considered seriously. As we shall suggest, green QE is perhaps the only feasible urgent strategy, rich enough to involve a spectrum of complementary measures, that can be flexibly applied to reverse climate change now, without further delay. However, green QE also requires coordination with governments and the international community of central bankers, as well as a deeper political and social consensus on climate justice. Such a fundamental and multidimensional task imposes the interdisciplinary approach we take in the present paper, attempting an informative synthesis of economics with environmental science, intergenerational ethics, political theory, philosophy. In it, we essentially combine three sets of normative issues in moral philosophy and political theory – namely, legitimacy, intergenerational distributive justice, and policy options to choose from – with a menu of pragmatic initiatives in economic, financial and social policy we refer to as (components of) green QE, to be implemented immediately and in a complementary way, but spanning over a long run and thus sharing costs and benefits across generations.

Perhaps because of the problems of regulators and elected governments to design and enforce a carbon tax first-best policy, political scientists (e.g., Blyth and Lonegran, 2014) as well as academic economists (e.g., Volz, 2017; de Grauwe, 2019; Fisher and Alexander, 2019) and monetary policymakers (e.g., Carney, 2015, at the Bank of England; Brainard, 2019, at the Federal Reserve Bank (Fed) in the United States (US); Lagarde at the ECB, as reported in Jan and Merle, 2019) have more recently defended the idea that central banks should take the lead in greening financial markets, even if this may be a second-best solution. However, it is clear too that such a solution might at the same time overburden unelected central bankers, as they should primarily focus on keeping price and financial stability (Volz, 2017; Schoenmaker, 2019). Thus, one contribution of the present paper is to connect recent debates about greening finance and central banks with theoretical work on intergenerational climate justice. This is important because such debates among political theorists and moral philosophers have neglected – with some welcome exceptions such as Broome and Foley's (2016) proposal for a World Climate Bank (WCB) – issues about finance crucial to intergenerational climate justice. On the other hand, economists and central bankers have not considered the reverse influence of finance and debt on the normative debates about intergenerational climate justice.

Even before becoming Special Envoy of the United Nations on Climate Action and Finance, the same Mark Carney, as Governor of the Bank of England at that time, was one of the first to declare openly in a speech at Lloyd's in 2015, when the issue of sustainable finance was still a marginal one, that we need to break the 'tragedy of the horizons' (Carney, 2015). Making an analogy with the tragedy of the commons, Carney said that we are delaying our efforts to mitigate climate change, making it every time more costly to do so, and we might face the day when it is too costly to tackle the problem. The Synthesis Report (SYR) of the 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) at the United Nations in 2014 had already emphasized a broad consensus that climate change will have a significant impact on our economies and the financial system. This report and Carney's speech immediately triggered an expanding interest among economists and central bankers in sustainable finance (e.g., Campiglio, 2016; Volz, 2017; Monnin, 2018 a, b), as well as among political theorists (e.g., van't Klooster and Fontan, 2020).

Central banks, for their important role in the financial system, are very well positioned to take the lead in switching to a sustainable global ecological environment. The central bank, as the institution in charge of maintaining price stability, and in some cases, other goals such as high employment and economic growth, needs to buffer from unexpected shocks or disruptions, and also – by analogy – from those potential disturbances or natural disasters that climate change will create to our economies and financial system. According to Lael Brainard (2019), a member of the Board of Governors of the Fed, projected climate change will increase extreme weather events, create agricultural disruptions, and other climate risks that will affect the economy and the financial system. Climate change will have negative consequences for productivity and economic growth. On the other hand, not only climate change will have a clear impact on financial and price stability, but also the transition to a low-carbon economy will undoubtedly affect food and energy prices. Thus, if the central bank aims at maintaining stable prices, it must take into account the effects of climate change on such basic resources. This requires, as a minimum, the supervision and right assessment by central banks of climate risks and of the impact of climate on the value of bonds and stocks and other financial instruments.

The first climate issue that raised interest among central bankers and economists was how climate change might affect financial markets and monetary policy (Carney, 2015; Matikainen et al., 2017; Monnin, 2018 a, b; Brainard, 2019; Shoenmaker, 2019). These authors claimed, initially, that central banks do not correctly assess certain businesses' climate risks. However, once having started from the correct assessment of climate risks, economists and political theorists soon began to argue in favor of more active policies to green the financial system, and the idea of green QE appeared (Anderson, 2015; De Grauwe, 2019).

The question, then, turns out to be: what can central banks do to promote a transition to a sustainable energy system without frustrating their primary goals of price and financial stability? The role of central banks in the low-carbon transition has been studied and discussed in a series of recent academic papers, policy notes, and articles, particularly by Battiston *et al.* (2017), Matikainen *et al.* (2017), Volz (2017), Monasterolo *et al.* (2018), Monnin (2018 a, b), Solana (2018), Battiston and Monasterolo (2019), De Grauwe (2019) and Schoenmaker (2019). These authors call for central banks to do more than just take climate change into account in their monetary interventions. Under QE in response to the GFC central banks have already purchased a wide range of financial assets with varying maturities, including government bonds, asset-backed securities, and corporate bonds and stocks. To invoke some numbers, the ECB has spent €2,600 billion across four sub-programs: Corporate Sector Purchase Programme (CSPP), Public Sector Purchase Programme (PSPP), Asset-backed Securities Purchase Programme (ABSPP) and Covered Bond Purchase Programme (CBPP3). If we take only the assets bought under the CSPP, launched in June 2016, 63% were issued by businesses operating within the most carbon-emitting sectors (such as extraction and distribution of fossil energy sources, and car manufacturing and equipment), and the most energy-consuming sectors (Jourdan and Kalinowski, 2019).

Central bankers have been traditionally reluctant to assume any climate responsibilities. For example, the Bundesbank claimed – in a recent address by Jens Weidman (2019) – that central banks should operate under a principle of market neutrality and cannot substitute for climate policymakers. Neutrality can have two different meanings here. First, it might mean that monetary policy should not interfere with the markets; and, second, that it should be neutral in its effects on the markets. This is, however, now an implausible view, given the contradictory conclusions on the redistributive effects of Quantitative Easing (see, e.g., Montecino and Epstein, 2015; Coibion *et al.*, 2018; Hohberger *et al.*, 2018). It is more reasonable to think that neutrality here refers to neutrality of justification (Raz, 1986; Kymlicka, 1989), and therefore the preferences of central banks for a broad range of liquid assets in their transactions are justified to achieve price and financial stability regardless of the effects of monetary policy on distributive or climate justice. Given the insufficiency of the market for 'green bonds', neutrality in effect has led to the purchase of 'brown or carbon-intensive bonds' by central banks (Schoenmaker, 2019). Indeed, until today central banks have not been environmentally neutral in their post-GFC QE operations: they have *de facto* favored what has become known as 'brown' assets (see, e.g., Papoutsi *et al.*, 2021). One first claim is that central banks should not implement QE without regard to the effects that the companies issuing the bonds and stocks they buy have on climate change. In buying bonds and stocks of carbon-intensive or brown companies, they prioritize the present generation by harming future generations that will suffer from climate change, and it does not seem enough to appeal to market neutrality to justify these harms. Given the influence of climate change on future generations, a monetary policy that exacerbates the problem of the effects of carbon-intensive industries is not only environmentally non-neutral; it is also unjust from the point of view of justice across generations.

We would argue that climate change mitigation should also become part of the mandate of central banks given the emergency of the climate crisis. More precisely, we identify three areas in which central banks can have an impact in mitigating, and adapting to, climate change. First, when launching QE programs central banks should assess correctly the climate risks associated to the bonds they buy. Second, central banks could even go further and change gradually the eligibility criteria to buy only green bonds, and not brown bonds, under QE programs. Third, central banks could also buy bonds from a public investment bank, or the WCB envisaged by Broome and Foley (2016), that will in turn invest in projects to reduce the emissions of GHG and switch to sustainable forms of energy. These last two areas of policy are normally known as initiatives or instruments of green QE or 'green' central banking, in the narrower sense the term has been used so far, since it was coined by Anderson (2015). In our broader interpretation of green QE in the present paper, we complement these 'initial' or 'core' – and more conventional – areas by several novel – and less conventional – initiatives, as discussed in detail further below.

In a preview of our approach, key results and related policymaking proposals with regard to green QE, let us state briefly here what we do and what we find in this study. Having first outlined the interdisciplinary background behind climate change and considered the main principles of intergenerational climate justice from the perspective of philosophy and political theory, we then take as a formal point of departure in our reasoning from the perspective of economic theory the stylized overlapping-generations model of climate mitigation policy proposed by Sachs (2015). We extend it for our purposes to incorporate as well the realistic features of economic growth, nominal interest, inflation, and the option for nonrepayment or partial repayment of public debt across generations. In addition, we replace the focus on fiscal policy transfers and government debt in Sachs (2015) by central bank monetary-fiscal involvement in solving the environmental intergenerational conflict. Given the continuing absence of a first-best carbon tax solution (otherwise complementary to it), we view the central bank, or rather the global network of central banks, as the best suited institution to implement climate mitigation policy, for reasons we clarify. In particular, in this global task and faced with the emergency of preserving life on our planet, central banks do not get involved in political action nationally, as they do not serve any political party or lobby or local social movement at all: they act in the global interest of mankind to let live future generations. In such a sense, we see no conflict with their usual mandates, even if central bank mandates may be expanded to accommodate this new global role in immediate climate change mitigation. Similarly to Sachs (2015), but even allowing for (complete or partial) debt nonrepayment by households and firms in the current or future generations of transfers from the central bank targeting an immediate switch to greening behavior, we find such kind of green QE policy to be Pareto-efficient across generations. But differently from him, we argue that neither the present, nor future generations need to repay the greening compensatory transfers we envisage to serve as a main financial instrument of central banks to trigger a decisive reversal of environmental deterioration now, in the current generation, given the emergency of the situation. Moreover, and in support of the economic considerations and incentives, we argue from the viewpoint of philosophy and political theory that such a financial scheme intermediated by central banks worldwide serves two types of principles of intergenerational climate justice: (i) principles that tell us to mitigate climate change now and avoid harm for future generations; and (ii) principles that tell us how to share mitigation costs fairly across generations. We, finally, aim at some pragmatic implications of our work, and propose a menu of green QE initiatives and options. It includes, notably, a novel concept of 'greening compensatory transfers (GCTs)' and issuance of up to a century-long coupon bonds to be held by central banks. Our green QE policy package allows much flexibility and complementarity in its practical implementation, in particular on voluntary partial repayment or not of these 'across-generation' climate bonds of several long maturities.

To present and justify our arguments in favor of green QE policymaking that central banks across the world could develop and engage with, thereby making a huge impact in our efforts to mitigate climate change, we go step by step and structure this paper accordingly. In the next section, we first look into the long-run trends in GHG emissions and real consumption per capita in the US, as a statistical background; we then provide a brief discussion of the notion of intergenerational climate justice from a philosophical and political theory perspective, and outline the QE that was imposed in policymaking in the wake of the GFC. After that, section 3 delves into considering a pragmatic menu of worthwhile options or policies that can be grouped within the range of various forms or extents of green QE. Section 4 then builds on the theoretical framework due to Sachs (2015) to formally show Pareto efficiency of optimal intergenerational environmental policy, highlighting in particular novel features in the analysis and their influence on the general pros and cons in the argument such as long-run economic growth, nominal interest rates trends, and expected generation-span inflation. Importantly, we also amend

Sachs's (2015) model to account for central bank GCTs to the current generation without necessarily being repaid by future generations, rather than taxing them to repay. This is essential with view that there is a 'power asymmetry' between the current generation and future ones and that the present generation cannot force unborn generations to be a counterparty in a financial contract, even if intermediated by a sequence of elected governments or unelected central bankers. Section 5 proposes an illustrative mechanism of a possible bond issuance to mitigate the adverse human influence on climate change by spreading the financial burden across several generations with leaving an opt-out, i.e., nonrepayment, option or a partial repayment option to future generations that have not been yet born when the bonds were issued. The final section recaps our key insights and offers some concluding remarks.

2 Statistical, Philosophical and Policymaking Background

This section presents the key relevant data and introduces the concept of intergenerational climate justice from a philosophical and political science perspective, linking it to climate change and the implied responsibilities of action for the current generation. Three normative problems arise from our green QE proposal in this paper. First, we examine the implications of green QE for intergenerational climate justice. Second, we look at the legitimacy problem created by the implementation of green QE. Third, we analyze the power asymmetry between the present and future generations. The section then proceeds to outline the typical and widespread policymaking package in response to the GFC that became known as QE, as a forebearer of green QE.

2.1 How Deep Is the Problem? A Look at the Data

Before providing some fundamental philosophical and political context, followed by an overview of the recent QE policies worldwide, we begin by summarizing the quantitative dimensions of the climate change problem we now face, scaled to the increase in real personal consumption per capita over the past three generations or so in the US. We use US data from the Fed database, FRED Data, because they cover the longest time period and are of the highest available quality.

Figure 1 presents the evolution in annual data since 1980 of carbon dioxide emissions in all economic sectors of the US economy across all fuels (coal, oil and natural gas). We can see the worrisome upward trend, but also that it has been broken just before the GFC stroke. Then comes the Paris Agreement in 2015, so we can expect further improvements, also given the urgency of the need for action by the current generation. However, this is just the US, and major polluter nations across the globe are not visible in the graph.

