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ROMA TRE
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No Country for Young People: Intergenerational Burdens of COVID-19 Policy Responses[1]

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Abstract:

This study examines intergenerational welfare effects of COVID-19 policy responses, focusing on containment measures, fiscal expansions, and debt repayment schemes. Using a life-cycle model, we find: (i) without containment, welfare losses fall mainly on older agents via demographics; (ii) lockdowns shift burdens toward younger cohorts; (iii) debt-financed fiscal expansions have modest effects compared to social distancing; and (iv) debt repayment strategies are decisive—front-loaded repayment penalizes the young, while postponed repayment favors the old. These results highlight critical trade-offs for equity and policy design in managing future large-scale crises.

JEL Classification: E130, I180, H510

Keywords: COVID-19 epidemic; generational effects; intergenerational welfare; containment policies; fiscal policy.

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No Country for Young People: Intergenerational Burdens of COVID-19 Policy Responses

1 Introduction

1.1 Motivation and research question

The COVID-19 pandemic is over, but its economic effects have been significant and its legacy is likely to be long-lasting. The literature, both theoretical and empirical, has explored several macroeconomic effects of the pandemic, including those produced on individual incomes and the real economy by the policies that were adopted in different countries, from the short-run ones of lockdown and social distancing, to the long-run ones of expansionary monetary and, especially, fiscal policies. In spite of the wide spectrum of addressed issues, in our opinion, the theoretical contributions presented so far have paid insufficient attention to one clear and statistically significant indicator of the pandemic, i.e., that it affected in extremely different ways the different age cohorts of the population.[2] The same can be claimed as for the generational effects of the alternative time horizons that can be chosen to bring the public debt back to its pre-pandemic levels.

From an economic perspective, younger generations were, and still are, expected to bear most of both the immediate and future costs of containment and COVID-related fiscal policies. They were not, and will not, be however enjoying the appropriation of (a significant part of) the benefits represented by reduced health damages, saved lives and stabilized economic activity. Older agents benefited instead the most from lockdowns or other containment policies, especially in terms of mortality reduction. For example, to provide a quantitative indication on this issue, Greenstone and Nigam (2020) monetize the impact of moderate social distancing on deaths from COVID-19. Using the projected age-specific reductions in death and age-varying estimates of the United States Government's value of a statistical life, they calculate that around 90% of the monetized mortality benefits of social distancing accrue to people aged 50 or older. At the same time, fiscal expansion mostly favoured the older generations that borne the higher risk of disrupted productions and job losses, whithout making them bear the servicing and the reduction of the public debt.

In this paper, we build on the view that these differentiated effects on the relative welfare of different generations are relevant and that the age dimension cannot hence be disregarded when assessing the consequences of the implemented policies. By representing the COVID-19 pandemic as a shock to the mortality rate, we aim to document the differentiated welfare effects on the main age groups in the population of the policy framework (containment policies and debt-financed fiscal expansions) adopted in response to the pandemic.

[2] To drastically summarize, "young" people experienced extremely small mortality rates due to COVID-19 and suffered from zero to low health damages, whereas "old" people were more severely hit, with heavy health consequences and high to very high mortality rates.

More in particular, our research question can be split into two but strictly interrelated issues. Firstly, we aim at evaluating the impact on the *relative economic* welfare of the two main age groups - "old" and "young" agents - of the *containment and social distancing measures* directly aimed at reducing the impact of the pandemics on the probability of survival of the most fragile and exposed sectors of the population, and of the *package of fiscal programs* simultaneously implemented with the objective of reducing the negative impact of the containment and lockdown policies on aggregate income and production. Secondly, we explore how d*ifferent public debt repayment schemes*, resulting from pandemic-driven fiscal expansions, shape the long-term evolution of generational welfare.

1.2 Methodology and approach

To address these questions, we build a model based on Gertler (1999), in which the pandemic is introduced as a negative shock to survival probabilities. Social distancing reduces mortality but also lowers labor productivity. This simple setup captures the key demographic fact that the pandemic disproportionately affected the survival prospects of older people. Rather than modeling the full demographic and epidemiological complexity, we adopt a tractable structure that preserves essential life-cycle properties without resorting to a full overlapping generations (OLG) framework. This allows us to focus clearly on age-based welfare trade-offs, even if it prevents us from incorporating finer distinctions such as differences in education or health status within age groups.

A central issue in our analysis is how to measure welfare. While it is difficult to conduct a complete welfare analysis in a setting with heterogeneous agents and overlapping generations, the analytical tractability of our model allows us to define simple welfare indexes for the two groups—"young" agents (active workers) and "old" ones (retirees). These can then be combined into a measure of relative welfare that helps us to directly address our research questions. As Basso and Rachedi (2021, p.112) note, Gertler's (1999) model deemphasizes within-group differences but is well-suited for highlighting heterogeneity across age groups.In our setting, relative welfare is determined mainly by two key variables: the young-to-old consumption ratio, and the (time-varying) young-to-old marginal propensity to consume.

1.3 Main results

We begin our analysis by comparing two scenarios: (i) a "pure pandemic" (PP) scenario with no containment measures, and (ii) a "pandemic with lockdown" (PL) scenario reflecting the social distancing policies actually implemented in the Umited States during 2020. We then study the effect of expansionary fiscal policies, such as those in the American Rescue Plan, which included infrastructure investment, tax rebates, and subsidies. In all cases, we use benchmark and counterfactual simulations to compare outcomes with and without the policies.

Our analysis yields two main results. First, under the counterfactual PP scenario, the welfare losses from the pandemic fall primarily on older agents, via a "demographic channel" linked to higher mortality. When lockdowns are implemented (PL scenario), the reduction in old-age mortality comes at the cost of a deeper recession. In that case, younger cohorts bear the larger share of welfare losses, and output falls more sharply. Second, by adding the expansionary fiscal packages targeted at the COVID-19 emergency, we find that while expansionary fiscal policies tend to favor older agents over younger ones, their effect on the relative welfare index is modest. We then conclude that the substantial impact on the welfare index can be attributed to the lockdown/social distancing measures, which are undoubtly unfavourable to the young agents.

The implemented fiscal packages led to a massive increase in the level of public debt, which can be repaid according to different schemes and time horizons that imply different time evolutions of the age-groups' relative welfare, an issue which has been insufficiently explored by the literature. Intuitively, the more the repayment scheme entails a postponement of debt repayment, the more the old agents should be favoured. By taking as a baseline scenario the projections of the U.S. public debt evolution provided by the Congressional Budget Office, we investigate how such different repaiment schemes impact on the direction and the amplitude of the relative welfare index of the two groups. As for this second issue, and taking as given the previous result of a marginal impact of the fiscal package on the relative age-group welfare, we show that debt repayment schemes heavily relying on the younger generations are unfair and/or undesirable.

1.4 Related literature

Several strands in the COVID-macro literature have advanced our understanding of the pandemic's economic fallout. One body of work embeds a canonical SIR block into otherwise standard macro frameworks. Eichenbaum, Rebelo, and Trabandt (2021) show that, while lockdowns save lives, they exacerbate recessions by curtailing consumption and labor supply. Acemoglu et al. (2021) extend this approach to a multigroup SIR model with age-dependent infection and fatality rates, demonstrating that restrictions targeted to high-risk cohorts can capture most of the mortality gains of uniform lockdowns at substantially lower economic cost. Atkeson (2020) surveys this SIR-macro literature, illustrating how endogenous self-protective behavior qualitatively alters epidemic and economic trajectories.

A second strand of the literature treats COVID-19 as a purely economic shock within DSGE settings. Fornaro and Wolf (2020) focus on persistent supply disruptions that can generate a "supply–demand doom loop" without strong policy support. Guerrieri et al. (2022) formalize the notion of Keynesian supply shocks—showing how sectoral shutdowns in contact-intensive industries can amplify aggregate demand losses economy-wide. Faria-e-Castro (2021) embed U.S. fiscal relief measures into a nonlinear DSGE model, finding sizable but state-dependent multipliers for unemployment insurance expansions and liquidity support. Yet, by modeling the pandemic shock as homogeneous, these frameworks abstract from the sharply divergent mortality risks and consumption behaviors across age cohorts that defined both the health and welfare impacts of COVID-19.

A related "behavior-augmented" strand endogenizes voluntary distancing and policy fatigue. Droste and Stock (2021) and Atkeson, Kopecky, and Zha (2021) calibrate time-varying feedback rules to match mobility and case data, while Baqaee and Farhi (2022) show how behavioral responses interact with sectoral network effects to shape downturn severity.

Most of these frameworks, however, either treat agents homogeneously or focus on infection dynamics without embedding a life-cycle structure. A limited OLG literature (e.g., Bairoliya and Imrohoroglu 2020; Gagnon et al. 2022) examines intergenerational mortality and welfare, but often assumes balanced fiscal budgets or abstracts from fiscal-debt dynamics. Recent work by Bayer et al. (2023) applies quarantine shocks directly to production without modeling demographic heterogeneity.

Our contribution departs from both the SIR-macro and standard DSGE strands by building on Gertler's (1999) life-cycle framework. We introduce the pandemic as an age-differentiated shock to survival probabilities, with social distancing reducing mortality at the cost of labor productivity. Our framework capture how pandemic, containment policies, debt-financed fiscal expansions, and alternative public-debt repayment schemes differentially affect the welfare of young versus old cohorts.

1.5 Paper Structure

The paper is organized as follows. In Section 2 we present a synthetic description of the analytical framework and present a derivation and justification of the choice of the relative welfare index adopted in the paper. Section 3 presents and discusses the results obtained from the model's numerical simulations. Section 4 concludes.

2 The model economy

The model economy consists of three types of agents: individual (private) agents, firms and the government. Each individual agent operates within two distinct phases of the life-cycle: when they enter the economy as "young" agents (they are born) they provide the labor services used in production, save and consume. They can become "old" with an exogenous probability, and continue to provide labor services (although their productivity is lower) while also collecting revenues from accumulated wealth and from social security payments. Old agents, who can hence be only partially and somehow inappropriately considered as "retirees", face a constant and exogenous probability of surviving into the next time period and a complementary probability of death.

Saving instruments are of two distinct types: physical capital and government bonds. Final goods, represented by a single net output used also as a numeraire, are produced by perfectly competitive firms, and are used for consumption and investment in physical capital. The government decides the amount of spending and of lump sum taxes, and the one-period debt evolves according to the fiscal budget constraint. Aggregate uncertainty is absent and we only consider (initially) unexpected changes in the survival probability of old/retirees agents and a (small) shock to the survival probability of young agents, together with exogenous changes in some of the relevant policy parameters and variables. Anti-epidemic policies affect the probabilities of death and entail costs - in terms of foregone production (as for social distancing and generalized quarantine) and greater public debt - that are differently distributed between age groups.

2.1 Life-cycle structure: young/workers and old/retirees

At each time period t, each agent belongs to one of two distinct groups indexed by z: young/workers ($z = y$) and old/retirees ($z = o$). The population of young agents N_t^y evolves according to the following dynamic law:

$$N_t^y = [(1-\omega_t)\gamma_t^y + (1-\gamma_t^y)\omega_t + (1-\omega_t)(1-\gamma_t^y) + n_t] N_{t-1}^y + \gamma_t^y \omega_t N_{t-1}^y$$

where $1 - \omega_t$ is the probability of becoming old (of retirement), γ_t^y is the probability of a young agent to survive into the next period and n_t is the rate at which new young agents are born. We assume that both ω_t and n_t are constant through time and equal to their long-run average values ω and n. The dynamic law hence simplifies into:

$$N_t^y = (1+n) N_{t-1}^y \tag{1}$$

The population of old/retired agents N_t^o follows the rule:

$$N_t^o = \gamma_t^y (1-\omega) N_{t-1}^y + \gamma_t^o N_{t-1}^o \tag{2}$$

where $\gamma_t^o \in (0; 1)$ is the probability to survive into the next period. From (1)-(2), we obtain the dynamic law of the population structure $\psi_t = N_t^o / N_t^y$:

$$(1+n)\psi_t = \gamma_t^y (1-\omega) + \gamma_t^o \psi_{t-1} \tag{3}$$

In order to preserve the main equilibrium properties of Gertler's (1999) model, we assume that $\gamma_t^y = 1$, except for a transitory shock occurring during the pandemic outbreak[3] (see section 3 below).

The preferences of a typical agent are described by a recursive non-expected utility function of the class proposed by Kreps and Porteus (1978) and by Epstein and Zin (1989):

$$V_t^z = \left\{ \left[(C_t^z)^q (1-L_t^z)^{1-q} \right]^\rho + \beta_{t+1}^z \left[\mathbb{E}_t (V_{t+1}|z) \right]^\rho \right\}^{\frac{1}{\rho}} \tag{4}$$

where V_t^z represents period-t utility, C_t^z is consumption, $q \in (0,1)$ and L_t^z is the fraction of time allocated to work by the agent; this functional form implies that: $\sigma = 1/(1-\rho)$ is the *elasticity of intertemporal substitution*. Young and old agents have distinct discount factors, as they face different probabilities of death:

$$\beta_{t+1}^y = \beta \gamma_{t+1}^y; \qquad \beta_{t+1}^o = \beta \gamma_{t+1}^o \tag{5}$$

The continuation value V_{t+1} in (4), which is different for young agents and for old agents due to the transition to the next phase of the life-cycle, is conditional on the agent remaining young ($z = y$) or becoming old ($z = o$). In particular, if the agent is initially young, he/she must consider the probability of entering the other group, given by $(1-\omega)$, and this explains the expectation operator $\mathbb{E}_t$ in (4). Hence we have:

$$\mathbb{E}_t (V_{t+1}|z) = \begin{cases} V_{t+1}^o & \text{if } z = o \\ \omega V_{t+1}^y + (1-\omega) V_{t+1}^o & \text{if } z = y \end{cases} .$$

[3] The probabilities γ_t^z are both affected by the COVID-19 pandemic, and by containment policies (lockdown) or social distancing behavior.

2.2 Old agents' choices

An agent born at s and entered into old age at τ solves the following dynamic optimization problem:

$$\begin{aligned} V_t^o(s,\tau) &= \max\left\{\left[C_t^o(s,\tau)^q\left(1-L_t^o(s,\tau)\right)^{1-q}\right]^\rho+\beta\gamma_{t+1}^o\left(V_{t+1}^o(s,\tau)\right)^\rho\right\}^{\frac{1}{\rho}} \qquad (6)\\ \text{s.t.} &: C_t^o(s,\tau)+K_t^o(s,\tau)+B_t^o(s,\tau)=E_t(s,\tau)+W_t\eta L_t^o(s,\tau) \qquad (7)\\ & +Tr_t^o(s,\tau)-T_t^o(s,\tau)+\frac{1}{\gamma_t^o}\left[\left(r_t^K+1\right)K_{t-1}^o(s,\tau)+R_{t-1}B_{t-1}^o(s,\tau)\right] \end{aligned}$$

where $C_t^o(s,\tau)$ is consumption, $L_t^o(s,\tau)$ is supply of work-time, $K_t^o(s,\tau)$ is investment in new capital stock, $B_t^o(s,\tau)$ is the demand for government's bond, r_t^K is the (net) rate of return on physical capital, W_t is the real wage rate and R_t is the bond's real interest factor. The parameter $\eta\in(0,1)$ measures the productivity of a unit of labor supplied by an older person relative to a younger one. The initial stocks K^o and B^o of the old agent, when entering the old-age phase, must coincide with the corresponding values of K and B he/she held as a young worker in that time period; hence it must be:

$$K_{\tau-1}^o(s,\tau)=K_{\tau-1}^y(s)\,; \qquad B_{\tau-1}^o(s,\tau)=B_{\tau-1}^y(s) \qquad (8)$$

As in Yaari (1965) and Blanchard (1985), old agents can insure themselves against the possibility of death. As they have no bequest motive and the insurance companies provinding the appropriate contracts operate in a competitive market, actuarial fairness requires that (in equilibrium) the return on the insurance contract is equal to $1+\frac{1-\gamma^o}{\gamma^o}=\frac{1}{\gamma^o}$, which is incorporated into the flow budget constraint of survivors (7).

We include in the model a simple social security system run by the public authority: each old agent receives an exogenous lump-sum payment of social security equal to $E_t(s,\tau)$, recevies an amount of other transfers $Tr_t^o(s,\tau)$ and pays an exogenous lump-sum tax equal to $T_t^o(s,\tau)$.[4]

From the first order conditions of the problem (6)-(7), we derive the labour supply condition:

$$L_t^o(s,\tau)=1-\frac{\varsigma}{\eta W_t}C_t^o(s,\tau) \quad \text{with: } \varsigma=\frac{1-q}{q} \qquad (9)$$

and a no-arbitrage equation equalizing the returns on the two assets:

$$R_t=r_{t+1}^K+1 \qquad (10)$$

which allows us to define the total wealth of the old agent:

$$A_t^o(s,\tau)=K_t^o(s,\tau)+B_t^o(s,\tau)$$

The model can be solved by formulating a conjectured solution of the form: $C_t^o(s,\tau)=\xi_t^o\left[\frac{1}{\gamma_t^o}R_{t-1}A_{t-1}^o(s,\tau)+D_t^o(s,\tau)+H_t^o(s,\tau)\right]$, where ξ_t^o is a time-varying *marginal propensity of consumption* (m.p.c.) and D_t^o and H_t^o are the discounted values of, respectively,

[4] The amuonts of $E_t(s,\tau)$, $Tr_t^o(s,\tau)$ and $T_t^o(s,\tau)$ are equal for *all old agents present at time t*; we retain the date specification (s,τ) so as to have a uniform notation for aggregate variables in the subsequent analysis.

the stream of social security payments and the old agent's (net) *human wealth* (the economic value obtained by employing/exchanging the agent's personal resources different from financial assets).[5] The conjecture can be verified and the following equilibrium equations can be obtained for the evolution of the m.p.c:

$$\frac{1}{\xi_t^o} = 1 + \gamma_{t+1}^o \left[\left(\frac{W_t}{W_{t+1}} \right)^{(1-q)\rho} \beta \right]^\sigma R_t^{\sigma-1} \frac{1}{\xi_{t+1}^o} \tag{11}$$

and for the equilibrium value function of the old agent:[6]

$$V_t^o(s,\tau) = \left(\frac{\varsigma}{\eta W_t} \right)^{1-q} (\xi_t^o)^{\frac{\sigma}{1-\sigma}} C_t^o(s,\tau) \tag{12}$$

2.3 Young agents' choices

A typical young agent, born at time s without any bequest left from past generations, chooses to consume, save and provide labor services. Given the no-arbitrage equation (10), both assets pay the return R_{t-1} and we can directly consider his/her total wealth $A_t^y(s) = K_t^y(s) + B_t^y(s)$. His/her optimization problem is then:

$$V_t^y(s) \quad = \quad \max \left\{ \begin{array}{c} \left[C_t^y(s)^q \left(1 - L_t^y(s)\right)^{1-q} \right]^\rho + \\ \gamma_{t+1}^y \beta \left[\omega V_{t+1}^y(s) + (1-\omega) V_{t+1}^o(s,t+1) \right]^\rho \end{array} \right\}^{\frac{1}{\rho}} \tag{13}$$

$$\text{s.t.} \quad : \quad C_t^y(s) + A_t^y(s) = \frac{R_{t-1}}{\gamma_t^y} A_{t-1}^y(s) + W_t L_t^y(s) - T_t^y(s) + Tr_t^y(s) \tag{14}$$

where $L_t^y(s)$ is the time of work supplied, $T_t^y(s)$ is the lump-sum tax paid and $Tr_t^y(s)$ the received transfers. Also young agents insure themselves againts the risk of death, and hence obtain, upon survival, an equilibrium return on the insurance contract equal to $1 + \frac{1-\gamma^y}{\gamma^y} = \frac{1}{\gamma^y}$, i.e., equal to 1 except under the transitory pandemic shock.[7]

From the first order conditions we derive the equation for the young agent labour supply:

$$L_t^y(s) = 1 - \frac{\varsigma}{W_t} C_t^y(s) \tag{15}$$

[5] That is, ignoring for semplicity the dates: (s,τ): $D_t^o = \sum_{i=0}^{\infty} E_{t+i}^o / \left(\prod_{j=1}^{i} \frac{R_{t+j-1}}{\gamma_{t+j}} \right)$ and $H_t^o = \sum_{i=0}^{\infty} \left(W_{t+i} \eta l_{t+i}^o - T_{t+i}^o + Tr_{t+i}^o \right) / \left(\prod_{j=1}^{i} \frac{R_{t+j-1}}{\gamma_{t+j}} \right)$.

[6] Derivations of the model's solution can be found in the Technical Appendix 1 available upon reuqest.

[7] This assumption implies that, in case of death (only under the pandemic shock, with $\gamma_t^y < 1$), the assets collected by the insurance companies from the deceased young agents must be given, as premium payments, only to the surviving young members. Although it may seem a strong assumption, this framework is needed in order to recover a closed-form analytical solution similar to that of Gertler (1999).

By conjecturing a solution of the same form as that of the old agent, we then obtain the equilibrium dynamic equations for the m.p.c. (ξ_t^y) and for the value function (V_t^y) of the young agent:

$$\frac{1}{\xi_t^y} = 1 + \gamma_{t+1}^y \left[\left(\frac{W_t}{W_{t+1}} \right)^{(1-q)\rho} \beta \right]^\sigma (R_t \Omega_{t+1})^{\sigma-1} \frac{1}{\xi_{t+1}^y} \tag{16}$$

$$V_t^y(s) = \left(\frac{\varsigma}{W_t} \right)^{1-q} \Delta_t^y C_t^y(s) \tag{17}$$

where $\Delta_t^y = (\xi_t^y)^{\frac{\sigma}{1-\sigma}}$ and Ω_t is an adjustment factor defined as: $\Omega_t = \omega + (1-\omega)\chi \left(\frac{\Delta_t^o}{\Delta_t^y} \right)^{1-\rho}$; where: $\chi = \left(\frac{1}{\eta} \right)^{1-q}$. As in the case of the old agent, it can be verified that the following conjecture is the actual solution for the equilibrium level of consumption:

$$C_t^y(s) = \xi_t^y \left[\frac{R_{t-1}}{\gamma_t^y} A_{t-1}^y(s) + H_t^y(s) + D_t^y(s) \right]$$

where the explicit definitions of the (expected values) of the *human wealth* $H_t^y(s)$ that the young agent would receive if he/she became old at $t+1$, and of the *stream of social benefits* $D_t^y(s)$ are defined analogously to the corresponding variables of the old agent, and can be found in the Technical Appendix 1 and 2.