Figure 2 plots the secular increase in real personal consumption expenditures per capita in the US measured in terms of constant US dollars of 2012. One can be impressed by how much our standard of living reflected in consumption of goods and services (as relevant from conventional microfounded modeling of the utility function in economic theory, which we also do in section 4) has been improving with every year and decade. Figure 3 provides the quarterly % change in the same variable, and we do not exclude from our end of the sample (the four quarters of 2020) the ten-fold rise and fall caused by the recent COVID-19 pandemic and the subsequent lockdowns. Figure 4 looks at the same quarterly growth rates of per capita real consumption in the US but now summarized through the lens of a histogram: we can see that the vast majority of the quarterly growth rates are clustered at positive values of 0-0.5% and 0.5-1% per quarter. Figure 5 finally computes mean levels of real personal consumption per capita in constant US dollars of 2012 across three generations. One can again be impressed by the pace of economic progress over the 20-th century and beyond, namely that each next generation consumes approximately twice as much as the previous generation (defined in a time span of about 25 years of active life in work). Indeed, the mean quarterly growth rate of per capita real personal consumption in the US over the whole sample from 1947 through 2020 is 0.5%, or 2% in an yearly increment. As Lucas (1988) has interpreted similar yearly growth rates, these values imply that real personal consumption per capita will double every 35 years – and as our Figure 5, roughly, demonstrates – with each generation span. These trends in real consumption per capita, reflecting parallel trends in real output (gross domestic product, or GDP) per capita and in real national income (gross national income, or GNI) per capita in most advanced and developing economies over the past 75 years or so, have been a reason for some political thinkers and philosophers to argue that some 'sacrifice' from the unborn future generations to fund (at least partially) the current generation might be indeed considered, and imposed, if it comes to triggering climate change mitigation policies now and without further delay. But more on this comes in the next subsection.

2.2 Intergenerational Climate Justice

We can distinguish, at least, between two kinds of principles of intergenerational climate justice. There are (i) principles that tell us to mitigate climate change and (ii) principles that tell us how to share mitigation costs fairly. In this section, we first argue that central banks can, and should, serve intergenerational climate justice by implementing policies that cut emissions and thereby reduce the climate burden on future generations. We then also argue that some of these policies justly shift some of the financial costs of mitigation onto future generations. Finally, given the 'power asymmetry' between the present generation and future ones due to their temporal position, we introduce the possibility of partial or full non-repayment on intergenerational financial instruments. Specifically, we offer a range of policy options that permits this cost-shifting to serve intergenerational climate justice in different ways, e.g., because it represents a more just distribution of mitigation costs between the present and future generations, or because it distributes more fairly the decision-making power across generations.

The idea that we should issue climate or green bonds to finance mitigation is not completely new in debates about intergenerational climate justice. This idea is the core part of Broome and Foley's (2016) proposal of a World Climate Bank (WCB) that would issue climate bonds with a long maturity paid by future generations. The idea is simple: we must mitigate climate change and take climate action now, but we might shift some of the costs of doing so to future generations. It has been referred to as 'the principle of borrowing from the future (BFF)' or as 'making our grandchildren pay', and has already been discussed by notable political philosophers working on intergenerational climate justice (Foley, 2009; Rendall, 2011, 2019; Broome, 2012; Maltais, 2015; Broome and Foley, 2016).

Gardiner (2017) distinguishes two types of arguments that could justify BFF. 'Concessive arguments' claim that although borrowing from the future is unjust because the present generation should bear the costs of mitigation and adaptation to climate change, it is defensible in light of the alternatives (Broome, 2012; Maltais, 2015). In contrast, 'enthusiastic arguments', such as in Rendall (2011), claim "that making the grandchildren pay brings about a moral improvement" because it "can help create morally preferable distributions of resources across generations" (Gardiner, 2017, p. 377). The concessive argument seems to involve both a normative claim: (i) BFF is less just than mitigation paid for by current generations; plus an empirical claim: (ii) BFF is an effective tool for getting current generations to engage in mitigation, since mitigation efforts are not politically feasible if current generations are required to bear the costs. Enthusiastic arguments reject the normative claim, but might still endorse the empirical claim that BFF is a way to get things done and take climate action immediately. According to enthusiastic arguments, the duty to bear the costs of mitigation and adaptation is not exclusively borne by the present generation; it is shared amongst several generations.

The most well-known concessive argument in favor of borrowing from the future was offered by Broome and Foley (2016) when justifying their institutional proposal of a World Climate Bank. They (*ibid.*, p. 159) claim that the emission of greenhouse gases creates an externality and that externalities can always be eliminated by promoting efficiency. That the emissions of GHG create an externality means that the price of burning fossil fuels does not include the damage that the emissions did to other people who are harmed by the effects of climate change. It is always possible, according to economists, to eliminate an externality by promoting efficiency. A Pareto improvement means that the externality can be eliminated, making someone better off without making anyone worse off. If we want to eliminate the externality created by burning fossil fuels and GHG, a Pareto improvement is possible in two different ways: 'efficiency with sacrifice' and 'efficiency without sacrifice'.

According to the former, we can remove the inefficiency if emitters pay the full cost of their economic activities. They would have "to pay a price for their emissions that is equal to the harm the emissions do to other people" (Broome, 2012, p. 40). One way to do that is to set up a carbon tax equal to carbon's social cost. This increase in carbon price will serve to compensate future generations for the damage caused by climate change. Furthermore, a carbon tax will encourage the substitution of green for carbon-intensive consumption goods as the latter become more expensive.

The other alternative to promote a Pareto improvement is 'efficiency without sacrifice'. This requires emitters to cut their emissions, whilst being compensated for their sacrifice by the receivers of emissions (Broome, 2012, p. 44). If those harmed by the emission of greenhouse gases pay a fee to the polluters and the polluters reduce their pollution to the level that those harmed would be willing to pay to avoid that harm, then everyone would be made better off without making anyone worse off. It is a Pareto improvement because the reduction in climate damage compensates future generations that will be better off even if they have to pay compensation to the present generation. At the same time, the latter will not be worse off precisely because future people pay them compensation for the financial costs of mitigating and adapting to climate change.

Crucially, Broome and Foley (2016) believe that the emission of GHG harms future people, and this constitutes an injustice. Even if efficiency without sacrifice eliminates the externality created by greenhouse gases and promotes efficiency, it does not remedy the injustice. If emitting GHG harms other people, the emitters might reduce their emissions by the victims paying a fee to them to cut the emissions. Broome and Foley (2016) clearly make a concessive argument when they claim that "although there is a Pareto improvement, the injustice remains" (*ibid.*, p. 160). However, they claim that it is more feasible than the principle of efficiency with sacrifice because any attempts made to deal with the emission of greenhouse gases have failed due to the unwillingness of the representatives of states to assume the cost of reducing such emissions.

Contrary to Broome and Foley (2016), we can also defend the principle of borrowing from the future not only in concessive terms but also in enthusiastic terms. One of these enthusiastic arguments claims that, since severe climate change will affect so many generations, we are clearly required to reduce GHG emissions to minimize deprivation for future people drastically. However, if climate change is not catastrophic, future generations will be more affluent than the present one (as figure 2 and 5 also convince). Thus, when we distribute the burden of reducing GHG emissions, it is "entirely fair" to shift it to our descendants (Rendall, 2011, p. 885).

When examining how we should distribute the costs of climate change mitigation and adaptation between the members of the present generation, political philosophers have distinguished between two main candidate principles. The 'polluter pays principle (PPP)' says that the costs of mitigating and adapting to climate change should fall on those who played the greatest role in contributing to those harms. In contrast, the 'ability to pay principle (APP)' claims that those who can mitigate or alleviate harm ought to do it, even if they are not responsible for the harm (Caney, 2010; Moss, 2015). When we think about applying these principles across generations, the Intergenerational Ability to Pay Principle (IGAPP) justifies borrowing from the future because we expect that future generations will be much richer than us, but the justification relies on the application of this principle between generations, not only between present wealthy and poor states. If, as Rendall (2011) suggests, we want to justify borrowing from the future applying the IGAPP, we will have to defend it against the PPP arguments for making the present generation pay for the costs of mitigation and adaptation.

Our argument to defend the IGAPP will draw on Caney's (2010) widely discussed account of the relationship between these principles across the members of the present generation. In Caney's (2010) account, the PPP has lexical priority over the APP. He justifies this lexical priority of PPP over APP in terms of the causal responsibility of the polluter and its intentionality in emitting GHG. However, Caney (2010) appeals to the APP to justify the payment of the costs of what he calls 'the remainder'; that is, the APP complements the PPP for these emissions that cannot easily be accounted for anyone, e.g., those emitted by the dead; and he also justifies applying the APP principle to not cause major sacrifices on those who cannot afford the costs of climate change mitigation and adaptation costs, even if they are responsible for part of the emissions. 'The remainder' refers to harmful climate changes that stems from: (i) the emissions of earlier generations; (ii) non-human-induced climate change; and (iii) the (legitimate) emissions of the disadvantaged (Caney, 2010). In connection with this third kind of emissions, Caney (2010) holds "that people should not fall beneath a certain standard of living" so "then the Polluter Pays Principle should be qualified to prevent it being the case that people are made to pay for emissions needed for their fundamental survival" (Caney, 2010).

Now, if we apply the IGAPP, presumably richer generations should pay more, while the present generation should bear the main part of the costs for the emissions caused by them. Here, we present shortly a second argument for minimizing the scope of the IGPPP. We need to take into account each generation's causal responsibility for emitting GHG given the technology inherited by previous generations. Some numbers might help. Suppose the present generation (G1) needs to emit 100 units of GHG to achieve a decent level of welfare. Since we are already taking an effort to mitigate climate change G2 will only need 50 units to achieve the same level of welfare, while G3 will only need 10 and G4, hopefully, only 1. If we, instead, apply an Intergenerational Polluter Pays Principle (IGPPP), we must think about this different ability to not emit for each generation. Therefore, each generation is only causally responsible for the emissions made beyond this level necessary to achieve a decent living-standard; while the costs to achieve this decent level should be distributed according to the IGAPP, as well as any other emissions that cannot be allocated to any generation according to the IGPPP. In short, we have presented a mixed view, according to which 'the intergenerational remainder' will be distributed according to the wealth of each generation. Once more, presumably, if climate change is not catastrophic, future generations will be richer than the present generation. Therefore, by applying the IGAPP we justify shifting some of these costs onto the future, or borrowing from the future.

There is a final point here we would like to address. Rendall (2019) claims that we should consider the risk that future people would not in fact be richer than us. Suppose that even if we are taking climate action now, borrowing money from the future, this turns out not enough, and future people will still suffer severe living conditions. We might think that they would have reasons not to pay back the debt that we issued today. Here, then, we have another reason to use some of the options in our proposed green QE menu later on that allow partial or non-repayment. To summarize, green QE, as we propose it in detail further below, allows to give some margin of decision-making power to future generations as to whether they should or should not pay back the climate debt.

In this subsection, we have addressed the normative issues raised by, in effect, 'making our grandchildren pay'. We have argued that we have reasons to favor the principle of borrowing from the future because it is an effective tool for getting current generations to engage in mitigation. However, the case for borrowing from the future should not be made exclusively on this concessive terrain. We have also argued that cost-shifting serves intergenerational justice too, because it represents a more just distribution of the costs of mitigation between the present and future generations. As already noted, the outlined philosophical background in the present section will underlie our political and economic arguments in sections 3, 4 and 5.

2.3 Legitimacy of Potential Central Bank Involvement with Climate Change Mitigation

We, next, summarize why we think the typical central bank's current (or immediate-future) mandate is compatible with green QE.

For decades, during what has been called "The Great Moderation Era" (e.g., Stock and Watson, 2002) central bankers were seen as technocratic, apolitical bodies. The independence of central banks was instrumentally justified when their only goal was to fix inflation with a single instrument, the short-term interest rate. Time-inconsistency problems caused by electoral pressures make governments less able to promote long-term stable inflation (Kydland and Prescott, 1977; Rogoff, 1985). Thus, delegating monetary policy to unelected experts was seen as a self-binding device to overcome such electoral pressures and promote long-term price stability (e.g., Elster, 1979, 1994, 2000; Dietsch, 2020).

It must be said that setting up an inflation target is a decision with distributional consequences. However, during several decades before the GFC of 2007-2009, it was normally thought that the fiscal authority was seen to have the tools needed to achieve distributive justice – despite the distributive effects of central bank decisions, and they could compensate for these. After the GFC, central banks recovered quickly their interest in broader financial stability, and started using various instruments besides managing the short-term interest rate. QE has to be understood as an instrument to achieve financial stability both in the financial system and the government's debt markets after the GFC.

These new QE policies and their distributional impact have gained interest amongst central bankers themselves, economists, and democratic theorists. Some think that it is less acceptable that independent experts can choose any unconventional means to achieve price and financial stability when these policies have deep distributional consequences (e.g., Fontan *et al.,* 2016; Tucker, 2018; van't Klooster, 2019, 2020). QE exacerbated the concern with the legitimacy of central banks. This concern asks whether it undermines political legitimacy for democratic governments to delegate very important decisions to an independent body that is not subject to re-election and not easily removed by the legislature.

Green QE raises the same distributional concerns and implications for the legitimacy of independent central banks (e.g., van't Klooster and Fontan, 2020). Thus, we need briefly to consider the issue about the democratic legitimacy of delegating decisions with such deep political value to unelected experts. It is desirable that the delegation of powers in favor of the independent central bank come from a law passed by the legislature, which can then impose limits on the central bank's remit. In the case of climate change mitigation, the law can gradually forbid the independent central bank from engaging in some kinds of open market operations, and it can also create a special committee with members of the government and the central bank to oversee such operations and discuss future policies. We disagree with Jens Weidmann (2019) at the Bundesbank when he claims that the central bank should not get involved in climate policies. The reasoning behind Bundesbank's stance is clear, and understandable: it recognizes the political status of these issues, and then concludes that central banks are not political institutions able to make this kind of political choices. While this is true in general, we believe that the special case of climate change is nonpolitical nationally as it is at a global scale and in the interest of future world generations. For this reason, the central banking community should get involved immediately, as part of our proposed green QE initiatives – but with powers explicitly delegated and limited by the legislature and the government in each country, even if coordinated internationally.[4]

2.4 Generational Sovereignty

Having defended the principle of BFF with concessive and enthusiastic arguments, we examine next one important objection to it. The objection claims that this principle constitutes a case of 'intergenerational extortion' (Gardiner, 2017). For Gardiner (2017), against enthusiastic arguments, there is a natural presumption that the polluting present generation should pay and ought not expose future generations to the threats of catastrophic climate change. These threats are precisely created by those who must be paid according to the principle of BFF (again, the present generation). This is, according to Gardiner (2017, p. 377) 'money for menace', a clear case of intergenerational extortion.