2.4 Aggregation of consumption, labor and wealth

The model allows for a straightforward aggregation procedure that greatly simplifies the analysis. Starting from the individual consumption of the typical old agent $C_t^o(s,\tau) = \xi_t^o \left[\frac{1}{\gamma_t^o} R_{t-1} A_{t-1}^o(s,\tau) + D_t^o(s,\tau) + H_t^o(s,\tau) \right]$, and indicating the aggregate variables by removing the date specification, e.g., $X_t^o = \sum_{\tau=s}^t \int_0^{N_t^o(s,\tau)} X_t^o(s,\tau)\, di$,[8] the aggregate consumption C_t^o of all the old agents who are present at t is:

$$C_t^o = \xi_t^o (\lambda_t A_{t-1} R_{t-1} + D_t^o + H_t^o) \tag{18}$$

where $A_{t-1} = K_{t-1} + B_{t-1} = A_{t-1}^o + A_{t-1}^y$ is the overall amount of financial wealth; $\lambda_t = A_{t-1}^o / A_{t-1}$ indicates the fraction of total financial wealth held by old agents; H_t^o and D_t^o are the aggregate values of the old agents' net human wealth and social security payments.

Similarly, starting from the individual consumption of the typical young agent $C_t^y(s) = \xi_t^y \left[\frac{R_{t-1}}{\gamma_t^y} A_{t-1}^y(s) + H_t^y(s) + D_t^y(s) \right]$, the aggregate consumption C_t^y at t of all the agents who are young at t is:

$$C_t^y = \xi_t^y \left[(1-\lambda_{t-1}) R_{t-1} A_{t-1} + H_t^y + D_t^y \right] \tag{19}$$

[8] $N_t^o(s,\tau) < N_\tau^o$ is the number of agents born at s and retired (old) at τ. See the Technical Appendix 1 for a more detailed discussion of the aggregation prcedure.

where H_t^y and D_t^y are the aggregate values of young agents' human wealth and social security payments.

Finally, we can directly compute the aggregate supplies of labour (L_t^o and L_t^y) by the two age-groups:

$$L_t^o = N_t^o - \frac{\varsigma}{W_t \eta} C_t^o; \qquad L_t^y = N_t^y - \frac{\varsigma}{W_t} C_t^y.$$

and the overall amounts of taxes and transfers: $T_t^o = N_t^o T_t^o(s,\tau)$ and $Tr_t^o = N_t^o Tr_t^o(s,\tau)$ for the old agents, and $T_t^y = N_t^y T_t^y(s)$ and $Tr_t^y = N_t^y Tr_t^y(s)$ for the young ones.

2.5 Firms and production

The representative firm operates in competitive markets for goods and production inputs, and adopts a constant-elasticity-of-substitution (CES) production function:

$$Y_t = \left[(1-\alpha) K_{t-1}^{\phi} + \vartheta_t \alpha (X_t L_t)^{\phi}\right]^{\frac{1}{\phi}}; \qquad \alpha \in (0;1)$$

where total real output Y_t is affected by exogenous (Harrod-neutral) technical progress, represented by the growth factor X_t applied to total labour input L_t. The parameter α represents the labor share in income distribution and ϕ determines the (constant) elasticity of substitution between inputs. Technology evolves through time at the constant rate x:

$$X_t = (1+x) X_{t-1} \tag{20}$$

The variable $\vartheta_t > 0$, which represents the impact of social distancing induced by policies and/or by voluntary reaction to the pandemic, is one of the key elements of our policy analysis. Whereas in normal times it is $\vartheta = 1$, we make its value change during the COVID-19 pandemic, to mimic the effect of lockdown, social distancing and restrictions on workers movements that were introduced in several countries and that imposed severe reductions in production activities.

The firm maximizes its profit Π_t:

$$\max_{K_{t-1};N_t^y} \Pi_t = Y_t - W_t L_t - \left(r_t^K + \delta\right) K_{t-1}$$

where δ is the depreciation rate on capital. Firm's optimization leads to the following equations for the demand of inputs:

$$W_t = \alpha \vartheta_t (X_t)^{\phi} (L_t)^{\phi-1} Y_t^{1-\phi} = \alpha \vartheta_t X_t \left(\frac{Y_t}{X_t L_t}\right)^{1-\phi}; \tag{21}$$

$$r_t^K = (1-\alpha) K_{t-1}^{\phi-1} Y_t^{1-\phi} - \delta = (1-\alpha)\left(\frac{Y_t}{K_{t-1}}\right)^{1-\phi} - \delta. \tag{22}$$

2.6 Fiscal policy and government's budget

Fiscal and social security policies can be financed by lump-sum taxes T and by issuing one-period government's bonds B. The accruals from these sources are used for unproductive expenditures G, transfers to old (Tr^o) and to young agents (Tr^y) and payment of social benefits E. The flow budget constraint of the government is then:

$$B_t = G_t + E_t - (T_t^y + T_t^o) + (Tr_t^o + Tr_t^y) + R_{t-1}B_{t-1} \tag{23}$$

We assume that the individual lump sum tax $T_t^o(s,\tau)$ for the old agent is proportional to the individual tax of the young one:

$$T_t^o(s,\tau) = a^o T_t^y(s) \quad \text{with} \quad a^o \geq 0$$

Total fiscal revenues can hence be written as: $T_t^y + T_t^o = (a^o N_t^o + N_t^y) T_t^y(s) = (1 + a^o \psi_t) T_t^y$. By adopting the same assumption for transfers, it follows that: $Tr_t^y + Tr_t^o = (a^o N_t^o + N_t^y) Tr_t^y(s) = (1 + a^o \psi_t) Tr_t^y$.

2.7 Macroeconomic equilibrium and detrended variables

A general equilibrium for the model economy (expressed in aggregate form) can be defined along the lines of Gertler (1999). The goods market equilibrium is given by the economy's resources constraint:

$$Y_t = C_t + I_t + G_t \tag{24}$$

where I_t is the amount of new capital goods (produced by converting consumption goods on a one-to-one basis). The amount of net aggregate investment is coherent with the time evolution of aggregate physical capital:

$$K_t = I_t + (1-\delta) K_{t-1} = Y_t - C_t - G_t + (1-\delta) K_{t-1} \tag{25}$$

The labor market clears according to the following condition:

$$L_t = L_t^y + \eta L_t^o$$

where ηL_t^o accounts for the effective labor time (i.e., weighted by its relative productivity η) supplied by the old agents.

Given a sequence of exogenous $\{X_t; N_t^y\}$ and of fiscal policy variables, a *macroeconomic equilibrium* is a sequence of endogenous variables satisfying the equilibrium equations.[9] Due to the exogenous dynamics of population (1) and technical progress (20), aggregate variables grow at the compound rate $(1+n)(1+x)$ along the balanced growth path (BGP). We hence express the endogenous variables in detrended values by dividing them by the "effective" amount of young agents $X_t N_t^y$ and indicate with a generic lower-case variable s_t the detrended value $s_t = S_t/(X_t N_t^y)$. The detrending of the labor input L_t, L_t^z only requires to divide the aggregate values by N_t^y:

$$l_t = \frac{L_t}{N_t^y} = \frac{L_t^y}{N_t^y} + \eta \frac{L_t^o}{N_t^y} = l_t^y + \eta l_t^o$$

[9] See Technical Appendix 2 for details.

while the detrended value of the real wage rate is equal to $w_t = W_t/X_t = \alpha\vartheta_t \left(\frac{y_t}{l_t}\right)^{1-\phi}$, and the detrended labor supply functions are given by $l_t^y = 1 - \frac{\varsigma}{w_t} c_t^y$ and $l_t^o = \psi_t - \frac{\varsigma}{w_t \eta} c_t^o$.

In order to add an element of realism, we include in our model economy a form of real wage rigidity according to which, in each time period, only a fraction of young workers can obtain a detrended real wage coherent with their utility maximization, while the remaining fraction obtains the wage set in the previous periods[10].

After detrending, we focus on the dynamic evolution of the following vector of variables:[11] $\mathbf{v}_t = [k_t,\ \lambda_t,\ \xi_t^o,\ \xi_t^y,\ \Omega_t,\ h_t^o,\ h_t^y,\ y_t,\ c_t,\ c_t^y,\ c_t^o,\ a_t,\ \psi_t,\ R_t,\ w_t,\ d_t^o,\ d_t^y,\ \theta_t,\ \theta_{Rt},\ g_t,\ e_t,\ b_t,\ l_t,\ l_t^o,\ l_t^y,\ m_t^{RS}]$ according to the equilibrium system detailed in Appendix A:

$$f\left(\mathbf{v}_{t+1}; \mathbf{v}_t; \mathbf{v}_{t-1}\right) = \mathbf{0}$$

The variable θ_t is defined as $\frac{T_t^y}{X_t N_t^y} = \theta_t$, the total fiscal revenues are $\frac{T_t^y + T_t^o}{N_t^y X_t} = (1 + a^o \psi_t)\,\theta_t$, and the total transfers are $\frac{Tr_t^y + Tr_t^o}{X_t N_t^y} = (1 + a^o \psi_t)\,\theta_{Rt}$.

Fiscal policy is defined by the following equations:

$$\begin{aligned}
e_t &= \rho_e e_{t-1} + (1 - \rho_e)\, r_t^e y_t; \\
g_t &= \rho_g g_{t-1} + \left(1 - \rho_g\right) r_t^g y_t; \\
\theta_{Rt} &= \rho_R \theta_{Rt-1} + (1 - \rho_R)\, r_t^R y_t \\
\theta_t &= \rho_\theta \theta_{t-1} + (1 - \rho_\theta) \left[r_t^\theta y_t + \delta_B \left(\frac{b_t}{y_t} - r^b \right) \right].
\end{aligned} \tag{26}$$

The exogenous processes of the ratios r_t^g r_t^R, r_t^e, r_t^θ are set by the policy makers and r^b is a target value for the debt-to GDP ratio, b/y, which we assume to be equal to the long-run stationary value calibrated for the U.S. economy. As it will be clarified below, each of the ratios r_t^g, r_t^e, r_t^R and r_t^θ include a stationary, long-run component and a temporary one. Short-run changes in fiscal policy are described as shocks to such temporary components. The equations (26) also include, *via* the coefficients $\rho_{\theta,g,R,e} \in (0;1)$, the possibility of a gradual adjustment of the fiscal variables g_t, e_t, θ_{Rt} and θ_t towards their stationary values after a policy change. We also assume that the government adjusts lump sum taxes θ_t (*via* $\delta_B \in (0;1)$) in response to deviations of the debt-to-GDP ratio from its stationary value r^b, so as to ensure debt sustainability in the long run (see, e.g., Auray and Eyquem 2020). The variable b_t hence endogenously adjusts to verify the budget equation:

$$(1+n)(1+x)\, b_t = g_t + e_t - (1 + a^o \psi_t)\,\theta_t + (1 + a^o \psi_t)\,\theta_{Rt} + R_{t-1} b_{t-1} \tag{27}$$

The other exogenous variables γ_t^o, γ_t^y and ϑ_t follow stochastic processes appropriately defined to describe the impact of the pandemic on the probability of survival of old agents and the effect of lockdown policies on production, respectively. Before the occurrence of the pandemic shock and of the subsequent policies, these two variables, together with the ratios r_t^g, r_t^e, r_t^R, r_t^b and r_t^θ, are set equal to their constant long-run values, coherently with the initial position of the economy along the BGP: $r_t^g = r^g$,

[10] The mechanism is standard and it is detailed in the Technical Appendix 3.

[11] The term $m_{t+i}^{RS} = \varsigma c_{t+i}^y / \left(1 - \widetilde{l}_{t+i}^y\right)$ is the target level of the wage rate in the staggered wage setting.

$r_t^e = r^e$, $r_t^R = r^R$, $r_t^\theta = r^\theta$, $\gamma_t^o = \gamma^o$, and $\gamma_t^y = \vartheta_t = 1$ (all stationary values are denoted without the time index).[12]

Coherently with the numerical exercises of Section 3, we assume that $\rho < -1$ and hence $\sigma \in (0;1)$. This implies that in the stationary state it must be $\Omega > 1$, and consequently $\xi^o > \xi^y$.

2.8 Welfare indicators of the two demographic classes

In order to explore the consequences on the two demographic groups $z \in \{y, o\}$ that inhabit the economy of the decreased survival probability produced by the COVID-19 pandemic, and of the different policies undertaken in response to it, it is necessary to define an appropriate *welfare index* for such groups. Notwithstanding the difficulty of carrying out a complete and rigorously founded welfare analysis in the context of agents' heterogeneity and overlapping generations,[13] the analytical tractability of the model presented in the previous section allows us to define an index for the aggregate welfare of each of the *two groups* in every time period t, which is suitable for our purposes.

We denote V_t^o and V_t^y the aggregate utility indexes at period t of the old and of the young agents, respectively. As the m.p.c.s, ξ_t^y and ξ_t^o, are common to all the agents who are present at t, we can carry out a simple aggregation of the two age-groups value functions:

$$V_t^o = \left(\frac{\varsigma}{W_t \eta}\right)^{1-q} (\xi_t^o)^{\frac{\sigma}{1-\sigma}} C_t^o; \qquad V_t^y = \left(\frac{\varsigma}{W_t}\right)^{1-q} (\xi_t^y)^{\frac{\sigma}{1-\sigma}} C_t^y$$

The variable V_t^z is the sum of all the optimal value functions (given by equations (12) and (17)) of the agents of group z who are present at t.

These indexes can be used to define a between-groups ("relative") welfare index, which: (i) is coherent with the specific features of the model and (ii) is useful to address our research questions. A direct measure of such a relative welfare index is:

$$\begin{aligned} v_t^{ratio} &= \frac{V_t^y}{V_t^o} = \frac{1}{\chi}\left(\frac{\xi_t^y}{\xi_t^o}\right)^{\frac{\sigma}{1-\sigma}} \frac{C_t^y}{C_t^o} = \frac{1}{\chi}\left(\frac{\xi_t^y}{\xi_t^o}\right)^{\frac{\sigma}{1-\sigma}} \frac{c_t^y}{c_t^o} \\ &= \frac{1}{\chi}\left(\frac{\xi_t^y}{\xi_t^o}\right)^{\frac{1}{1-\sigma}} \frac{(1-\lambda_{t-1}) R_{t-1} a_{t-1} + h_t^y + d_t^y}{\lambda_{t-1} R_{t-1} a_{t-1} + h_t^o + d_t^o}. \end{aligned} \tag{28}$$

[12] The steady state of the model can be calculated by focusing on the restricted set of variables and equations described in the Technical Appendix 5.

[13] The main issues are, among others, the choice of a discount factor for the aggregate welfare index and/or the choice of the correct weight to be assigned to the utility of each heterogenous agent in the aggregate welfare index. See, e.g., the discussion in Fujiwara and Teranishi (2008) and in Baska and Munkacsi (2019). See the Technical Appendix 4 for further details.

3 Numerical analysis and policy exercises

Pandemic and social distancing measures

In order to explore the model's prediction on the effects of pandemic-related policies, we specify a numerical version using empirical figures for the U.S. The time period t corresponds to one year.

A special role in our analysis is played by the probabilities of survival, which can be described, in general terms, as:

$$\gamma_t^o = \gamma^o\left(u_t^{\gamma o}, \vartheta_t\right); \qquad \gamma_t^y = \gamma^y\left(u_t^{\gamma y}, \vartheta_t\right).$$

The COVID-19 pandemic shock affected γ_t^o and γ_t^y, via the shocks $u_t^{\gamma o}$ and $u_t^{\gamma y}$, with $\frac{d\gamma_t^o}{du_t^{\gamma o}}, \frac{d\gamma_t^y}{du_t^{\gamma y}} < 0$. As previously mentioned, we set the stationary value of γ_t^y to 1, and keep it to this value in all the time periods in which the pandemic shocks are absent. The stationary level of γ_t^o is instead set according to long-term demographic data of the U.S. In general, we assume that γ_t^o is also affected by lockdown policies: $\frac{d\gamma_t^o}{d\vartheta_t} > 0$. When these policies are active, ϑ_t rises above its stationary value (see below), i.e., $\vartheta_t > 1$, (partially) offsetting the negative effect of $u_t^{\gamma o}$ on γ_t^o by slowing down the diffusion of the pandemic. Temporary deviations of ψ_t from its stationary value $\psi = (1-\omega)/(1+n-\gamma^o)$ are traced back to the pandemic shock $u_t^{\gamma o}$ via the dynamic equation (3). Containment and social distancing policies can also have offsetting effects on the probability γ_t^y, when this variable is hit by the pandemic shock. Nevertheless, as in the next section we show that the fall in γ_t^y due to $u_t^{\gamma y}$ is very small, to simplify the analysis we assume that lockdown policies have no effect on γ_t^y $\left(\frac{du_t^{\gamma y}}{d\vartheta_t} = 0\right)$.[14]

The production function $y_t = \left[(1-\alpha)\, k_{t-1}^{\phi} + \vartheta_t \alpha l_t^{\phi}\right]^{\frac{1}{\phi}}$ shows that lockdown policies directly impact on y_t via ϑ_t. We assume that $\vartheta_t = \vartheta(u_t^{\vartheta})$. When lockdown and/or social distancing policies are active ($u_t^{\vartheta} > 0$), these measures impact on production activities: $\frac{d\vartheta_t}{du_t^{\vartheta}} > 0$. As in our exercises we set $\phi < 0$, in order to induce a reduction in y_t (and an overall recessionary push), the temporary change in ϑ_t must be positive.[15]

Fiscal policy response

In the model economy, the activation of lockdown/social distancing measures (i.e., an increase in ϑ_t above 1) under a pandemic shock ($u_t^{\gamma z} > 0$) generates a severe recessionary push. In order to mitigate this economic consequence (which was often of dramatic proportions), important expansionary fiscal programs were implemented, in the U.S. and in several other Countries. These fiscal programs can be represented in the model by writing the following ratios:

$$r_t^g = f\left(r^g; u_t^g\right); \quad r_t^R = f\left(r^R, u_t^{\theta R}\right); \quad r_t^e = f\left(r^e, u_t^e\right); \quad r_t^\theta = f\left(r^\theta; u_t^\theta\right). \qquad (29)$$

The terms r^g, r^R, r^e and r^θ represent the (calibrated) stationary values of the ratios $\frac{g}{y}$, $\frac{e}{y}$, $\frac{\theta_R}{y}$ and $\frac{\theta}{y}$, respectively. The exogenous variables u_t^g, $u_t^{\theta R}$ u_t^e, and u_t^θ describe

[14] Numerical simulations available from the authors show that the results remain substantially unaltered if we allow for a small countervailing effect of ϑ_t on γ_t^y.

[15] The functional forms of γ^o, γ^y and ϑ will be specified below, in accordance with the specific needs of our numerical applications.

deviations of expenditures, transfers and lump sum taxes from their stationary values and are related (through the function f) to the fiscal policies introduced to contrast the adverse supply effects of the containment policies.

3.1 Stationary state and parameterization

We adopt the baseline parameterization summarized in Table 1;

Table 1 - Baseline parameterization

$\alpha = 0.67$	$\beta = 0.99$	$\delta = 0.1$	$\sigma = 0.6$
$q = 0.4$	$\phi = -0.35$	$\eta = 0.72$	$\rho_w = 0.85$
$x = 0.02$	$n = 0.01$	$\gamma^o = 0.9285$	$\omega = 0.9777$
$r^g = \frac{g}{y} = 0.150$	$r^e = \frac{e}{y} = 0.0405$	$r^b = \frac{b}{y} = 0.983$	$a^o = 1$
$r^{\vartheta R} = \frac{\theta_R}{y} = 0.107$			

The values of the main preference and technological parameters, together with the capital depreciation rate $(\alpha, \beta, \delta, \sigma)$, are commonly adopted in the literature, while q is taken from Gertler (1999) and η from Basso and Rachedi (2021);[16] the elasticity parameter ϕ is set so as to obtain a realistic figure for the long run interest factor R. As for the average retirement rate ω, as well as for γ^o, we adopt a strategy centered on the main demographic features of the U.S. Our point of departure is the average life expectancy for the U.S. population, which is 78.86 years at birth.[17] We then assume that people, roughly in line with the approach inaugurated by Auerbach and Kotlikoff (1987), on average, enter the labor market at 20 years of age and leave it at 65, for a total of 45 years of productive/active life; after that period, they are left with 14 years to be spent in retirement, so that the total (average) life-span is 79. The implied values of the two parameters are: $\omega = 1 - \frac{1}{45} = 0.9777$ and $\gamma^o = 1 - \frac{1}{14} = 0.9285$.[18]

As for the fiscal policy ratios, we use data from the FRED database for the U.S., in the period 2009-2019, and compute the values in Table 1 as averages of the corresponding ratios. We choose this time range for $r^{g,e,b,\theta}$ in order to have, as a benchmark, a description of the fiscal structure over a relatively short time period. These figures can also be employed int the subsequent fiscal policy experiments and scenarios, in which the economy is allowed to start from a stationary state characterized by fiscal parameters close to the recent estimates. The factor multiplying the old agents' taxes, a^o, is kept equal to 1; the parameter ρ_w measures the persistence of the wage level, and the chosen value of 0.85 is in line with the figures frequently adopted for the Calvo rule parameter in models with sticky wages.

[16] Basso and Rachedi (2021) when calibrating their equivalent of our parameter η, state: "[...] hourly wage of individuals above 65 years equals on average 72 percent of the hourly wage of individuals between 30 and 64 years" (p. 129).

[17] See OECD data, pre-covid 2019 value, retrieved on 20 February 2025 at the URL https://data-explorer.oecd.org/?tm=life%20expectancy&pg=0&snb=21. See also OECD (2023) and Goldstein and Lee (2020).

[18] The resulting stationary value of the population structure, $\psi = 0.27362$, is roughly in line with the average ratio of the old age population (65 and more) and the working age population (15-64), which is equal to 0.199 in the period 1977-2018.