Gardiner (2017) defines extortion as the 'attempt to obtain money or other valuables employing a threat' or, more generally, 'through the inducement of wrongful use of force, intimidation, or the undue or illegal exercise of power'. However, Gardiner's (2017) account of intergenerational extortion turns to be inadequate for several reasons. First, the 'gang' (the current generation) cannot ask the 'shopkeeper' (future people) for a tribute amount because future people do not exist yet. As Gardiner (2017) correctly claims, instead, the present generation can unilaterally shift resources from the future to the present, but it cannot ask future people. Instead, it has to figure out a justification for them, as we tried to do when defending the IGAPP with relation to our several policy proposals in this paper. For the same reason, future 'shopkeepers' cannot decide whether or not to pay because they do not exist yet. Again, the present generation might think about how much future people will be willing to pay to convince the present generation to take climate action. To conclude, we think Gardiner's (2017) case against intergenerational extortion fails due to the problem of the nonexistence of future people and the impossibility of communication between the present and future generations.

Nevertheless, Gardiner (2017) raises another kind of a more plausible worry, but which can be accommodated by the range of policy proposals defended hereafter. He also argues that BFF implies a problematic use of intergenerational power due to the temporal asymmetry between the present generation and futures ones. We address this worry allowing options to future generations to pay partially or not accumulated climate change debt they had not agreed formally to share in. The idea here is that we should preserve generational sovereignty, with collective rights and duties attached to it. More

[4] It is insightful, or ironic, that climate change seems to have reversed a long-lasting trend toward central bank noninvolvement with (national) political issues and influence from the (national) government, that started since Kydland and Prescott (1977), and focussing exclusively on inflation targeting – see also the evolving views in the present context of one of the coauthors here in, e.g., Arestis and Mihailov (2009) and Mihailov and Ullrich (2015). However, we stress that climate change mitigation is a global emergency nowadays and is therefore nonpolitical in a national sense. It is thus justified internationally to become part of the central banks' remit (as an exception, and quite differently from other political or social issues of a more local and less crucial nature) – as we also argued earlier from the grounds of moral philosophy and political theory.

precisely Gosseries (2016) argues that a future generation has "effective sovereignty during its period of existence to the extent that it is free from extra-generational jurisdictional claims by other generations and have enough material resources to actually be able to decide among meaningful options." On this view, historically, some authors have defended that future generations should be treated as independent entities and that it is illegitimate to exercise extra-generational power over them (see, e.g., Locke, 1689; Kant, 1784; or much more recently Otsuka, 2003; Gosseries, 2016).

The different schemes proposed hereafter can restrict future generations choices in a legitimate way. We leave enough space for future generations to exercise their generational sovereignty. Thus, green QE enhances generational sovereignty in two ways. First, it helps to take climate action now and leave enough resources in terms of a clean atmosphere to future generations. Secondly, once the central bank enters in the equation of BFF, our proposals allow to preserve the generational sovereignty of future generations, with the option for nonrepayment or partial repayment of public debt across generations.

2.5 Quantitative Easing

After the extensive overview in the preceding three subsections of the philosophical, legal and political-theory background on how generations could share or not the costs of climate change mitigation now, by the current generation, we proceed by outlining densely the macroeconomics of QE. Based on this 'now conventional' QE (then, in the wake of GFC, 'unconventional' monetary policy), we further propose, in section 3, a possible range of financial instruments that could form part of a next, 'green' QE.

Independent central banks have general goals, such as controlling the money supply and fixing the interest rate through open market operations and securing price and financial stability. The main role of central banks, e.g., as expounded by Goodhart (2010), is to be in charge of the money supply through open market operations, to adjust their balance sheet and fix the interest rate, and to monitor the risks related to strategic financial institutions. To understand how QE works, we need to take a look at the most important feature of central banks, that is, the fact that they have the monopoly on the issuance of currency. There is a hierarchy of money, and 'central bank money', or the monetary base (i.e., cash in circulation and bank reserves on accounts with the central bank) is the ultimate form of settlement between economic agents (e.g., Pistor, 2013; McLeay *et al.*, 2014 a, b). It is true that the central bank is not the only institution that creates money, private banks create deposits as if 'out of nothing' when they grant loans to their customers and also when they operate in the interbank market. Bank deposits constitute 97% of the broad money (i.e., notes and coins in circulation and deposits at banks) used in the UK economy (McLeay *et al.*, 2014 b, p. 15). However, it is this special power of the central bank that makes it the key institution of our democracies to achieve price and financial stability. A simple explanation holds that to achieve price stability the central bank has control over the short-term interest rate charged to commercial banks. Since commercial banks keep reserve accounts at the central bank, this official short-term interest (or policy) rate affects their operational costs, and thus, they adjust the interest rate they charge to other market participants as a markup (or spread) over the policy rate. These changing costs on economic agents influence their decisions about investment and consumption, which in turn change the level of inflationary pressures on the economy (see, among many others, Dietsch *et al.*, 2018, p. 7).

The main channel for monetary policy implementation actually consists in open market operations. To get access to more liquidity, commercial banks can turn to each other in the interbank lending market, that is, the market where commercial banks lend to each other to meet their short-term liquidity needs. To influence the effective interest rate in the interbank market, the central bank changes the amount of liquidity to which commercial banks have access through open market operations. Central banks swap with commercial banks amounts of liquidity for specific assets that act as collateral. To inject liquidity the central bank acquires assets from commercial banks, creating central bank reserves, and these open market operations "affect all the other interest rates by first affecting the availability of cheap credit on the interbank lending market" (again, see, e.g., Dietsch *et al.*, 2018, p. 8).

In 2000, Japan was the first country – via its central bank – that launched QE programs to fight deflation when nominal interest rates were close to their zero lower bound. In 2008, the US Fed and the Bank of England responded to the global financial meltdown with 'unconventional' monetary policy such as QE, and the ECB joined them a few years later. These central banks, first, modified and extended their open market operations in size, range of collateral, and length. Second, they launched QE programs, that is, the outright purchase of large amounts of financial assets in secondary markets. Under these programs, central banks have purchased a wide range of financial assets with varying maturities, including government bonds, asset-backed securities, and corporate bonds and stocks.

Quantitative easing implied a massive increase in money supply – of about more than €2 billion for the ECB – to purchase bonds and stocks, increasing the size of major central banks' balance sheets five or six times (Fontan *et al.*, 2016). A growing number of political philosophers have been examining the issues of the social responsibility of finance and the distributional consequences of QE programs. The financial system is one of the basic structures of society, and it is important to note that the system contains private elements, such as commercial banks and investors, and public ones, such as the central bank and regulators (Pistor, 2013; de Bruin *et al.*, 2018). Central banks and regulators, being the public elements of the financial system, connect finance with questions of legitimacy and justice (Fontan *et al.*, 2016; Tucker, 2018; Dietsch *et al.*, 2018; van't Klooster, 2019).

The argument made so far claims that QE implies decisions made by independent nonelected officials that have huge distributional consequences for the life prospects of people, and this calls into question the legitimacy of independent central banks. Here, though, we are concerned with another kind of normative issue, arising from green QE: namely, a global issue of intergenerational climate justice, and proposals to use central banks' hierarchical position in financial markets to facilitate a transition to sustainable finance. Sustainable finance implies that financial markets should not be used to facilitate investments in carbon-intensive industries; they should be instead used in financing the transition to a sustainable energy system that is not based on burning fossil fuels and emitting GHG.

3 A Pragmatic Menu of Green QE Initiatives Worth Highlighting

In a recent interview in the Financial Times (of 8 July 2020), Christine Lagarde, President of the ECB, announced a €2.8 billion program to buy green bonds; that is, basically, the ECB is going to implement green QE. In this interview, Lagarde states that she thinks about her grandchildren and her great grandchildren and that she does not want them to think that the present generation were the rascals that caused damaging climate change and severe life conditions for them. She adds that environmentalists should also understand that money matters when dealing with climate change mitigation and adaptation, and that is the reason why central banks have to take the lead to finance the costs of a transition to sustainable forms of energy. More importantly, she also claims that the design of these green bonds is a political matter. In agreement with those who raised concerns about conventional QE and the problem of the political legitimacy of decisions with deep distributional consequences taken by independent central bankers (Fontan *et al.*, 2016; Tucker, 2018; van't Klooster, 2019), Lagarde thinks that launching green QE programs requires cooperation among different branches of the government and regulators. We will return to the question of legitimacy and the mandate of central banks later once again. However, it is important to understand that the design of green bonds has political implications and should concern policymakers and political theorists. The aim of this paper is also to make a normative case, on the grounds of Pareto-optimal environmental policy across generations, in favor of green QE and to illustrate in what follows the more pragmatic design of several varieties of green finance according to the principles of intergenerational climate justice discussed in the previous section.

3.1 Climate Risks

In building up the spectrum of possible green QE initiatives or instruments that are worth highlighting, and perhaps implementing, we go step by step in the remainder of this section. In order to remedy the impact of the financial system on climate change, we can distinguish between three green QE policies. As already mentioned, the first climate issue concerning QE that raised the interests of central bankers and economists was the issue of climate risks. Due to the principle of market neutrality, when buying bonds and stocks under QE programs, central banks require a broad basket of assets to choose from and a certain degree of solvency by the issuer of the bonds and liquidity of the bonds. This degree of solvency and liquidity is basically assessed by rating agencies, but the problem is that these are private entities that have been under suspect for their conflicts of interests with the companies they assess (Matikainen *et al.*, 2017; Solana, 2018).

Central banks often take these ratings for granted when choosing which bonds to buy under QE programs, and this causes the potential risk of dominance of brown assets in central bank portfolios relative to green assets, as was discussed earlier (see, again, Jourdan and Kalinowski, 2019; and Papoutsi *et al.*, 2021). Matikainen *et al.* (2017) claim that rating agencies are private entities and they do not assess correctly climate risks associated to certain businesses. As an example, British Petroleum might have a very good valuation by these agencies without taking into account that their profits are necessarily going to decline if we are to make a transition to sustainable forms of energy that do not require burning fossil fuels, which at some point will be inevitable. In addition to these transitional costs, that is the cost of carbon-intensive businesses becoming obsolete, there are two other types of climate risks for the financial system. One of them, called 'physical' risk, is associated to weather phenomena such as storms and floods and more severe weather events that come along with climate change and will affect financial markets. In the end, climate change can create systemic risk for the entire financial system, if not tackled in time. Finally, the third type of climate risk can be referred to as 'financial', and is associated to individuals and businesses seeking for compensation from those that they hold responsible for their damage (Volz, 2017). Greening finance in the sense of the present subsection requires to develop and apply methodologies to identify and measure climate-related risks to financial institutions, enforce or encourage disclosure of climate-related financial risks by firms and investors, incorporate environmental considerations into prudential regulations, and integrate sustainable environmental, social and governance (ESG) criteria in the evaluation of the overall risk of an asset purchased (Jan and Merle, 2019; Schoenmaker, 2019).

3.2 Standard Green QE

In addition to and beyond climate risks, we can distinguish two types of green QE policies. Even if the distinction is not so clear in practice, analytically it is useful to differentiate between 'standard' green QE policies that help to make a transition to sustainable finance and cut emissions so as not to harm future generations, and 'progressive' green QE policies that also distribute the financial burdens of climate change mitigation more fairly across generations. If we invoke again the two distinct principles of intergenerational climate justice, standard green QE serves intergenerational climate justice by implementing policies that cut emissions and thereby reduce the climate burden on future generations, while progressive green QE justly shift some of the financial costs of mitigation onto future generations.

What we can call standard green QE requires central banks to buy bonds and stocks only from companies that are not brown, that is, not carbon-intensive companies. The companies issuing bonds that are eligible for QE programs do benefit from a tighter credit spread. That is, eligible bonds for QE programs have a lower gap in yield to government debt compared to the bonds that are not eligible for QE programs (Volz, 2017; Battiston *et al.*, 2017; Shoenmaker, 2019). This lower gap in yield compared to government bonds makes financing for companies whose bonds are eligible for QE programs much cheaper. Thus, implementing standard green QE will have the effect of increasing the financial costs for carbon-intensive industries while making credit available for green projects at a cheaper financial cost. Ideally, there will be coordination between green monetary policy and fiscal policy. Standard green QE will supplement the effects of a carbon tax to switch from a fossil fuel energy system to sustainable forms of energy. Standard green QE can also be extended to all open market operations that the central bank undertakes and not only to QE programs.

Schoenmaker (2019, p. 2) emphasizes that not only QE, but all monetary policy operations – including conducting open market operations, managing foreign exchange reserves, and operating the payment system – "involve allocation decision when purchasing assets and taking collateral (through the so-called 'eligibility criteria')." Extending standard green QE to all open market operations means that when intervening in the interbank lending market, the central bank will only accept as collateral a commercial bank's assets from non-carbon intensive industries or, in short, green bonds. This approach can also be extended to the entire interbank lending market: when commercial banks are lending to each other, they will only accept as collateral green assets. The effects of standard green QE in the whole financial system would be huge, given liquidity and stable demand for green bonds. Since green assets would become safer assets than brown ones, investors would look for green assets as a form of secure investment. Moreover, as a last resort, the central bank has the capacity to step into the market for green bonds and secure their liquidity and marketability. Indeed, the most significant effects are that it will reduce central bank's balance sheet exposure to brown assets and make credit cheaper to green projects and more expensive for carbon intensive businesses.