Under the parameterization of Table 1, we numerically solve the system of stationary equations by adopting the following strategy. We set a target value for the stationary debt-to-GDP ratio $r^b = \frac{b}{y}$ and require the fiscal variables g, θ_R and e to adjust according to their stationary ratios: $\frac{g}{y} = 0.150$, $\frac{\theta_R}{y} = 0.107$ and $\frac{e}{y} = 0.0405$.[19] The fiscal revenues θ then adjusts in order to satisfy the budget equation $(1 + a^o \psi)\,\theta = g+e+[R-(1+n)(1+x)]\,b$, and the resulting value ($\theta = 0.186482$) ia used to compute the stationary ratio $r^\theta = \frac{\theta}{y} = 0.259$. This value of r^θ is subsequently inserted into the third equation of (26) to carry out the numerical simulations of the model's system of difference equations. By so doing, we obtain values for the main endogenous variables which are in line with some relevant empirical findings for the U.S. economy. For example, the main ratios of aggregate demand components over GDP are: $\frac{c}{y} = 0.6$ and $\frac{y-c-g}{y} = 0.25$, while the real interest factor is: $R = 1.0328$ (3.3%). The m.p.c. of old agents ($\xi^o = 0.0846$) is almost twice as much as that of the young agents ($\xi^y = 0.0478$), while the amount of labor services supplied by the old agents ($l^o = 0.075$) is significantly lower than that supplied by the young ones ($l^y = 0.488$), who constitute the bulk of the labor force and are relatively more productive.

Finally, we set the following parameters' values of the fiscal policy rules (26) that are needed to obtain proper simulation results in the Benchemark and Counterfactual scenarios described in following sections: $\rho_e = 0,5$, $\rho_g = 0.45; \rho_R = 0.4$ and $\rho_\theta = 0.99$. The adjustment parameter of the debt/GDP ratio δ_B is set to 0.02 in the Benchmark and Counterfactual scenarios of section 3.3, but it will be modified in the simulations carried out in section 3.4.

3.2 Economic dynamics following a pandemic shock: demographic and social restriction channels

Our first simulation exercise focuses on the economic impact of the COVID-19 pandemic shock. We first investigate how our model reacts to the pandemic when the main fiscal variables, g_t, e_t θ_{Rt} and θ_t, are anchored to the BGP and consequently set $r^g_t = r^g$, $r^e_t = r^e$ $r^{\theta R}_t = r^{\theta R}$ and $r^\theta_t = r^\theta$. This allows us to gain a direct insight of the basic reactions of agents and markets to a demographic and health-related shock. This experiment requires to pin down the dynamic behavior of γ_t and ϑ_t during the period in which the pandemic unfolds. As discussed above, the causes of economic disruption under the pandemic are not uniquely related to policy measures (lockdown or similar restrictions), but also to "precautionary" or fear-related behavioral responses by individual agents. Changes in ϑ_t hence include both phenomena.

To shape the numerical impact of the COVID-19 shock on the dynamic behavior of γ^o_t and γ^y_t, we employ the estimates of the impact of the pandemic on life expectancy presented by Goldstein and Lee (2020) and OECD (2021, 2023). According to Goldstein and Lee (2020), in the abscence of any significant containment or lockdown/social distancing policies, in 2020 the total death toll due to the pandemic would have been equal to two millions (their "worst" scenario), equivalent to a reduction of 5.08 years in life expectancy. More recent estimations by OECD (2021, p. 46) provide a fall in life

[19] This is also coherent with the equations (26) computed at their stationary levels.

expectancy in 2020 equal to 1.8 years, with the total death toll due to the virus equal to 725,000 up to mid-October 2021 (hence including also the effects of the lockdown policies implemented during the pandemic's first year). For 2021, the OECD estimates an additional decrease of life expectancy to the value of 76.4.

Starting form the stationary values of Parameterization A in Table 1, we use these estimates to carry out the following experiment. We first assume, counterfactually, that the COVID-19 is not followed by social distancing policy/behavior, so as to induce a fall in $\gamma^o_{t=2020}$ corresponding to a reduction of 6 years in life expectancy[20] (the *"pure-pandemic", PP, scenario*). We then adopt the OECD (2021) estimates of the reduction in life expectancy in 2020 (1.8 years), and impose a corresponding fall in $\gamma^o_{t=2020}$, letting at the same time ϑ_t increase above its stationary value. We compute the values of ϑ_t to target the fall in the real percapita U.S. output recorded by FRED data, which amounts to a fall in the cyclical component of real per capita GDP for 2019-2020 equal to $\Delta y_{2020} = -0.0452$ (the *"pandemic&lockdown", PL, scenario*). As for the increase of the death probability of "young" persons (less than 65 years old), we allow for very small changes in γ^y_t under both PP and PL scenarios, that however does not alter the results significantly.[21]

As for our research objective it is particularly interesting to compare the reactions of the welfare indicators in the two scenarios, Figure 1 depicts the behavior of the level of the group-specific welfare indicators and their ratio v^{ratio}_t under *PP* and *PL*[22], while

[20]This figure can also be considered as roughly in line with the discussion in Gagnon et al. (2020), who assume that a total death toll of 2.5 millions for COVID-19 would be consistent with the economy's population reaching herd immunity. See also Verity (2020).

[21]This is confirmed by the data. For example, the OECD Report (2023) shows that, on average across 22 OECD countries by April 2022, more than 90% of all cumulative deaths related to COVID-19 were among people aged 60 and over.

[22]In *PP* and *PL* we specify exogenous dynamic laws for the three quantities $\gamma^o_t = \gamma^o - u^{\gamma o}_t$, $\gamma^y_t = 1 - u^{\gamma y}_t$ and $\vartheta_t = 1 + u^{\vartheta}_t$, where the shock variables $u^{\gamma o}$ and u^{ϑ} take on different values under the PP and the PL scenarios ($u^{\gamma y}_t$ remains the same in both scenarios). Under *PP*, we target the values $\gamma^o_{t=1\ (2020)} = 0.875$ (life expectancy falling to 73) and $\gamma^o_{t=1\ (2021)} = 0.9275$, and set $u^{\gamma o}_{t=1,2}\,(PP) = [-0.0535; 0.001]$, and $u^{\gamma o}_t = 0$ for all subsequent periods. Under the *PL* scenario, we target $\gamma^o_{t=1\ (2020)} = 0.91803$ (life expectancy falling to 77.2) and $\gamma^o_{t=1\ (2021)} = 0.91304$, and consequently we set $u^{\gamma^o}_{t=1,2}\,(PL) = [0.010\,47; 0.015\,46]$ together with $u^{\vartheta}_{t=1}\,(PL) = 0.00836$ and zero otherwise. In both the scenarios, we set $u^{\gamma y}_{t=1,2} = [0.0012, 0.00005]$, together with $u^{\gamma y}_t = 0$ in the subsequent periods.

Figure 2 compares the path of other relevant variables.

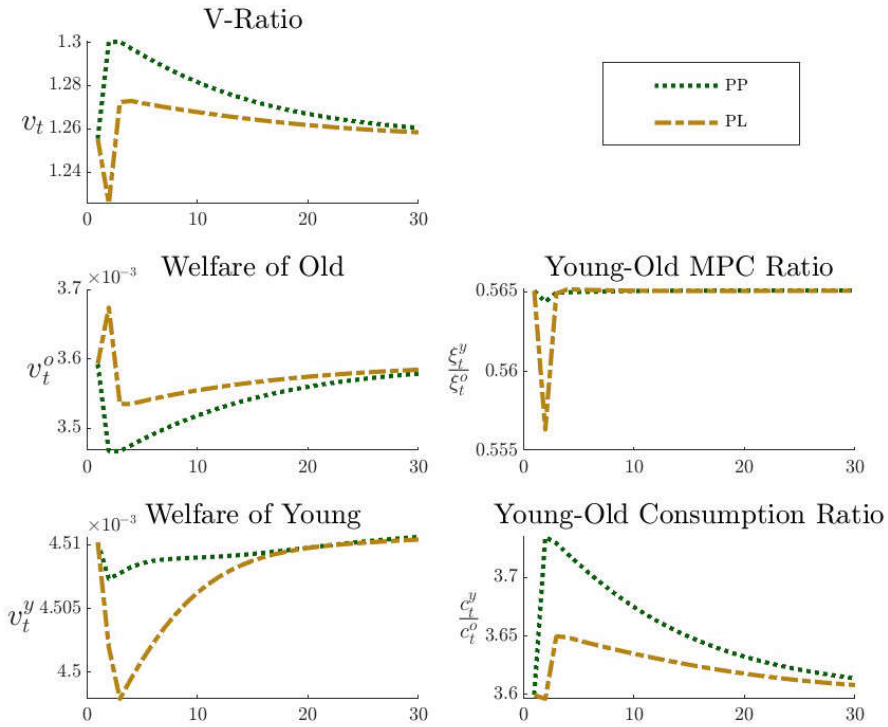

Figure 1 – Response of v_t^{ratio} and its components under *PP* and *PL* (levels).

The initial impact and the subsequent dynamics of v_t^{ratio} is strongly unfavourable to the young agents under the *PL* scenario, while it is unequivocally more favourable under the *PP* scenario. The different behavior of v^{ratio} in the two scenarios can be traced back (via equation 28) to the behavior of the two ratios ξ_t^y/ξ_t^o and c_t^y/c_t^o.

Under *PP*, a specific *demographic channel* is at play: the decline in life expectancy, γ_t^o, leads to a sharp contraction in the labor supply of old agents. In contrast, the labor input from young agents rises, though not sufficiently to offset the overall decline in total labor supply. As a result, the consumption of old agents, c_t^o, falls markedly, while that of young agents, c_t^y, increases moderately (see Figure 2). This divergence drives up the young-old consumption ratio, c_t^y/c_t^o. The m.p.c. of both groups decrease slightly, but their ratio remains virtually unchanged, contributing little to the dynamics of v_t^{ratio}. Thus, under this mechanism, the group more reliant on labor income—young agents—benefits relatively more. This is further reflected in the rising path of the real wage, w_t, alongside a decline in the real interest factor, R_t.

Under *PL*, an additional mechanism—referred to as the *social restrictions channel*—comes into play. Unlike the *PP* case, the consumption of young agents declines, while that of old agents also falls, albeit less sharply. The m.p.c. increases for both groups, with a notably larger increase for the old. Consequently, the initial decline in v_t^{ratio} during the first year of the pandemic is mainly driven by the drop in the m.p.c. ratio, which quickly reverts to its steady-state level. The subsequent dynamics of v_t^{ratio} is instead shaped by changes in the consumption ratio c_t^y/c_t^o, which first rises and then gradually coverges to its long-run value. This pattern reflects the asymmetric impact of lockdown measures on the diffrent types of income sources. Labor income—critical for young agents, who make up the majority of the workforce—is strongly affected by the restrictions. In contrast, income from financial assets, which constitutes a larger share of older agents' resources, is relatively insulated; actually, when lockdown policies and/or social distancing are present, a transfer of wealth from younger agents to old ones takes place.[23] Once restrictions are lifted, the evolution of v_t^{ratio} mirrors the dynamics observed under *PP*: a sharp rise followed by a gradual return to the steady state. However, the recovery in labor supply and "human wealth" is faster for young agents than for the old ones, resulting in a transition path for v_t^{ratio} that lies below that seen in the PP case.

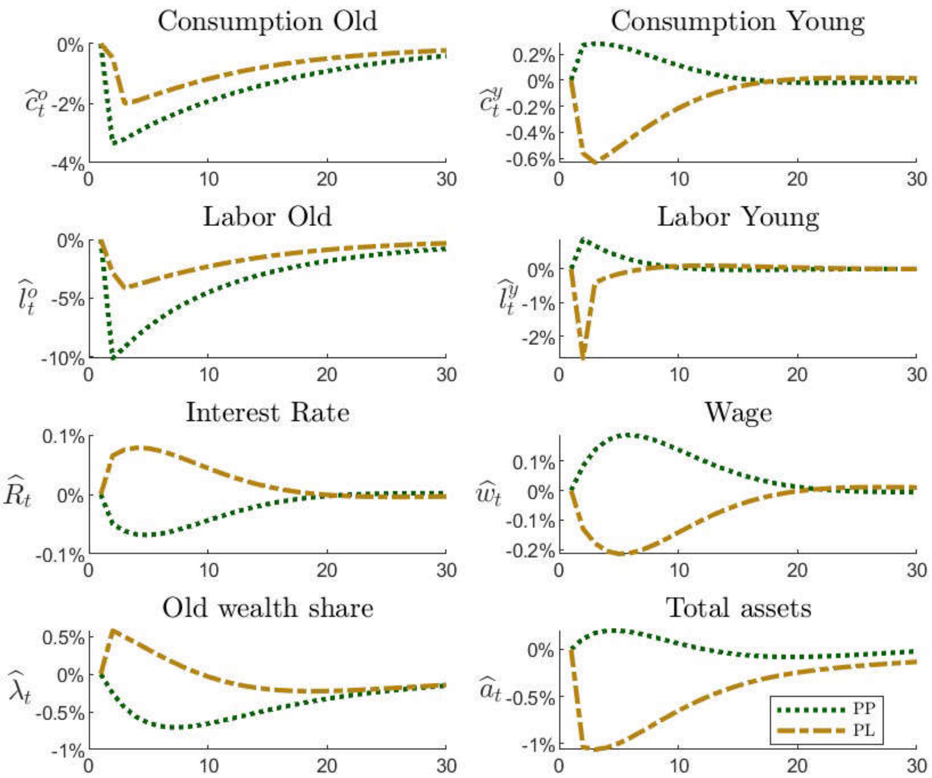

Figure 2 – *PP* and *PL* simulations: main macroeconomic variables. Vertical axis show percentage deviations from the stationary state.

In summary, the social restrictions channel disproportionately penalizes those dependent on labor income, while favoring individuals whose income relies more on accumulated wealth.[24]

3.3 The generational effects of the "Covid" fiscal expansion

Our next exercise aims at investigating the effects of the fiscal policies undertaken during the pandemic period on the relative welfare index. In this case we must elaborate

[23] As can be seen by the increase in the share of financial assets accruing to the old generation, λ_t.

[24] Actually, under *PL*, the real return on capital R_t incresases while the real wage w_t suffers a substantial fall in the first periods after the shocks.

a more complete simulation, which includes the time evolution (in the first years of the pandemic) of the main fiscal variables included in the model, along with the demographic shock hitting life expectancy (which is calibrated as in the *PL* scenario of the previous section) and the lockdown measures represented by increases in ϑ_t. In carrying out this numerical exercise, which we call the *Benchmark simulation*, we follow the general idea of Bayer et al. (2023), and focus on the shocks on the relavant exogenous variables, that is: $u_t^{\gamma o}$ (and $u_t^{\gamma y}$), u_t^{ϑ}, u_t^{g}, $u_t^{\theta R}$ and u_t^{e}. First, we set the functional form for the fiscal policy ratios $r_l^{g,e,\theta_R,\theta}$ defined in (29):

$$r_l^s = f\left(r^s; u_t^s\right) = r^s \exp\left(\vartheta^s u_t^s\right); \qquad s \in \{g, e, \theta_R, \theta\}$$

The scaling parameters ϑ^s are set constant at these values: $\vartheta^g = 0.8$, $\vartheta^\theta = -0.2$, $\vartheta^e = \vartheta^{\theta R} = 1$, and we retain the values of $u_t^{\gamma o}$ and $u_t^{\gamma y}$ which we justified in the *PL* scenario. Hence, we set the values of u_t^{g}, $u_t^{\vartheta R}$ and u_t^{e}, and also of the "lockdown" shock u_t^{ϑ}, so as to match (with the official data) the time evolution of the cyclical component of percapita GDP for the first four years after the pandemics (Δy_{2020} to Δy_{2023}) and the time evolution of changes in the "fiscal ratios" $\frac{g_t}{y_t}$, $\frac{e_t}{y_t}$ and $\frac{tr_t}{y_t}$ in the same time period.

This benchmark simulation will then be compared with a different scenario in which we counterfactually assume that fiscal policy did not include any specific program targeted at counteracting the negative impact of the COVID-19 pandemics. More specifically, while we keep the values of u_t^{ϑ} as in the Benchmark simulation, we adjust the values of the fiscal policy shocks u_t^{g}, $u_t^{\theta R}$ and u_t^{e} so as to obtain the time evolution that the variables g_t, θ_{Rt} and e_t would have followed if no *specific components due to COVID-related measures/programs* were present. We call this "no action" or "passive" scenario the *Counterfactual simulation*. Finally, in order to evaluate the impact of the fiscal support policies on the generational structure of welfare, we compare the evolution of the relative welfare index v_t^{ratio} in the Benchmark and the Counterfactual simulations.

The Benchmark Simulation

Our empirical targets are taken from the FRED dataset. Besides the values of the changes in the cyclical components of per-capita GDP (after the removal of a log-linear trend) in the first four years after the pandemic, we collect data for the ratios of the fiscal variables over GDP: $\frac{G_t}{Y_t}$, $\frac{E_t}{Y_t}$, $\frac{Tr_t}{Y_t}$ for the same years. For each variable $S_t \in \{G_t, E_t.Tr_t\}$ we then compute the percentage change $\Delta\left(\frac{S}{Y}\right)_t^{FRED} = \frac{(S/Y)_t - (S/Y)_{t-1}}{(S/Y)_{t-1}}$ for $t = 2020 : 2023$. We hence set a time sequence of values for the policy shocks[25] u_t^{g}, $u_t^{\theta R}$, u_t^{e} so as to exactly match the time evolution of the simultated changes in the fiscal ratios, $\Delta\left(S/Y\right)_t^{BENCH} = \frac{(S/Y)_t - (S/Y)_{t-1}}{(S/Y)_{t-1}}_{(\text{model})}$, with that of the data, that is:[26] $\Delta\left(S/Y\right)_t^{FRED} = \Delta\left(S/Y\right)_t^{BECH}$ for $t = 2020 : 2023$. The results of the Benchmark simulation compared with the actual data from FRED are shown in Figure B.1 in Appendix B. The model closely replicates the behavior of GDP and of the main fiscal

[25] The values of the lockdown variable u_t^{ϑ} are also adjusted to guarantee a match with the fiscal ratios, but they are set primarily to target the changes in the cyclical component of the percapita GDP, especially for the first two years: $\Delta y_{2020} = -0.0452$ and $\Delta y_{2021} = 0.03738$.

[26] Additional information and details on the Benchmark and the other simulations are provided in the Technical Appendix 6-8.

variables (their ratios over GDP) in the four year following the inception of the pandemic. The benchmark simulation can hence be considered as a sufficiently realistic description of the impact of the pandemic on the economy as a whole, to be contrasted with a counterfactual scenario. To this task we now turn our attention.

The Counterfactual Simulation

In order to evaluate the effects of the fiscal policies aimed at counteracting the negative effect of the lockdown/social distancing measures on the relative welfare index of the two age groups, we build a *Counterfactual scenario*. We keep the same calibration and the same values for the shocks on γ and ϑ used in the Benchmark simulation and, at the same time, we remove from the effective fiscal ratios $((S/Y)_t^{FRED}$, $t = 2020{:}2023)$ an estimate of the amounts apportioned by the U.S. government that are explicitly related to the COVID-19 emergency, so as to obtain the "countefactual" fiscal ratios $(S/Y)_t^{COUNT}$ for each of the fiscal variables:

$$\left(\frac{S}{Y}\right)_t^{COUNT} = \left(\frac{S}{Y}\right)_t^{FRED} - \left(\frac{S}{Y}\right)_t^{COVID} \quad \text{for } S \in \{G, E, Tr\} \text{ and } t = 2019 : 2023$$

where the quantities $\left(\frac{S}{Y}\right)_t^{COVID}$ are the amounts of the expenditure made to explicitly tackle the economic impact of COVID-19. Given the above ratios $\left(\frac{S}{Y}\right)_t^{COUNT}$ (with a separate estimate for 2019), we can compute the time changes of the same ratios:

$$\Delta\left(\frac{S}{Y}\right)_t^{COUNT} = \frac{\left(\frac{S}{Y}\right)_t^{COUNT} - \left(\frac{S}{Y}\right)_{t-1}^{COUNT}}{\left(\frac{S}{Y}\right)_{t-1}^{COUNT}} \qquad S \in \{G, E, Tr\}\,;\, t = 2020 : 2023$$

We finally specify time series for the shocks components (u_t^g, $u_t^{\theta R}$ and u_t^e) of the counterfactual simulation to target the values of the $\Delta\left(\frac{S}{Y}\right)_t^{COUNT}$ in the four years of the pandemic.

The crucial part of this exercise is to obtain sufficiently accurate figures of $\left(\frac{G}{Y}\right)_t^{COVID}$, $\left(\frac{E}{Y}\right)_t^{COVID}$ and $\left(\frac{Tr}{Y}\right)_t^{COVID}$ for the period 2020-2023. To this aim, we first gather data on the *overall* value of the COVID-related fiscal programs and packages undertaken by the U.S. Government from 2020 to 2023[27] and compute the ratio of such *overall values over the GDP*. We then use the evidence and information gathered during the pandemic (especially Wilson 2020) to decompose these overall fiscal ratios into the amounts that can be assigned to the single fiscal variables, G_t, E_t and Tr_t, and hence estimate the ratios $\left(\frac{S}{Y}\right)_t^{COVID}$ for $S \in \{G, E, Tr\}$ for the period 2020-2023. Figure C.1 in Appendix C, shows that also the counterfactual simulation can generate a close match between the values of variables simulated by the model and those computed form the data.

Discussion and economic mechanism

The two simulations, the Benchmark and the Counterfactual, generate different dinamics of the relative welfare index v_t^{ratio} defined in (28) and of the v_t^z of the two age

[27] There is a residual amount of these programs extending in 2024, but ist value is sufficiently small (1.03% of GDP) to be ignored.

groups. The comparison is offered in Figure 3.