Standard green QE requires changing the eligibility criteria of the central bank when it buys bonds and stocks under QE programs. It also requires promoting a higher number of green bonds and certain homogeneity so that these can be securitized and bought under green QE programs (Matikainen *et al.*, 2017; De Grauwe, 2019). One worry about green QE is that it might lead to print too much money and create inflation. As noted, it is important that a central bank can potentially buy all debt, wait until its maturity and substitute for new debt. De Grauwe (2019) points out that there is no limit to the amount of financial assets the central bank can buy. In principle, the central bank could purchase all existing financial assets, but that would increase the money supply in such a way that inflation would rise dramatically, and the value of money would fall sharply (De Grauwe, 2019).

A rise in inflation will compromise the primary role of central banks: to maintain price stability. In reality, price stability is interpreted by most modern central banks to correspond to an inflation target of 2% *per annum*, on average. Taking the ECB as an example, De Grauwe (2019) claims that it could also purchase bonds issued to finance environmental investments. The only restriction on these purchases is that they do not endanger the 2% inflation target. De Grauwe (2019) notices that under QE the ECB has bought €2,600 billion of corporate and government bonds without fueling inflation and "it has announced that when these government and corporate bonds come to maturity, new bonds will be bought in the market so as to keep the money stock (money base) unchanged. This creates a 'window of opportunities' for the ECB. It could replace the old bonds with new 'environmental bonds', i.e. bonds that have been issued to finance environmental projects. In doing so, the ECB would not create new money. It would only reorient money flows towards environmental projects. As the total amount of money would remain the same there would be no risk of additional inflation."

Even if the above inflation risks find some decent solution, the main problem for standard green QE is that green bond markets are not developed enough. For example, the total value of green bonds in European financial markets is less than the value of bonds bought under CSPP undertaken by the ECB. Thus, the switch to green eligibility criteria should be made gradually if we do not put into risk price stability and the usual transmission channels of monetary policy (Schoenmaker, 2019). An appropriate transmission channel of monetary policy requires a broad basket of bonds (green or brown) that ensures that the efforts of the central bank to keep inflation under control are adequately reflected in financial markets. This means that the transition to green monetary policy must be gradual, giving the central bank the choice between green and brown bonds that secure the transmission mechanisms of monetary policy, until the market of green bonds is wide enough to ensure this crucial function of the central bank. Schoenmaker (2019) shows that a small tilt through green requirements in collateral transactions will reduce ECB's balance sheet exposure to carbon-intensive industries by more than 40% and create a spread of 4 basis points between green and brown bonds. However, central banks can do more than changing the eligibility criteria, they can help to create and promote a deep and liquid market of green bonds and long and stable demand for these bonds (Volz, 2017). To see how, we have to look into more direct policies for making a transition to a sustainable financial system.

3.3 Progressive Green QE

'Progressive' green QE goes beyond standard green QE in encompassing measures that also are deemed to achieve a more just distribution of mitigation costs across generations. It has been suggested that the central bank 'prints' money to buy bonds from a public investment bank (Anderson, 2015; Matikainen *et al.*, 2017; De Grauwe, 2019), or an international climate bank such as the World Climate Bank (WCB) proposed by Broome and Foley (2016), which in turn directs programs aimed at reducing CO2 and CH4 emissions. The particularity of green QE is that it allows us to design green bonds, either public or private, that are specially created to finance projects to switch to sustainable forms of energy and take action to stop global warming and climate change. Therefore, there is a window open to design these green bonds according to the principles of intergenerational justice that distribute fairly the costs of mitigation and adaptation to climate change across generations. This progressive form of green QE requires, again, some degree of coordination between monetary and fiscal authorities that might take the form of a special committee with members of the government and the central bank.

A proposal for progressive green QE can include climate bonds with different maturity dates, some of them very long, precisely to distribute the costs of mitigation across several generations. This implies that it might happen that within this very long period of time, inflation does not remain as low as it has been during the last decade of QE programs. Therefore, the central bank might need to apply a contractionary policy and sell these green climate bonds. The idea we defend here is that green QE programs will only be in place during recessions and periods of low inflation throughout a sequence of business cycles, and the central bank will sell the climate bonds when inflation surges. Since the central bank will have changed its eligibility criteria and only accept green collateral in their operations with its reserves and the interbank lending market will also have this limitation, we expect that there will still be stable demand for green bonds even if the central bank takes a contractionary policy stance. One of the main aims of progressive green QE is to help develop a market for green bonds that is big enough to be sufficiently broad and liquid to ensure that the transmission channel of monetary policy operates correctly with only green bonds. More interestingly, from the perspective of political philosophy progressive green QE allows to design green bonds according to intergenerational climate justice principles, i.e., with several maturity dates – say, every 25 years, which corresponds to a generation span – and therefore redistribute the financial burden of mitigation across generations.

3.4 A Climate Bad Bank

Green bonds will be used to finance a transition to sustainable forms of energy that do not emit GHG and mitigate the effects of human economic activity on climate change. But they can be used for other purposes too, and in addition, as complementary, to other financial instruments and regulation policies in a portfolio to mitigate climate change. A transition to a sustainable economy will create winners and losers, and amongst the latter shareholders and workers in carbon-intensive companies (Salin and Daumas, 2020). A just transition from a social viewpoint will have to invest in retraining the workers of these industries and help them find jobs in other sectors, while minimizing the likely period of initial, and hopefully brief, unemployment spell for all of them. Equally, there should be a corresponding restructuring of these brown industries into green ones, where feasible, by an upgrade of their technological processes. Furthermore, some of these brown companies may not have the prospect of a viable technological upgrade into green companies; then, the value of their capital will fall drastically, creating losses for their shareholders.

Who must pay for these losses? One economic response to that problem, as proposed by Salin and Dumas (2020), is to create a Climate Bad Bank (CBB) that will buy all these assets from carbon-intensive industries that cannot be restructured into green ones, and compensate both its shareholders and former workers. The central bank is key in this case because it can finance this CBB, either by financing debt issued by the CBB to buy these brown assets (Salin and Daumas, 2020), or by buying them directly, to just keep them on its balance sheet and depreciate their value.

There are big normative issues too that are raised by this proposal of a Climate Bad Bank. E.g., we might support investment in retraining for workers; but we might think that shareholders who have knowingly invested in carbon-intensive industries ought not to be compensated. These issues are outside of the scope of our argument here, but they can be accommodated by concessive arguments in favor of BFF, such as Broome and Foley's (2016) proposal of efficiency without sacrifice.

3.5 Central Bank Mandates and Green QE

We already discussed, in the preceding section, the key legitimacy issues of a potential central bank involvement in mitigating climate change. We, essentially, argued that climate change mitigation is a global, and hence not a nationally political, urgent task. We shall now link these arguments to our green QE proposal and expand a bit more on other aspects of the legitimacy issue.

While focusing on price stability as a primary objective, it is common amongst more than 50 central banks in the world to have a secondary goal to support the respective country's broader economic policies (Dikau and Volz, 2019 a, b). Thus, to mitigate climate change in order to protect future people from adverse environmental developments that may even result in loss of consumption should be understood as forming part of, or being situated within, these broader economic goals of the country. Being so, it should not be perceived to contradict the main goals of the central bank to preserve price and financial stability. The same case has been made for the ECB: in particular, Articles 3 and 11 of the Treaty of the European Union (TEU) specify the sustainable and environmental economic goals for the EU (Solana, 2018; Schoenmaker, 2019). The problem Volz (2017) and others raise is whether green QE will be in contradiction with central banks' primary goals of price and financial stability. Indeed, we want to design green QE measures that will be effective in abruptly improving the environment, yet with central banks still protecting us from inflationary pressures and debt unsustainability.

Some have questioned green QE on the grounds that to make active green policies the central bank will have to face a tradeoff between price stability and green monetary policy that will jeopardize its primary price stability objectives. The main problem here is the lack of a broad market for green bonds that, if it existed, would facilitate the transmission mechanisms of green monetary policy. Progressive green QE is meant to facilitate the development of such a broad market for green bonds. But until it comes into wide operation, the transition to sustainable finance must be gradual, as we noted.

How do we design green bonds is a political question that should awake the interests of policymakers and political theorists; indeed, it should be the legislature or the government that is responsible to design the bonds that should be bought under progressive green QE (and by extension under any QE program). Furthermore, and as discussed, progressive green QE requires coordination between fiscal and monetary authorities, and as a more general point, a complete optimal green economic policy requires both a carbon tax and green QE. This coordination between branches should reinforce the procedural and democratic legitimacy of the institution while preserving the instrumental value of independence. We want to emphasize that our proposals in this paper should be viewed not as a unique solution to climate policy, but more realistically as part of a comprehensive package of complementary well-designed and coordinated policies, which include, and do not exclude, proposals such as those for a World Climate Bank, a Climate Bad Bank, fiscal policy (carbon) tax measures and incentives at the level of national governments or international treaties, or legislatures, and their enforcement.

In addition to the concern with legitimacy, QE exacerbated as well the concern with economic justice. It asks whether the policies of independent central banks, which – as we argued in the earlier sections – have a deep distributional impact on citizens, are in line with economic justice. With regard to these two concerns, we think that one should avoid construing central bank independence in binary terms, so that central banks either are, or are not, independent. This way of construing the possibilities confronts us with a dilemma. Either we must endorse the instrumental case for central bank independence – namely, that it is necessary for economic efficiency – or we must reject that case for the sake of democratic legitimacy and economic justice.[5] We think that one should instead construe central bank independence in scalar terms so that independence admits degrees. This helps us to avoid the dilemma by allowing us to develop an account of independence in which central banks can retain independence to the extent necessary for economic efficiency, while meeting reasonable concerns regarding legitimacy and economic justice. Historically as well as institutionally, the role of the central bank has changed, and its relation with the government too (Goodhart, 2010; Tucker, 2018). But nowadays, and with view to an urgent and effective climate change mitigation as we propose in this

[5] We assume that economic justice, encompassing possibly the concepts of social fairness or social equity, differs from economic efficiency, usually understood in the sense of Pareto optimality.

paper, modern society should construct a degree of independence that allows the central bank to raise up to the emergency of intergenerational climate justice while still meeting its primary goal of price stability as well as its democratic and procedural legitimacy.

3.6 Greening Compensatory Transfers

A final idea we have related to the above considerations, and at the same time offering potentially another financial instrument, that could be complementary to the array of those already discussed and having gained by now some popularity, to be used to induce a quick and decisive shift toward nonpolluting technologies is what we would call 'greening compensatory transfers (GCTs)'. We envisage this novel financial instrument, targeting and specialized to 'reimburse' cost differences, to consist in cash transfers to consumers, workers and shareholders that have the only purpose to compensate them for the monetary (or market-valued) costs to switch from brown to green products, jobs and securities, respectively. Imagine that a consumer has an option to buy a brown product that is cheap relative to a (complete or close) substitute that is produced using green technologies with no (or much smaller) pollution to the environment. Then such a consumer GCT will 'rebate' the monetary cost of switching to the more expensive green product.

Of course, that way only the consumer's choice has been compensated for its greening, but there are yet losers from the switch in consumption, namely the workers in the brown industry that produced the cheap brown substitute and the shareholders in the firms in this industry, as the latter is doomed to decline unless it is (gradually) transformed into one depending only on green technologies. Hence, there need to be two additional GCTs related to the consumer GCT we just outlined. The first may be termed a worker GCT, and it will cover the cost of retraining the labor force in a brown industry either to use green technologies or to get an update in qualifications so that it can be employed in another, green industry. The second may be termed a shareholder GCT, and it may possibly – provided earlier arguments whether the brown assets have been knowingly purchased or held – compensate the loss of market value in the portfolio of stock holders, e.g., with a substantial exposure (say, above 67.7%) in brown industries that undergo a transition to greening (for some period of time, e.g., 3-5 years) or that are being sized down and ultimately closed.

The funding for these three types of related GCTs can come from either fiscal or monetary policy, and in the latter case it could either be monetization of government budget deficits or direct cash transfers that are like a gift of money. The GCTs we propose are indeed similar to the old idea of 'helicopter money' (of Friedman, 1969) having become popular with the advent of the COVID-19 pandemic once again (e.g., Benigno and Nisticó, 2020). However, the difference is that GCTs can be used for the prescribed special purpose only, and this needs to be verifiable and ascertained, in principle *ex post* (e.g., by purchase receipts or other accounting methods – which is feasible and easy with IT payment technologies everywhere), but could be perhaps *ex ante* too. Through such GCTs, central banks could play a key role in implementing quickly, and at no harm for either the present or future generations, mitigation policies to the effect of cleaning up the global ecosystem. Of course, there will be some impact on inflation, while consumers and firms switch to more expensive, but green, products and technologies, respectively. But there will be no conventional spur in inflation caused by too much money chasing too few goods. In this sense, there cannot be a danger of persisting inflation, beyond the implementation of such GCT-based mitigation policy.

Blyth and Lonegren (2014) support a similar idea where the central bank should provide cash transfers directly to the people, perhaps the bottom 80% of the income distribution for fairness reasons, especially when a recession looms on the horizon. Then this 'helicopter money' should be spent to spur the economy and, possibly, eradicate recessions.[6] In our case, the argument is that such GCTs to individuals should only be used for the specific purpose of buying a consumption good or service substitute that is green and more expensive rather than the cheaper brown alternative. As mentioned, analogous CGTs could be applied to firms, both their workers and shareholders, but only to encourage investment in green technologies or shifts toward such technologies.