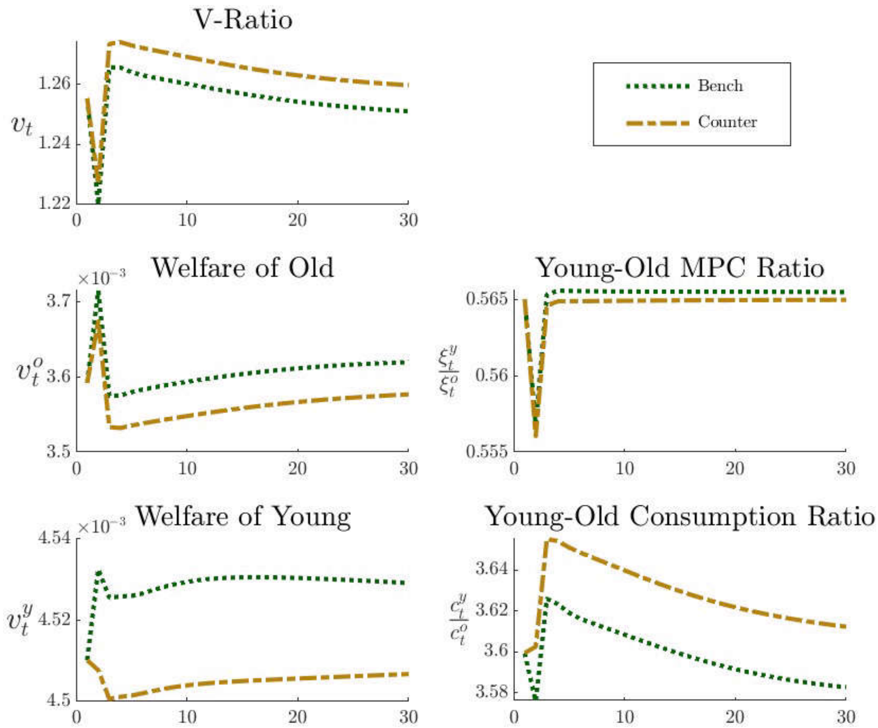

Figure 3 – Time evolution of the welfare indexes under the Benchmark and the Counterfactual simulations. Vertical axis show the values of the respective indexes.

The introduction of specific expansionary fiscal measures aimed at supporting the economy during the pandemic seems to be beneficial for both age groups. However, in relative terms, the older generation is favoured by the "Covid" fiscal package when compared with the younger one. In the benchmark simulation, the relative welfare index v_t^{ratio} falls because the welfare of the old agents, v_t^o, rises much more sharply (in percentage-point terms) than that of the young agents, v_t^y. As shown in Figure 3, the impact on v_t^o is roughly an order of magnitude larger than on v_t^y.

By contrast, under the counterfactual simulation the initial shock pushes the two groups' welfare in opposite directions: the welfare of the young falls, while that of the old rises thanks to the lockdown measures. Once these measures are later lifted, the pattern reverses—the old, who had gained the most from the restrictions, suffer a pronounced drop in welfare, whereas the young experiences only a mild additional decline. Thereafter both indices drift smoothly back toward their steady-state levels, so that, over the entire horizon, v_t^{ratio} ends up slightly more favourable to the young.

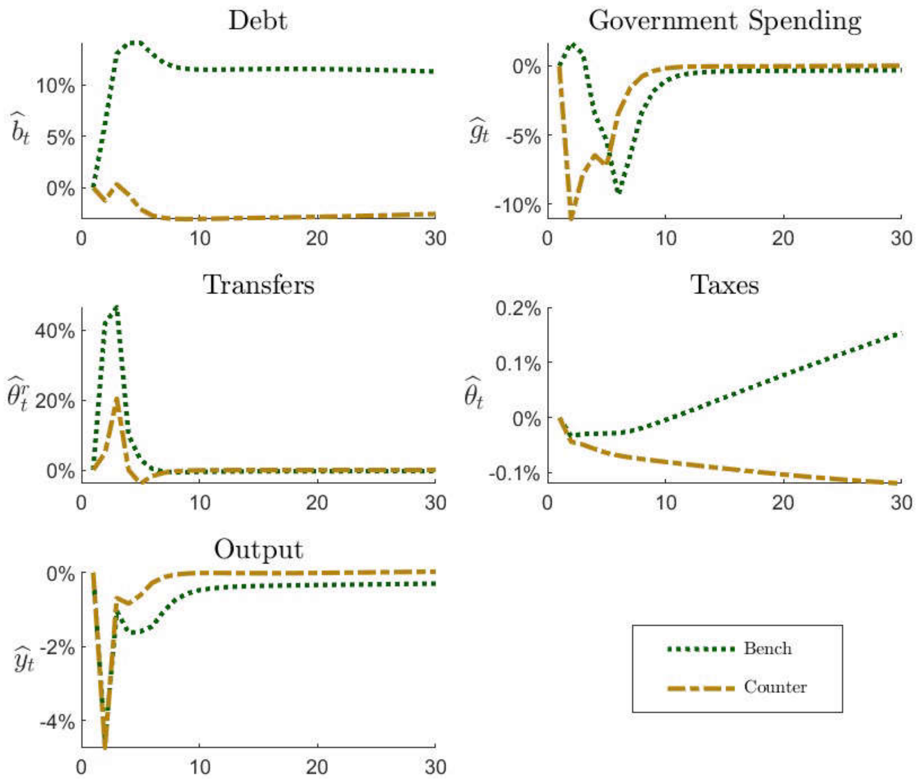

Figure 4 – Benchmak vs. Counterfactual simulation. Fiscal variables and output. Vertical axis show percentage deviations from the stationary values.

From a macroeconomic perspective (see Figure 4 and 5), the counterfactual and the benchmark simulations generate a similar recession in the year of the pandemic's peak (2020). Furthermore, as expected, in the "realistic" scenario (Benchmark), the percentage increase of the transfers θ_{Rt} is much greater than the increase of public expenditures g_t. The expansionary fiscal policy implemented in the two years of the pandemic (2020 and 2021) translates into a substantial increase in the stock of public debt b_t and hence in total assets a_t.

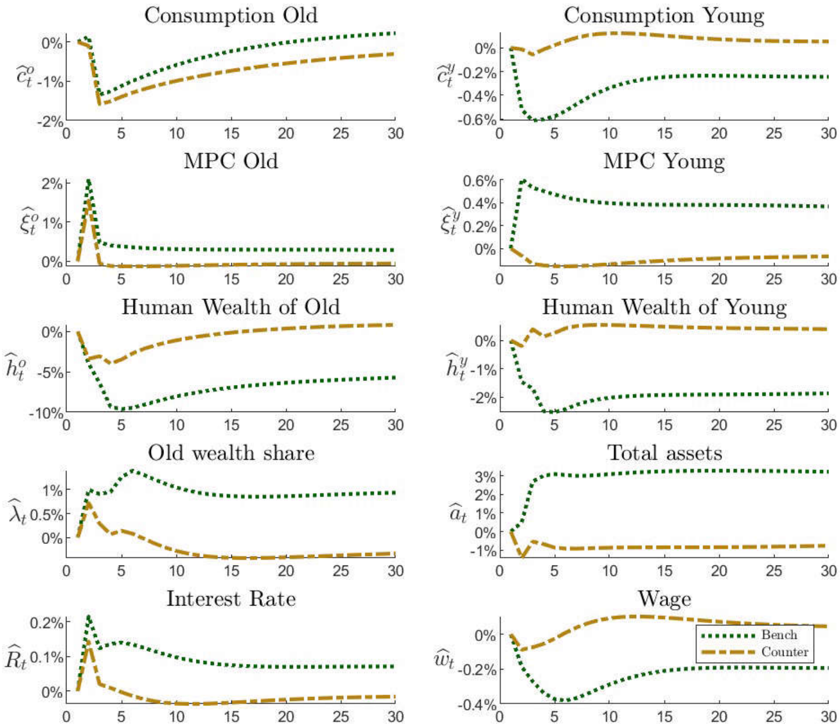

Figure 5 – Benchmak vs. Counterfactual simulation. Main macroeconomic variables. Vertical axis show percentage deviations from the stationary values.

The impact of the Covid-19 fiscal package (i.e., the Benchmark scenario) appears to be significantly sharper on the economic behaviour of older agents, while it has a more limited effect on younger agents. This is particularly evident when comparing *the magnitude of the impact* responses of key variables—such as consumption c_t^z, marginal propensity to consume ξ_t^z and human wealth h_t^z—across the Benchmark and Counterfactual scenarios. Moreover, the response of variables associated with young agents differs more markedly between the two scenarios than is the case for the old. While the old exhibit consistently large shifts, the young display greater sensitivity to the presence or absence of the fiscal package.

These differences are driven by the interaction of two main channels. As already discussed in the analysis of the *PP* and *PL* scenarios, the demographic channel plays a crucial role. The pandemic shock significantly reduces the survival probability of older agents (γ_t^o), even in the presence of lockdown measures, while leaving the survival probability of young agents essentially unchanged. As a result, the old experience a relevant reduction in their population, which leads to more abrupt and intense adjustments in the consumption behaviour of the surviving cohort.[28] By contrast, young agents face less severe demographic consequences from the pandemic and therefore exhibit less intense changes in consumption, and also in the m.p.c. ξ_t^y.

The second channel is the income redistribution effect of the fiscal policy. Under the Benchmark scenario, the increase in public debt (see Figure 4) leads to a significant rise in total assets a_t, which in turn pushes the interest factor R_t up. As noted by Gertler

[28] The time path of c_t^o shows a strong reduction and a gradual recover to the steady state; the variable $c_t^o = C_t^o / (X_t N_t^y)$, incorporates the fall of consumption due to the old agents death rate in the numerator, while the denomitator is basically unaffected.

(1999), in this life-cycle model, a rise in government debt shifts wealth from young workers to older retirees because the latter group , as asset holders benefit from the higher returns, while the young, who rely primarily on labour income, bear the burden of future tax increases. Further evidence for this mechanism comes from the Counterfactual scenario. In the absence of fiscal intervention, both a_t and b_t decline, reversing the redistribution observed in the Benchmark case. This reversal is also consistent with the milder drop in wages w_t—the main income source for young agents—compared to the sharper fall observed in the Benchmark simulation. Lastly, the more pronounced decline in c_t^y under the Benchmark scenario can be interpreted as the result of fiscal crowding out. The accumulation of public debt increases the expected tax burden, which forward-looking young agents internalize, leading them to reduce consumption more sharply. This "Ricardian" behavior is typical of the younger cohorts, although an overall Ricardian equivalence is absent in the model.

The effects on intergenerational welfare of the repayment of the accumulated public debt is the subject of the next section.

3.4 Different Debt-Repayment-Schemes in the wake of the pandemic shock

In order to address our second research question, i.e., the effects of the expansionary fiscal measures related to the COVID-19 pandemics on a longer time persepctive, we focus on the projections of the time evolution of the public debt relative to GDP after the pandemics. Firstly, we notice that the COVID-19 fiscal package had a relevant impact on the level and the dynamics of public debt, imparting a relevant push to the amount of the overall debt held by the public. Secondly, the increased debt repayment represents an additional burden that agents take into account in their economic planning for the future. Yet the abscence of the Ricardian equivalence in this model implies that the dynamic evolutions of this burden depend upon the specific time profiles of repayment chosen by the government, that may produce different effects on the relative welfare of younger and older age groups. In order to investigate this issue in the context of our model, we focus on different *Debt Repayment Schemes* (DRSs) and on the associated time evolutions of debt-to-GDP ratio and of relative welfare.