In this sense, and as part of a broader green QE campaign that involves the array of financial instruments discussed in the present section, central banks – in coordination with elected governments – could take the lead in mitigating climate change. Indeed, as will be argued formally in the next section, using a somewhat modified model due to Sachs (2015), this novel role for central banks, under the urgencies of our time and given their institutional evolution over centuries, emerges as a Pareto-efficient solution across generations of the greening of the planet and, so, is also consistent with the related principles of intergenerational climate justice discussed thus far.

4 A Theoretical Framework to Analyze Climate Change Mitigation

Sachs (2015) proposes similar economic arguments on climate mitigation across generations to those examined in the preceding sections and a stylized model to analyze optimal environmental policy. He uses as a main instrument of climate change mitigation policy intergenerational fiscal transfers, whereas we argue in favor of central bank involvement by means of green QE, and in particular our idea of greening compensatory transfers to the current generation not requiring ultimate repayment. Sachs (2015) assumes that "the fundamental case for climate change mitigation applies", which – as he shows formally – requires that "the present value of the benefit of a unit of mitigation [...] is greater than the marginal cost of mitigation." Under this – perhaps plausible – condition, Sachs (2015) finds that mitigation policy is Pareto-improving across the two generations, in the sense that "the young generation can vote a mitigation strategy and transfer policy that is financed by government debt. The next generation will repay that debt by taxes on labor income. Today's young generation is left unharmed. The second-period young generation is made better off."

To study climate change mitigation under fiscal policy transfers, Sachs (2015) writes down the simplest possible model with two-period overlapping generations (OLG). To convey and check theoretically our proposed spectrum of options within green QE, we do not need to move too far away from Sachs's (2015) framework. For this reason, we follow the structure of his two-period model, yet we also adapt it in order to highlight a few novel features in the analysis and how they influence the discussion in general on the advantages and limitations of green QE climate policies, such as long-run economic growth, nominal interest rates and expected inflation across generation spans. We, notably, amend Sachs's (2015) model to be able to account for central bank GCTs to the current generation without necessarily being repaid by future generations, rather than taxing them to repay. Such an option in the analysis seems crucial from the intergenerational climate justice viewpoint we emphasized in earlier sections that the current generation cannot force unborn generations to be a counterparty in a financial contract, even if the contract is intermediated by a sequence of elected governments or unelected central bankers.

[6] However, even real-world socialism in the 20-th century could not eradicate the long-run cyclical nature of market economies that was restored after the transition back to private property. As it turned out during this 'grand experiment', under the central plan the controlled smooth path of the economy crashed into the distorted economic incentives and the resulting inability of the social system for even a minimalist material reproduction (see, e.g., Farvaque *et al.*, 2018). This is a warning of caution not to ruin economic incentives and mechanisms in any kind of social reforms or policy implementations.

4.1 Assumptions

As usual, we begin by listing concisely the main assumptions of the model.

1. We consider a global closed economy comprised of overlapping generations, where each time period has two generations that overlap: one young and working, and the other old and retired.

2. Each generation lives for two periods of time: it works in the young period and retires in the old period.

3. Subscripts to variables denote units of time, and a time period t corresponds to a generation span (say, 25 years or so).

4. Superscripts to variables denote whether the generation is young and working, if y, or old and retired, if o, in each particular time period t.

5. A generation t is denoted by the active time span when it is young and working; i.e., the combination of a subscript t with a superscript y defines generation t.

6. For our purposes, it is sufficient to focus on two generations, each living for two periods; hence, the model economy will last for three periods.

4.2 Model Setup

Generation 1 is born, works, consumes and saves in period 1, and retires in period 2, consuming only from savings made in its active period 1 out of its disposable income. Generation 2 is born, works, consumes and saves in period 2, and retires in period 3, consuming only from savings made in its active period 2 out of its disposable income. We stop here in our theoretical analysis, although the sequence can continue forever.

Savings can be either in physical capital K or in financial capital B, and following Sachs (2015) we assume that the net real return (or interest) rate on both assets is the same constant percentage r. In each period, workers earn a pre-tax wage W_t and pay net taxes T_t.

To capture the economics of climate change in this simple model, the global economy emits GHGs, and policy could mitigate the environmental pollution. As in Sachs (2015), wages depend on climate policy since mitigation is costly, and there are two scenarios to consider: (i) 'business as usual (BAU)', which is characterized by not activating mitigation policy, and then the concentration of emissions in period 2 is E; and (ii) a policy that activates a costly emission mitigation technology M_1, where $0 \leq M_1 \leq 1$, so that now emissions in period 2 are reduced by the degree of mitigation, and are thus given by $(1 - M_1)\,E$. The government – or, in a broader sense, that could be the central bank or a coordinated monetary-fiscal policy, or even a specific intergenerational institution charged with implementing a long-run environmental mandate such as in the Paris Agreement – chooses the degree of climate pollution mitigation to be enforced by regulatory policies prescribed to the private sector.

The market wage in period 1 is, then, the equilibrium wage W reduced by an amount devoted to mitigation in the same period:

$$W_1 = W - \lambda M_1 \tag{1}$$

GHG concentration in the global atmosphere in period 2, G_2, evolves over time depending on the mitigation policy in period 1:

$$G_2 = (1 - M_1)\,E \tag{2}$$

The market wage in period 2 is assumed to be affected by the quality of the global environment in terms of GHG concentration, as in Sachs (2015); but differently from Sachs (2015), we also allow a constant generation-span trend growth in wages, at a net % rate g, which is consistent with the secular increase in GDP per capita, income per capita and consumption per capita, as evidenced in the data – see again figures 2 and 5:

$$W_2 = (1+g)\,W - \theta G_2 \tag{3}$$

Disposable income for each working generation in any period t is standard:

$$Y_t = W_t - T_t, \qquad t = 1, 2 \tag{4}$$

We now model what can be broadly interpreted as coordinated monetary-fiscal policy in the long run, to mitigate the human-polluting consequences of climate change. Sachs (2015) interprets this mechanism as fiscal policy only, i.e., net transfers of the government, positive to generation 1 and negative to generation 2, so that an intergenerational government budget constraint is satisfied in present value terms:

$$T_1 + \frac{T_2}{1+r} = T_1 + \frac{1+\pi^e}{1+i} T_2 = 0 \tag{5}$$

We make the analysis explicitly dependent on (net) expected generation-span inflation π^e by using the *ex-ante* Fisher definition of the real interest rate in the above equation, linking also to the (net) nominal interest rate i. What Sachs (2015) proposes is to assume that the government makes transfers to generation 1 in period 1, i.e., $T_1 < 0$, by selling government bonds B_2, which it then redeems by taxing generation 2 in period 2; under his scenario, then, $B_2 = -\,T_1$ and $T_2 = (1+r)\,B_2 = \frac{1+i}{1+\pi^e} B_2$. We shall propose variations and alternative interpretations of monetary-fiscal policy in the slightly more general context we embed here in the model.

Using (2) in (3) and then (3) in (4) for $t = 2$, one can express the net disposable labor income of generation 2 in period 2 in terms of the mitigation and monetary-fiscal policies implemented on generation 1 in period 1:

$$Y_2 = (1+g)\,W - \theta\,(1-M_1)\,E + \frac{1+i}{1+\pi^e} T_1 \tag{6}$$

As far as saving is concerned, we follow Sachs (2015) and assume a constant saving rate s out of disposable income that presumably maximizes life-time utility. Differently from him, but without consequences for the analysis of interest here, we allow generation 2 to live for a second period, during $t = 3$, and thus also save for retirement. So when generation t is young, it works and saves:

$$C_t^y = (1-s)\,Y_t^y, \qquad t = 1, 2 \tag{7}$$

Its savings are invested in a portfolio of financial assets (or government bonds, in the narrower interpretation in the model) and physical capital:

$$B_{t+1} + K_{t+1} = sY_t^y, \qquad t = 1, 2 \tag{8}$$

And when generation t is old, it consumes out of the return on past savings:

$$C_{t+1}^o = \frac{1+i}{1+\pi^e}\,(B_{t+1} + K_{t+1})\,, \qquad t = 1, 2 \tag{9}$$

We further assume, as in Sachs (2015), that the population is constant, L, in each generation. The national income identity for period 1 then states that output Q is equal to income:

$$Q_1 = W_1 L \tag{10}$$

An analogous (but richer, due to saving in period 1) identity holds for period 2:

$$Q_2 = W_2 L + r K_2 \tag{11}$$

We, finally, specify the lifetime utility function U_t^l, with $t = 1, 2$, of each generation in terms of their lifetime consumption levels:

$$U_1^l = U_1^l \left(C_1^y, C_2^o\right) \tag{12}$$

$$U_2^l = U_2^l \left(C_2^y, C_3^o\right) \tag{13}$$

As Sachs (2015) points out, if these utility functions are well-behaved, as we assume, they can be written in terms of disposable labor income:

$$U_j^l = U_j^l \left(Y_t\right) \qquad j = 1, 2 \tag{14}$$

From (14), (4) and (1), the welfare of generation 1 can now be expressed in terms of mitigation and monetary-fiscal policies as:

$$U_1^l = U_1^l \left(Y_1\right) = W - \lambda M_1 - T_1 \tag{15}$$

From (14) and (6), the welfare of generation 2 can similarly be expressed in terms of mitigation and monetary-fiscal policies as:

$$U_2^l = U_2^l \left(Y_2\right) = (1+g)\, W - \theta \left(1 - M_1\right) E + \frac{1+i}{1+\pi^e} T_1 \tag{16}$$

4.3 Optimal Intergenerational Environmental Policy

A conventional utilitarian approach to optimal intergenerational environmental policy will assign an equal weight to each generation by not discounting the future. This leads to an intergenerational environmental social welfare criterion (IESWC) that can be written as a weighted average of generational utilities:

$$IESWC = V\left(U_1^l, U_2^l\right) = 0.5 U_1^l + 0.5 U_2^l \tag{17}$$

We can now consider three cases of intergenerational environmental policy, as proposed by Sachs (2015).

4.3.1 Balanced Budgets Create Intergenerational Conflict

This is the case of $T_1 = T_2 = 0$. It is evident from (17), after plugging (15) and (16), that

$$IESWC \left(T_1 = T_2 = 0\right) = 0.5 \left[W - \lambda M_1 + (1+g)\, W - \theta \left(1 - M_1\right) E\right] \tag{18}$$

and so for the case of zero trend growth of output, income and consumption, $g = 0$, climate change mitigation policies generate an extreme intergenerational conflict of interest: as in Sachs (2015), generation 1 favors $M_1 = 0$ (i.e., no mitigation sacrifices), whereas generation 2 favors $M_1 = 1$ (i.e., excessive or complete mitigation policies). Given the equal weighting of the two generations in the IESWC, then $M_1 = 0.5$, which results in (18) becoming

$$IESWC \left(T_1 = T_2 = 0, g = 0, M_1 = 0.5\right) = -0.25 \left(\lambda + \theta E\right)$$

With long-run economic growth, the welfare of generation 2, of course, increases, by an additional negative gW term in the brackets of the expression above, so there might be arguments on the ground of intergenerational climate justice, as we proposed in the earlier sections, that the mitigation policy could be somewhat milder, i.e., $M_1 < 0.5$.

4.3.2 Present Generation Voting Biases Against Mitigation Policies

It is also clearly seen that democratic societies would bias the present generation to delay mitigation policy. Indeed, if generation 1 is asked to decide by voting, instead of relying on a 'benevolent social planner' or an analogous institution intermediating between generations as we suggested, the economic interest reflected in the equations of the model selects $M_1 = 0$. This will be implied by the logic of the modeled behavior unless altruistic or ethical features in utility are explicitly introduced. We leave this avenue of exploration for further work.

4.3.3 Intergenerational Climate Justice as Intergenerational Pareto Efficiency

Finally, a third scenario to consider – and this is the key insight from our theoretical analysis in the present section of optimal intergenerational environmental policy – is when we allow for monetary-fiscal policy that may not necessarily involve balanced budgets across generations. We begin by following the case analyzed in Sachs (2015), and then make it more general.

The case of no economic trend growth, $g = 0$, considered in Sachs (2015), implies a Pareto optimality of a fiscal policy that sets $T_1 = -\lambda M_1$. As can be verified in (18), then generation 1 is compensated completely by the net government transfer for the cost of mitigation policy, and so the latter is implemented, thanks to the intervention of the policymaker. In this scenario the disposable income of generation 1 is as high as it would have been under the BAU bias of $M_1 = 0$. Now looking at the welfare of generation 2, they have to repay back the accumulated fiscal debt due to the transfer to generation 1 that was needed to offset its sacrifice on mitigation. With $g = 0$ as in Sachs (2015), we obtain from (6) and policy $T_1 = -\lambda M_1$:

$$Y_2 = W - \theta\left(1 - M_1\right)E - \frac{1+i}{1+\pi^e}\lambda M_1$$

The above expression shows that Y_2 increases with M_1 only if the positive influence of the middle term is stronger than the negative influence of the last term. More formally:

$$\frac{\partial Y_2}{\partial M_1} > 0 \Leftrightarrow \theta E - \frac{1+i}{1+\pi^e}\lambda > 0$$

Hence:

$$\frac{1+\pi^e}{1+i}\theta E > \lambda \tag{19}$$

This is a key result in Sachs (2015), which is interpreted in the usual way: the present value of the marginal benefit (of a unit) of mitigation, $\frac{\theta E}{1+r}$, should exceed its marginal cost λ. Assuming this inequality holds, which Sachs (2015) refers to as 'the fundamental case for climate mitigation', he then shows that mitigation policy is Pareto-improving across the two generations. In words, generation 1 votes in favor of a mitigation policy financed by net transfer from the government to itself to offset their sacrifice; generation 1 does not suffer in this way from the costs of mitigation, and implements it. Generation 2 then inherits a cleaner planet and no matter that it repays the accumulated government debt, as long as the fundamental case for climate mitigation (19) applies, it is still made better off.

4.4 Incorporating Growth, Interest, Inflation and Nonrepayment

We now can add detail and extend the analysis beyond the initial one in Sachs (2015). We shall do that in four steps, emphasizing four respective refinements in the presented theoretical intergenerational cost-benefit analysis and its potential – and complementary – real-world implementation strategies, institutional actors and financial instruments.

4.4.1 Economic Growth Favors Future Generations

First, we incorporate economic growth. As can be seen, the derivative sign condition (19) is not affected by allowing $g > 0$. However, secular economic growth as observed in long-run data (see again figures 2 and 5) strengthens the case of the future generation being constrained by the balanced intergenerational budget of the elected sequence of governments or of a nonelected institution with an intertemporal nature and vision such as the central bank. This is so because, as seen by the first term in (16), economic growth increases wages, and standards of living (provided an environmental catastrophe is avoided) of each subsequent generation. Being (much) richer than us, our great-grandchildren could thus bear at least a fraction of the cost of the mitigation policy implemented by our generation in the name of longevity of life on our planet, hence in part in their inherent and genuine interest too.

4.4.2 Central Banks Manage Nominal Interest Rates and Inflation Expectations

Second, we highlight the role of the nominal interest rate and expected (generation-span) inflation on the tradeoffs involved. One can see in (19) that lower nominal interest rates and higher inflation expectations improve the chances for implementing climate change mitigation policy via government bonds or monetary-fiscal transfers to the present generation because they increase the present value of its marginal benefit relative to its marginal cost. Intuitively, lower real interest rates make borrowing from the future generation(s) cheaper. In particular, central banks in the world are the technocratic or expert institutions that are responsible to manipulate nominal interest rates and to manage inflation expectations. In this sense, central banks may be better suited than a sequence of elected governments of potentially different colors and opposing policy views to be entrusted with the lead role on mitigating climate change, as envisaged in our menu of options along the spectrum of green QE.

4.4.3 The Return on Green QE Bonds Could Just Protect from Ex-Post Annual Inflation

Third, if we want to alleviate further the burden of repaying for the future generation, we could set the nominal interest rate on the bonds or transfers across generations at zero, $i = 0$. Then, as in one of our proposed (in section 5 next) green QE implementation strategies, with sharing of the costs and benefits of mitigation policies across 3-4 generations, the central bank (or government) bonds of GCT nature and long maturities will not bear nominal return, and will thus be similar to Treasury inflation-protected securities (TIPS) or corporate inflation-protected securities (CIPS) available since the late 1990s in US and international financial markets. That is, to alleviate the burden of this environmental policy intergenerational financial instrument, the issuers of the bonds (firms or households) will only repay the principal augmented by inflation (not expected, but with an annual *ex-post* observed indexation) and only for their lifetime. This pragmatic, or implementation, proposal of ours with regard to GCTs in particular and green QE more generally through bond issue will be discussed shortly in section 5.

4.4.4 Central Banks Could Transfer Greening Compensatory Cash to the Current Generation without Repayment

Fourth, in a still milder version of the burden for the future generations, we can modify the presented theoretical framework in a way that does not require repayment of the bonds by the future generation(s). Why is this important? As we argued when discussing in earlier sections intergenerational climate justice, if future generations that are not yet born cannot sign financial contracts with the current active generation, then why should they be bound to repay these? It could be that they may have the option to not repay anything, or repay partially as much as they deem fair, looking back from their future time to our present choices, and taking in account the damage to the planet we have incurred to them or not been able to prevent for them. Why are central banks needed in such a scenario? Because governments cannot maintain unbalanced budgets intertemporally and accumulate huge debt, whereas the central bank can simply print money at its own will and allocate it for the specific mitigation policy via GCTs, without requiring repayment (for analogous arguments, but in the post-COVID-19 pandemic context, see, e.g., Benigno and Nisticó, 2020). In such a particular version of green QE, via GCTs as we propose, central banks seem the only institutions that could implement it.

Under these considerations, the presented model can be modified in a way that sets $T_2 = 0$. Consequently, (15) remains the same but (16) now becomes simpler (as its last term vanishes):

$$U_2^l = U_2^l\left(Y_2\right) = \left(1+g\right)W - \theta\left(1-M_1\right)E$$

Sachs's (2015) fundamental case for climate mitigation (19) then simplifies too, becoming

$$\frac{\partial Y_2}{\partial M_1} > 0 \Leftrightarrow \theta E > 0$$

which is always satisfied, by construction; unless GHG emissions are completely controlled, and ruled out at zero, $E = 0$; and, similarly, unless future wages do not depend on GHG concentration, so that $\theta = 0$. Intuitively, the future generation in this scenario only benefits: from a cleaner environment it inherits due to the implementation of the climate mitigation policy of central banks as part of a green QE package that includes a sort of 'intergenerational debt forgiveness'; the future generation bears no costs. The current generation does not bear a cost either, as the cost of mitigation policy is fully covered by the net transfer of compensatory cash from the central bank, or from the government but monetized by the central bank. This outcome is, again, a Pareto-optimal equilibrium, made possible with the generous institutional intermediation of central banks between generations, via GCTs and their unique function to print money without creating debt.

5 A Proposal for Issuing Generation-Shared Green QE Bonds

We here aim to propose an illustration of a possible implementation of some variant of green QE by means of an extremely long-term bond issue by households and firms as debtors of the present generation to be held by the central bank as creditor (or an analogous government bond issue monetized by the central bank, which is approximately equivalent). The point in this type of very-long-term bond issuance is that it allows sharing of the repayment burden across generations, with an option of the future – and even the present – generations to pay partly or not at all (and then the remaining debts will be written off). The very urgency and grand scale of environmental policy require, we think – and have also argued from the philosophical and political theory perspectives of intergenerational climate justice as well as from the perspective of economic theory and intergenerational Pareto optimality – nonstandard measures and nonstandard financial instruments to induce that the current generation launches the saving of the planet immediately and with the necessary depth and commitment. Indeed, as e.g., Broome (2018) argues, while the inaction of the current generations for several decades may well be explained with egoism, materialism and unwillingness to sacrifice costs of their own income or welfare, that is, to internalize the polluting externality, climate mitigation is much more than a usual externality in economics: if not tackled on time, that is right now, by the current generation, in a century or two the human race may be extinguished by the destruction of the living conditions on the Earth.

If we assume that future generations will be richer than the present one, as is the historical trend – see once again figures 2 and 5, we can borrow from them to take action against climate change and protect them from further harm caused by climate change. Progressive green QE allows us to design bonds with several maturity dates, let us say every 25 years – which, roughly, corresponds to a generation span – over a long run of 100 or more years to come. We propose to link their yield to just cover from *de facto* annual inflation, protecting bond holders from inflation *ex post*, and reducing the borrowing costs for the present generation via not requiring to pay a nominal interest rate different from zero, as we deem fair within the logic of such financial instruments. There is still a cost for the holder, that is, central banks as we propose, the loss of interest above the inflation rate; and there is, of course, a cost for the current and future generations in repaying, fully or partially; but we, notably, argued – in the context of GCTs, in particular – that the private sector, both living and unborn, may not bear any cost on climate change mitigation, only the central bank can bear the cost, yet it can also always print money.

Suppose for a moment that, in one possible future scenario with government-held – not necessarily central bank-held – public debt, 'generation 4' (say, 100 years from now) arrives at a situation in which it suffers severe climate change and still has to face a huge remaining debt repayment. Probably, they will find a better argument than the one presented so far and conclude that the present generation should have borne all or much more of the cost of taking climate action. The central bank, because of its potential, could then buy all the existing green bonds at that moment and write-off the green debt, as it does in a financial crisis when it considers that financial assets are bad assets with no actual value. This, of course, would have economic consequences that the future people would have to consider by themselves, as it is impossible to fully anticipate them.

We assume, as a benchmark example of our calculations regarding the potential super-long-run bond issues with shared and optional repayment across generations, a coupon bond that pays back to the creditor, that is, the central bank, a coupon of 100 monetary units at the end of every calendar year, i.e., on 31 December, augmented only with the net rate of annual inflation *ex post*. In the illustration, we have instead assumed a constant inflation of 2% *per annum* and have calculated the due inflation-augmented coupons *ex ante*, in the last-but-one, 6th, column of Table 1.

How shall one read Table 1? The first column lists the coupon in constant face value of 100 monetary units per year. The second column is meant to take into account the usual in macroeconomics and finance subjective discount factor of $\beta = 0.96$, in annual frequency, which corresponds to an annual average return on investment of about 4% (roughly) consistent with the data. The 3rd column in Table 1 counts the years, and the 4th column calculates the present discounted value (PDV) of the coupon of 100 units of money in every subsequent year. Column (5), then, introduces the constant 2% inflation expected (for the purposes of the calculation, mostly) every year from now into the future, and column (6) computes the coupon due every year that the borrower (households and firms) should repay annually topped up with this *ex-ante* constant inflation rate. The final column (7) then calculates the PDV of this *ex-ante* constant-inflation-augmented annual coupon, yet in a practical implementation the *ex-ante* coupon, as we would recommend, should be replaced by an *ex-post* coupon that augments the 100 face value by observed inflation, e.g., by a usual indexation scheme.

The bottom line of the table provides the magnitudes of the financial variables. In column (1), we see the face value of 10000 monetary units, in column (4) we see its PDV, in column (6) we see the equivalent of the future value of a present coupon bond over 100 years at face value of 10000 monetary units today, and column (7) gives its PDV. We have used for illustration a maturity of 100 years, but this can be split in at least 2 shorter maturities, namely, 25 years = 1 generation span or 50 years = 2 generation spans (or also 75 years = 3 generations spans). The computations will be analogous, and the face value of the 100 coupon per year will be the same as the corresponding inflation-augmented annual values in column (6). In such a scenario, the central bank (or government) will provide more flexibility on repayment options, if the 'free-lunch' GCT-only implementation we propose is not undertaken (for reasons of being rejected as extreme), as it may be expected that each generation pays for, say, 25 years, then the next generation continues, and so forth; moreover, we envisage that each generation – in a non-GCT-only implementation of this super-long-run climate change mitigation bond scheme – may pay only for 5-10-15 years, or not at all, and then the debt will ultimately be written off. That is why the central bank seems to be indeed the only institution to operate such bond scheme without any negative effects on society (such as accumulating government debt: see, again, Benigno and Nisticó, 2020, on this crucial difference between the government and the central bank, as the latter only can perform the role of 'a lender of last resort to the nation').

We think, as we argued, that it is fair to allow an option to the future generations to repay partly or not repay a contract they have never signed, some of them being even unborn. As to any potential costs, mainly in the form of inflation created by the implied long-run cycles of monetary expansions, we propose that central banks issue these green QE bonds predominantly in times of recessions over the course of several business cycles – hence the long maturities envisaged, with the shortest being 25 years. Moreover, if such periodic and countercyclical monetary expansions are implemented in relation to GCTs only, as we suggested, or mostly in such a form, the inflationary consequences will be further reduced. We are aware that writing off debts is an unusual and unproductive measure in normal times that would distort financial and economic incentives and will lead most likely to a social crash with tragic and long-term consequences similar to that of socialism in the 20-ths century. Nevertheless, we believe that the costs of writing off some such green QE debts (or bond repayment to the central bank) will be justifiably minimal compared to the vital task of saving the life on our planet.

6 Concluding Remarks

This paper aimed to contribute – theoretically (normatively) and in terms of policymaking (positively) – to the economics, politics and philosophy of intergenerational climate justice in an interdisciplinary and innovative way. We argued in favor of green QE that central banks across the world could design and engage with, in coordination with governments and international organizations, which has the potential of making a huge impact in reversing immediately human-influenced environmental deterioration.

We began by analyzing the long-run trends in GHG emissions and real consumption per capita in the US, as a statistical background; we then provided an analogous anchoring within the notion of intergenerational climate justice from a philosophical and political-theory perspective; we, finally, summarized the original QE in policymaking in the wake of the GFC. Against this motivating context, we next outlined a policy-relevant menu of worthwhile financial initiatives that can be grouped within the range of various forms, or extents, of green QE policies. The economic theory behind our arguments built upon, and extended, the framework in Sachs (2015), and showed formally a Pareto-efficient intergenerational environmental policy. In our extension to his initial model, we highlighted novel features in the analysis and how they matter in the argument, such as long-run economic growth, nominal interest rate trends, and expected generation-span inflation. Importantly, we also took into account a novel instrument, 'green compensatory transfers' by the central bank to the current generation without necessarily being repaid by future generations, rather than taxing them to repay. Our discussion and proposal along these lines are essential because the current generation neither can implement the first-best solution of a carbon tax, nor can force unborn generations to enter a financial contract, even if intermediated by a sequence of elected governments or unelected central bankers. We, finally, presented an illustration of a possible long-run bond issuance by the current generation credited and held by the central bank, either GCT-only or not. Its goal is to mitigate the adverse human influence on climate change by spreading the financial burden across several generations with leaving an opt-out, i.e., nonrepayment, option or a partial repayment option to the present as well as future generations.

Our main theoretical results and related policymaking proposals highlight the value and options within green QE, and central bank monetary-fiscal involvement in solving the environmental intergenerational conflict, more generally. We argued that the central bank, or rather the global community of central banks, is the best suited institution to implement climate mitigation policy, for a number of advantages (relative to governments or other institutions) we clarified and given the continuing absence of a first-best carbon tax solution – otherwise complementary to it. In particular, faced with the emergency of preserving life on our planet and raising to this new global task, central banks do not get involved in political action nationally: they do not serve any political party or lobby or regional social movement at all but act in the interest of mankind to let live future generations, and in this sense we see no conflict with their usual mandates, even if these may be expanded to accommodate such involvement in immediate climate change mitigation. Similarly to Sachs (2015), but even allowing for (complete or partial) debt nonrepayment by households and firms in the current and future generations of cash compensatory transfers from the central bank targeting an immediate switch to greening behavior, we found such kind of green QE policy to be Pareto-efficient across generations. Differently from him, we stressed that neither the present, nor future generations need to repay the GCTs we envisaged to serve as a main financial instrument of central banks to trigger a decisive reversal of environmental deterioration immediately, by the present generation. Moreover, and in support of the economic considerations and incentives, we argued that such a financial scheme intermediated by central banks worldwide appears broadly justified on the philosophical, legal and political theory grounds underpinning intergenerational climate justice. Focusing on some pragmatic implications of our work for policymakers, we emphasized a spectrum of several green QE initiatives and mechanisms to be possibly implemented together, in a complementary and comprehensive way.

Of course, this paper was only a step ahead, mostly from the viewpoint of economic and political theory, into an exploratory direction within an interdisciplinary territory of accumulating complex knowledge such as climate change, and how it can be tackled successfully by the present generation. It goes without saying that our stylized modeling and the related policymaking proposals are not final or conclusive. While we trust that what we reported, and recommended, constitutes an 'essential core' in optimal environmental intergenerational policy, much remains to be done on refinements and quantification, as well as on the precise design of financial instruments and their implementation, for the ambitious green QE scheme we outlined here to eventually leave a cleaner planet to our great-grandchildren. Further research, and coordination across science disciplines and policy institutions globally, will be urgently needed.

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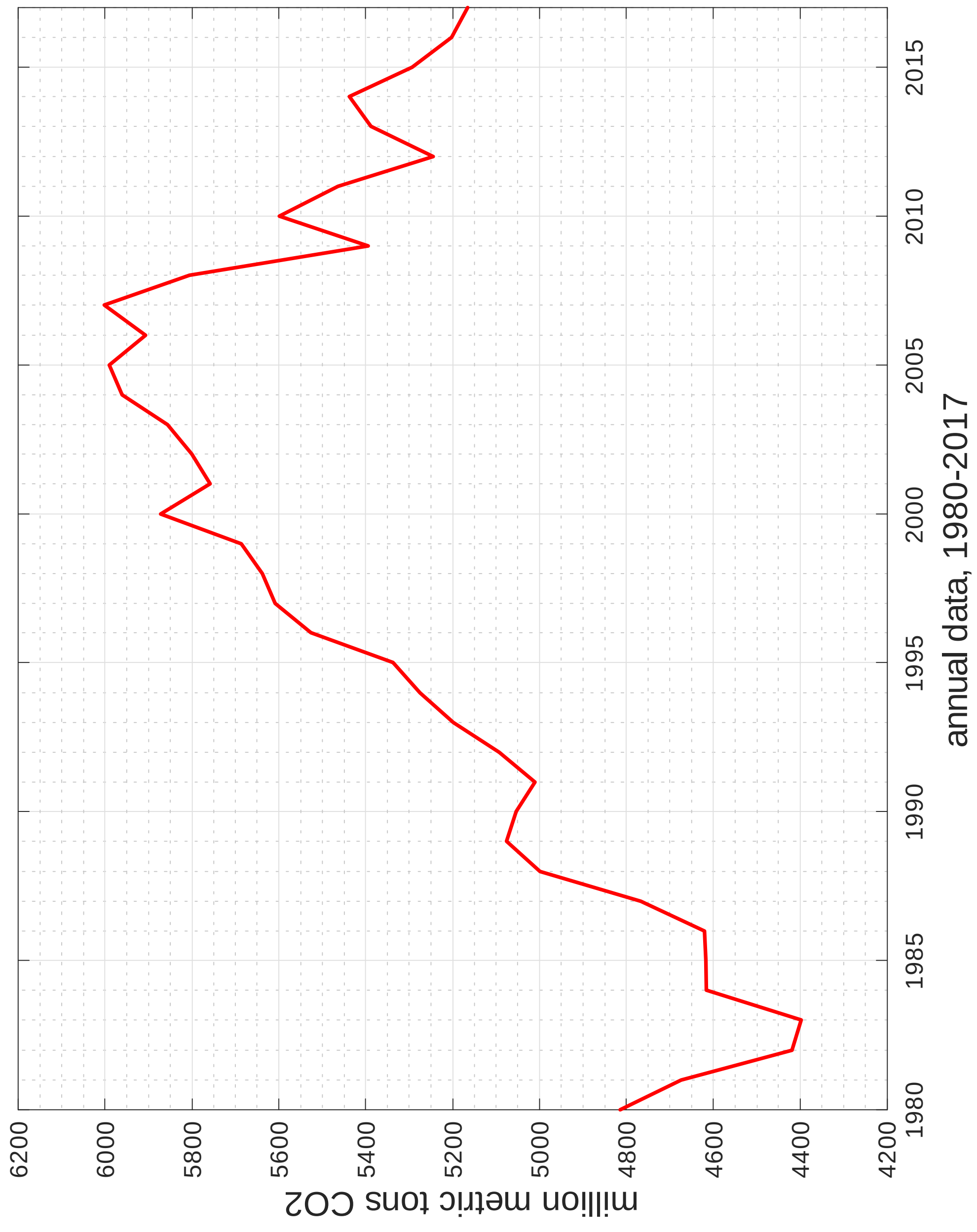

Figure 1: Total Emissions of Carbon Dioxide, US. *Source:* FRED Data.

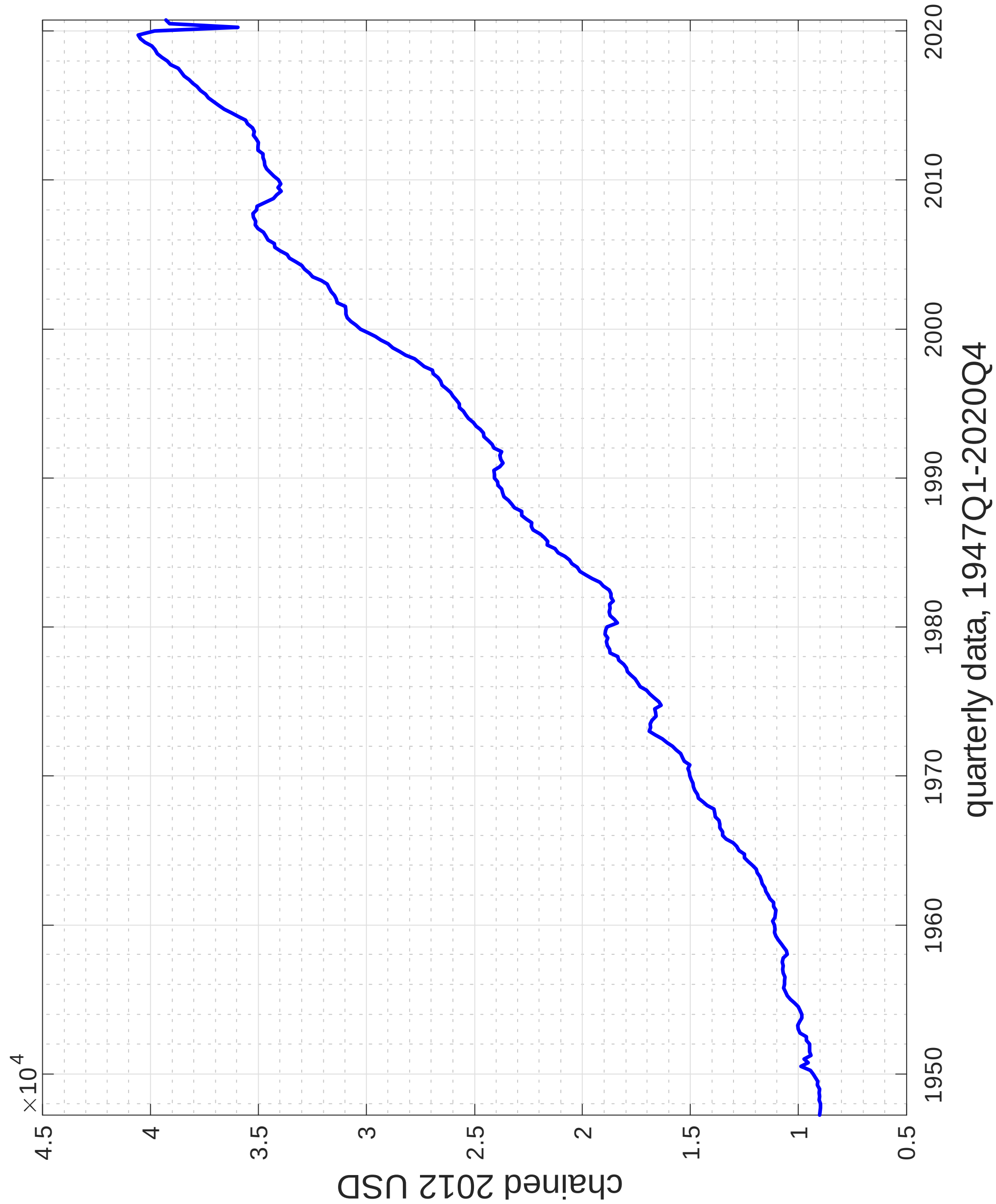

Figure 2: Real Personal Consumption Expenditures Per Capita, US. *Source:* FRED Data.

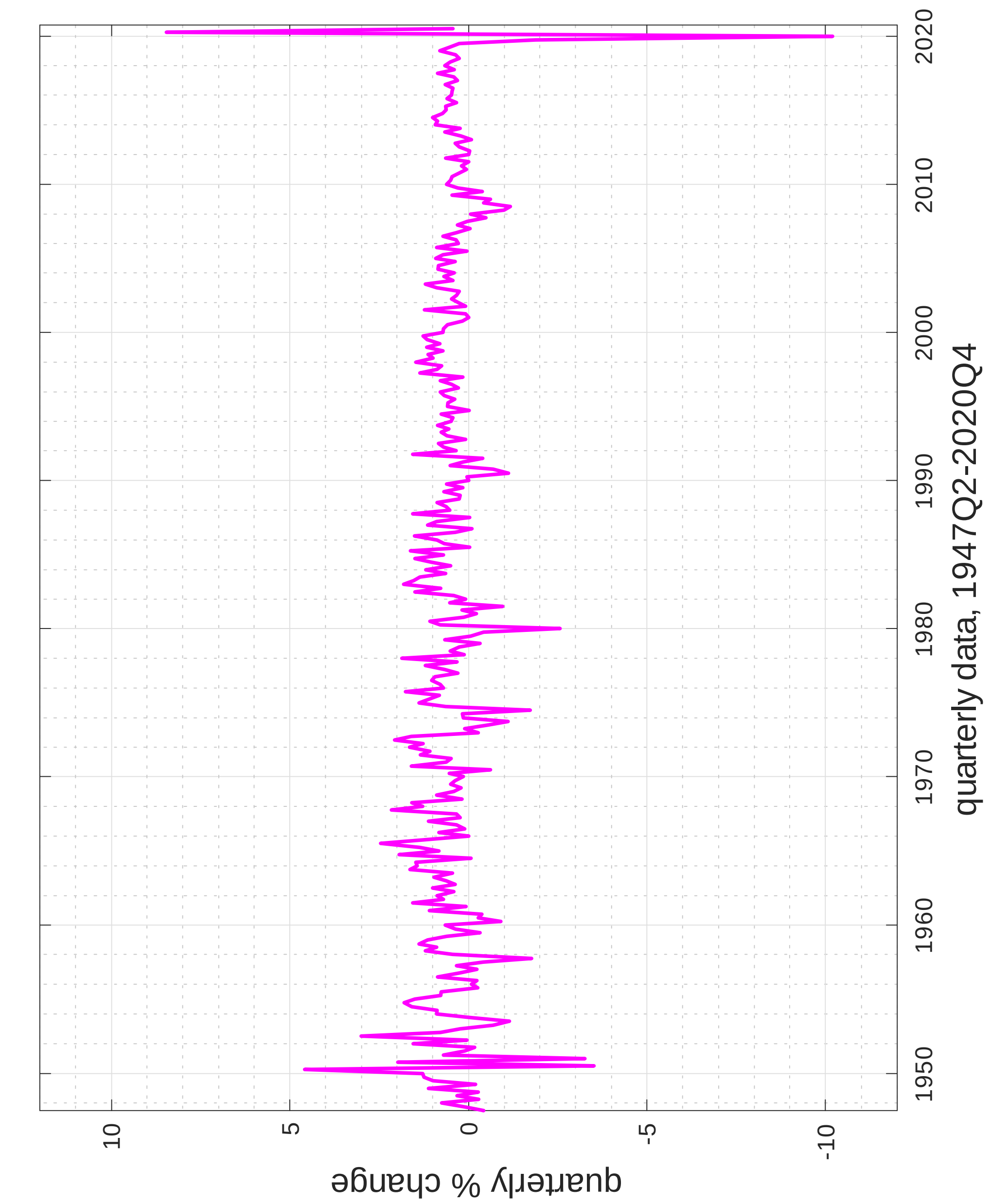

Figure 3: Real Personal Consumption Expenditures Per Capita, US, % Change. *Source:* FRED Data. Authors' calculations.

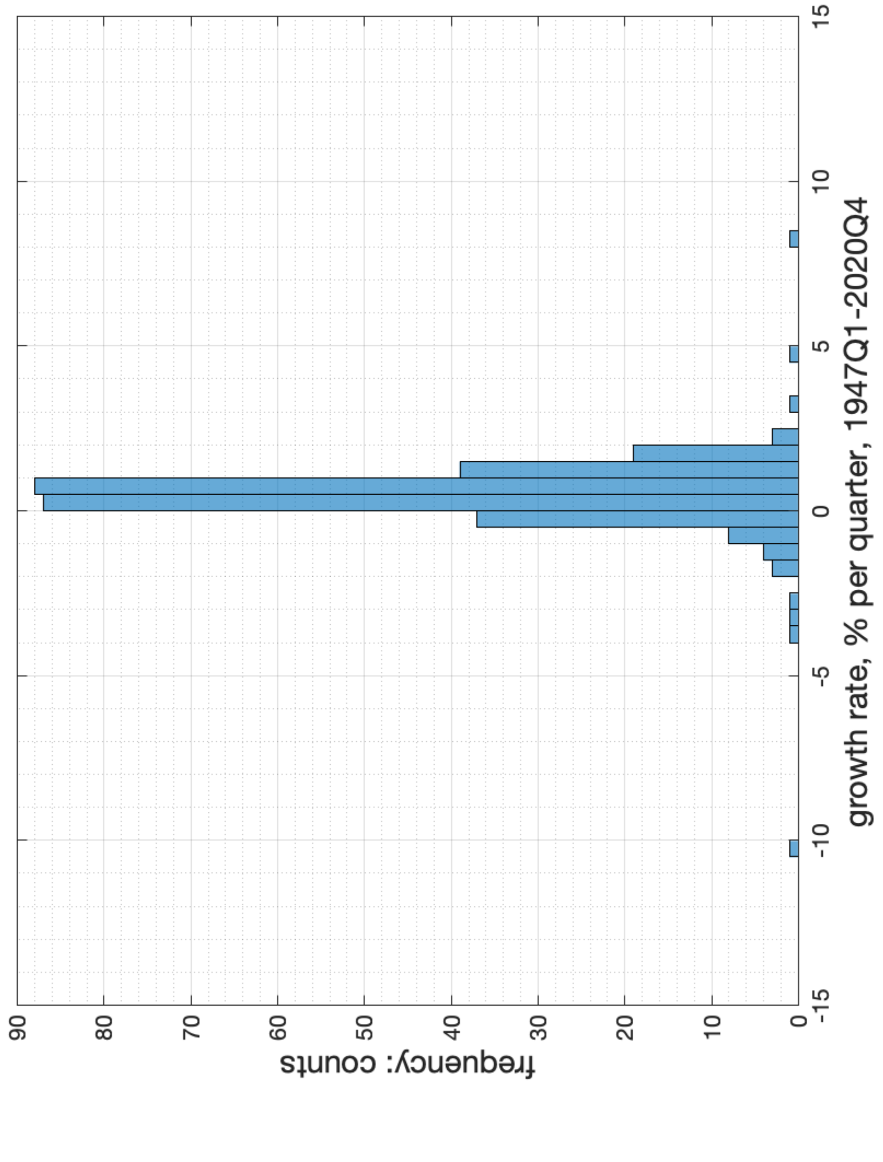

Figure 4: Real Personal Consumption Expenditures Per Capita, US, Histogram of % Changes. *Source:* FRED Data. Authors' calculations.

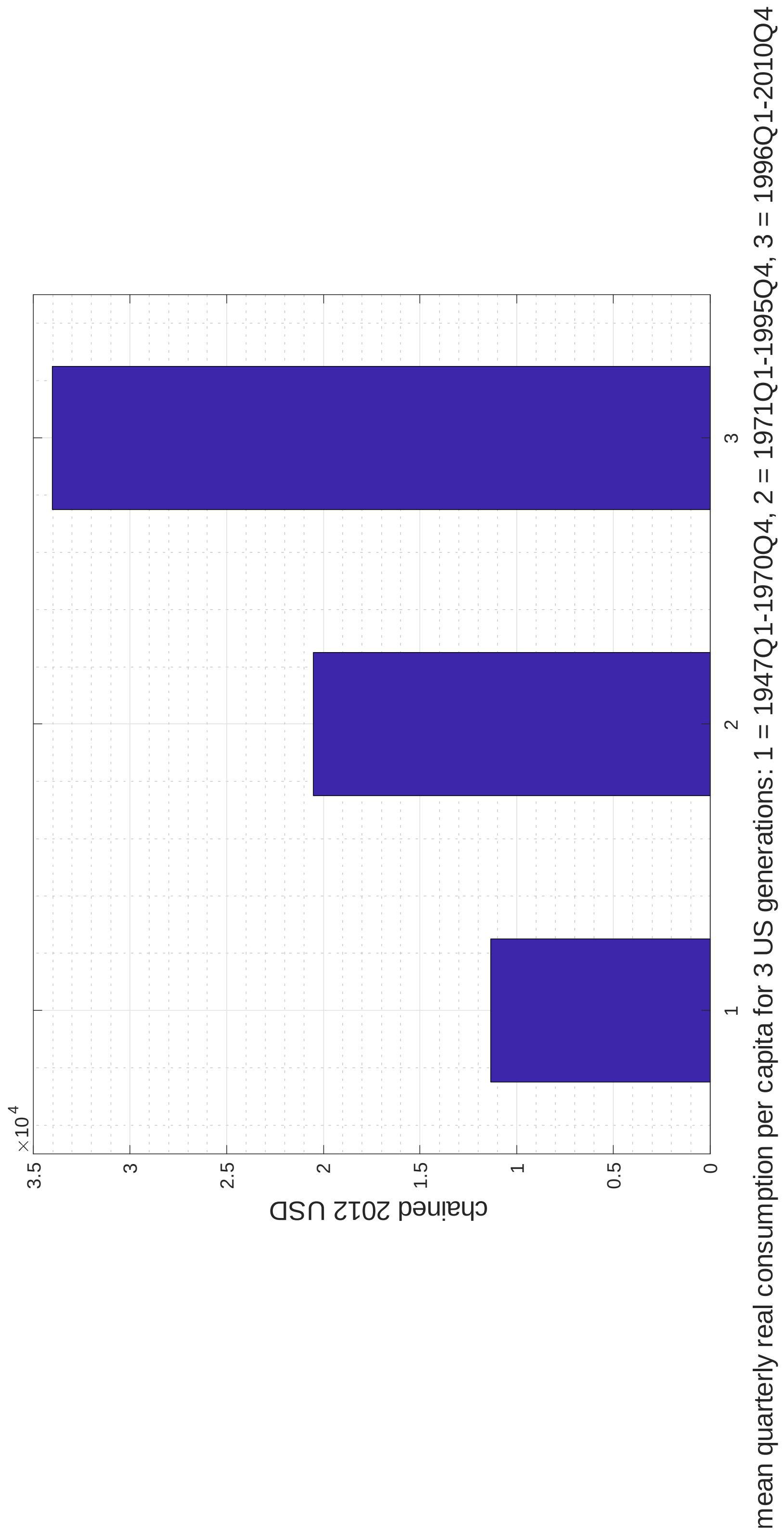

Figure 5: Real Personal Consumption Expenditures Per Capita, US, Mean in 3 Generations. *Source:* FRED Data. Authors' calculations.

Coupon	β	Year	PDV	Inflation	Coupon with Inflation	PDV with Inflation
(1)	(2)	(3)	(4)=(1)×(2)	(5)	(6)=(5)×100	(7)=(2)×(6)
100	0.9600	1	96.00	1.0200	102.00	97.92
100	0.9216	2	92.16	1.0404	104.04	95.88
100	0.8847	3	88.47	1.0612	106.12	93.89
100	0.8493	4	84.93	1.0824	108.24	91.94
100	0.8154	5	81.54	1.1041	110.41	90.02
100	0.7828	6	78.28	1.1262	112.62	88.15
100	0.7514	7	75.14	1.1487	114.87	86.32
100	0.7214	8	72.14	1.1717	117.17	84.52
100	0.6925	9	69.25	1.1951	119.51	82.76
100	0.6648	10	66.48	1.2190	121.90	81.04
100	0.6382	11	63.82	1.2434	124.34	79.36
100	0.6127	12	61.27	1.2682	126.82	77.71
100	0.5882	13	58.82	1.2936	129.36	76.09
100	0.5647	14	56.47	1.3195	131.95	74.51
100	0.5421	15	54.21	1.3459	134.59	72.96
100	0.5204	16	52.04	1.3728	137.28	71.44
100	0.4996	17	49.96	1.4002	140.02	69.95
100	0.4796	18	47.96	1.4282	142.82	68.50
100	0.4604	19	46.04	1.4568	145.68	67.07
100	0.4420	20	44.20	1.4859	148.59	65.68
100	0.4243	21	42.43	1.5157	151.57	64.31
100	0.4073	22	40.73	1.5460	154.60	62.98
100	0.3911	23	39.11	1.5769	157.69	61.67
100	0.3754	24	37.54	1.6084	160.84	60.38
100	0.3604	25	36.04	1.6406	164.06	59.13
100	0.3460	26	34.60	1.6734	167.34	57.90
100	0.3321	27	33.21	1.7069	170.69	56.69
100	0.3189	28	31.89	1.7410	174.10	55.51
100	0.3061	29	30.61	1.7758	177.58	54.36
100	0.2939	30	29.39	1.8114	181.14	53.23
100	0.2821	31	28.21	1.8476	184.76	52.12
100	0.2708	32	27.08	1.8845	188.45	51.04
100	0.2600	33	26.00	1.9222	192.22	49.98
100	0.2496	34	24.96	1.9607	196.07	48.94
100	0.2396	35	23.96	1.9999	199.99	47.92
100	0.2300	36	23.00	2.0399	203.99	46.92
100	0.2208	37	22.08	2.0807	208.07	45.95
100	0.2120	38	21.20	2.1223	212.23	44.99
100	0.2035	39	20.35	2.1647	216.47	44.05
100	0.1954	40	19.54	2.2080	220.80	43.14
100	0.1876	41	18.76	2.2522	225.22	42.24
100	0.1800	42	18.00	2.2972	229.72	41.36
100	0.1728	43	17.28	2.3432	234.32	40.50
100	0.1659	44	16.59	2.3901	239.01	39.66
100	0.1593	45	15.93	2.4379	243.79	38.83
100	0.1529	46	15.29	2.4866	248.66	38.03
100	0.1468	47	14.68	2.5363	253.63	37.24
100	0.1409	48	14.09	2.5871	258.71	36.46
100	0.1353	49	13.53	2.6388	263.88	35.70
100	0.1299	50	12.99	2.6916	269.16	34.96

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Coupon	β	Year	PDV	Inflation	Coupon with Inflation	PDV with Inflation
(1)	(2)	(3)	(4)	(5)	(6)=(5)×100	(7)=(2)×(6)
100	0.1247	51	12.47	2.7454	274.54	34.23
100	0.1197	52	11.97	2.8003	280.03	33.52
100	0.1149	53	11.49	2.8563	285.63	32.82
100	0.1103	54	11.03	2.9135	291.35	32.14
100	0.1059	55	10.59	2.9717	297.17	31.47
100	0.1017	56	10.17	3.0312	303.12	30.82
100	0.0976	57	9.76	3.0918	309.18	30.18
100	0.0937	58	9.37	3.1536	315.36	29.55
100	0.0900	59	9.00	3.2167	321.67	28.93
100	0.0864	60	8.64	3.2810	328.10	28.33
100	0.0829	61	8.29	3.3467	334.67	27.74
100	0.0796	62	7.96	3.4136	341.36	27.17
100	0.0764	63	7.64	3.4819	348.19	26.60
100	0.0733	64	7.33	3.5515	355.15	26.05
100	0.0704	65	7.04	3.6225	362.25	25.51
100	0.0676	66	6.76	3.6950	369.50	24.98
100	0.0649	67	6.49	3.7689	376.89	24.46
100	0.0623	68	6.23	3.8443	384.43	23.95
100	0.0598	69	5.98	3.9211	392.11	23.45
100	0.0574	70	5.74	3.9996	399.96	22.96
100	0.0551	71	5.51	4.0795	407.95	22.48
100	0.0529	72	5.29	4.1611	416.11	22.02
100	0.0508	73	5.08	4.2444	424.44	21.56
100	0.0488	74	4.88	4.3293	432.93	21.11
100	0.0468	75	4.68	4.4158	441.58	20.67
100	0.0449	76	4.49	4.5042	450.42	20.24
100	0.0431	77	4.31	4.5942	459.42	19.82
100	0.0414	78	4.14	4.6861	468.61	19.41
100	0.0398	79	3.98	4.7798	477.98	19.00
100	0.0382	80	3.82	4.8754	487.54	18.61
100	0.0366	81	3.66	4.9729	497.29	18.22
100	0.0352	82	3.52	5.0724	507.24	17.84
100	0.0338	83	3.38	5.1739	517.39	17.47
100	0.0324	84	3.24	5.2773	527.73	17.11
100	0.0311	85	3.11	5.3829	538.29	16.75
100	0.0299	86	2.99	5.4905	549.05	16.40
100	0.0287	87	2.87	5.6003	560.03	16.06
100	0.0275	88	2.75	5.7124	571.24	15.73
100	0.0264	89	2.64	5.8266	582.66	15.40
100	0.0254	90	2.54	5.9431	594.31	15.08
100	0.0244	91	2.44	6.0620	606.20	14.77
100	0.0234	92	2.34	6.1832	618.32	14.46
100	0.0225	93	2.25	6.3069	630.69	14.16
100	0.0216	94	2.16	6.4330	643.30	13.86
100	0.0207	95	2.07	6.5617	656.17	13.58
100	0.0199	96	1.99	6.6929	669.29	13.29
100	0.0191	97	1.91	6.8268	682.68	13.02
100	0.0183	98	1.83	6.9633	696.33	12.75
100	0.0176	99	1.76	7.1026	710.26	12.48
100	0.0169	100	1.69	7.2446	724.46	12.22
10000			2359.51		31847.70	4132.32

Authors' calculations.

Table 1: Illustration of a 100-year Coupon Bond with Assumed Constant Inflation