Our first step is to elaborate a "yardstick" scenario for the process of debt repayment, that we label *baseline DRS* and that is characterized by two central elments. The first one is the numerical values of the shocks $u_t^{\gamma y}$ (and $u_t^{\gamma o}$), u_t^{ϑ}, u_t^{g}, $u_t^{\theta R}$ and u_t^{e} for the period $2020 - 2024$ (corresponding to the pandemics and its immediate aftermaths), which are set as in the Benchmark simulation described above. The second element is the specification of a time series for one (or more) of these shocks over a longer time horizon, so as to describe a possible (and somehow "consesual") evolution of the debt-to-GDP ratio b_t/y_t. More specifically, we feed the model with a time profile for the shock component of the public transfers specified in the sequence $\left\{u_t^{\theta R}\right\}_{\text{baseline}}$ that generates a time path for the ratio b_t/y_t capable of replicating the projections of the Debt/GDP ratio for the U.S. from 2025 to 2055 reported in the Budget and Economic Outlook (2025) of the Congressional Budget Office (CBO). In this experiment, the crucial parameter affecting the profile and the speed of repayment, δ_B in the last equation of (26), is kept at its reference value of 0.02. The matching between the baseline DRS simulated data and the CBO projections can be appreciated in Figure D.1 in Appendix D.

We then compare the baseline DRS with a series of alternative scenarios characterized by different DRS generated by changing the debt-adjustment parameter δ^B: we consider the following values: $\delta_B \in \Delta^{b/y} = \{\, 0.7, 0.4, 0.2, 0.1, 0.06,\ 0.02_{(baseline)} \,\}$, while keeping ρ_θ fixed at 0.99.[29] We label this numerical exercise the *DRS simulation*.

In performing the DRS simulation, we sequentially consider the six values of δ_B included in $\Delta^{b/y}$, maintaining in each model run the same sequence of shocks $u_t^{\theta R}$ used in the baseline DRS simulation. Changes in the fiscal variables are hence limited only to the transfers θ_t^R, while the other variables adjust according to the dynamic rules (26), without further variable-specific shocks. Whereas the choice of a particular DRS in the set $\Delta^{b/y}$ does not have a significant impact on the dynamic evolution of GDP, Figure 6 shows that things are different for the Debt-to-GDP ratio and for the relative welfare index v_t^{ratio}, especially in the long run.

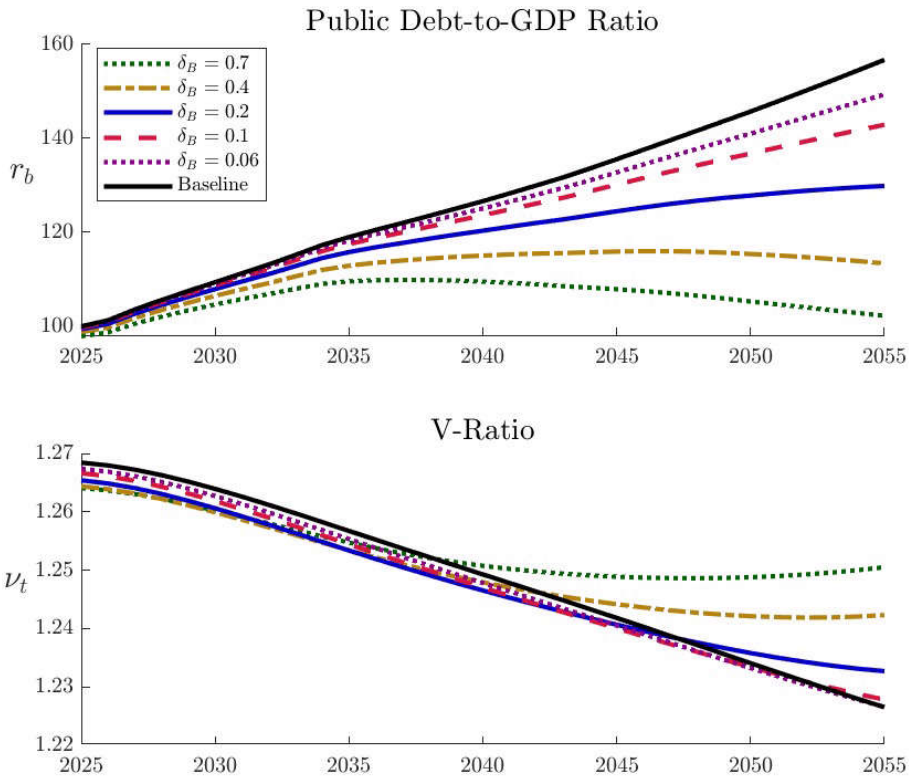

Figure 6 – DRS simulation: different DRS with $\delta_B \in \Delta^{b/y}$.

The time profile of debt repayment following the expansionary fiscal policy produces a sizeable reallocation effect on the relative generational welfare, as shown by the second panel of figure 6: the more the DRS entails a postponement of the repayment, the more the old agents are favoured, especially when a sufficiently long time horizon is considered. This is evident by comparing the different time paths of the welfare index

[29] *Coeteris paribus*, the higher is the value of the parameter, which is constrained to be smaller than 1 for convergence reasons, the shorter is the time horizon for the repayment of the debt and the more rapid is the DRS.

v_t^{ratio} under the two extreme values of $\Delta^{b/y}$, i.e., $\underline{\delta_B}$= 0.02 and $\overline{\delta_B}$ = 0.7. Under the "delayed" DRS, $\underline{\delta_B}$,[30] the young agents initally benefits from the postponing of the burden related to debt repayment, but subsequently experience a heavier burden (which increases through time, also due to the accumulation of interest payments). When the "rapid" DRS $\overline{\delta_B}$ is considered, the opposite is true: young agents are initially disavantaged, due to the amount of taxes they have to pay for a faster repayment process. At a certain point in time (precisely after 15 years) the path of $v_t^{ratio}\left(\overline{\delta_B}\right)$ intersects that of $v_t^{ratio}\left(\underline{\delta_B}\right)$, and from then onwards the evolution of v_t^{ratio}under the rapid DRS is much more favorable to the young cohorts with respect to the delayed DRS. This is due to the fact that in the former case the burden of repayment has been substantially borne in the first time periods.

The reason behind the behavior of v_t^{ratio} under the different DRS can be related to a form of "generational distributive conflict", whose fundamental elements are graphically shown in Figure 7. Under the delayed DRS ($\underline{\delta_B}$= 0.02), the consumption of the young agents declines in the long run, whereas that of the old agents increases. This is due to debt accumulation: as shown by the time path of λ_t, a longer debt repayment tanslates into a growth of financial wealth which, through time, is more and more held by the older generations.

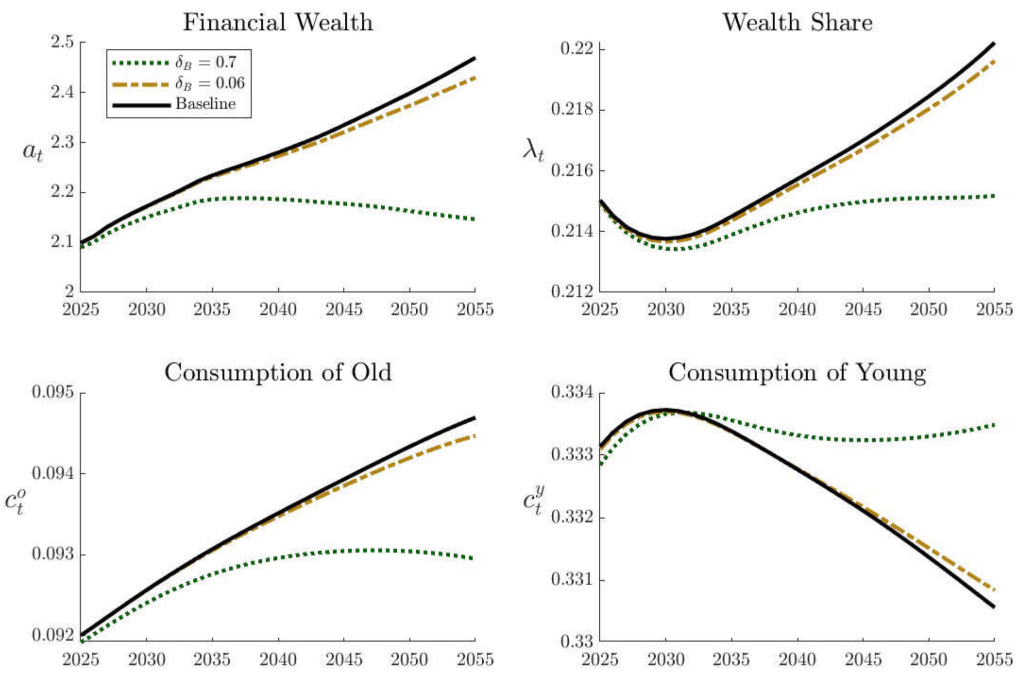

Figure 7 – Distributive conflict between old and young age groups over the public debt's DRS. Vertical axes show the simulated values of the variable under the two "extreme" DRS in $\Delta^{b/y}$ alongside with the basline.

At the same time, real prices show a time evolution that favours the holders of

[30]And under the time profile of transfers specified in $\left\{u_t^{\theta R}\right\}_{\text{baseline}}$.

financial wealth, with a marked growth in R_t coupled with a decline in w_t (Figure 8).

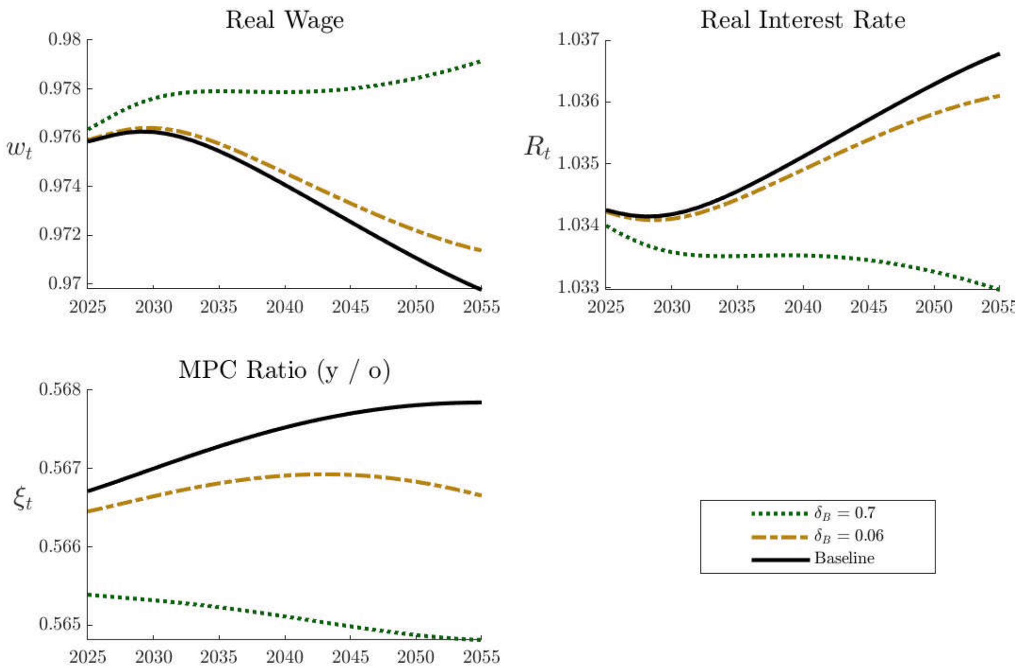

Figure 8 – Capital/financial income and labour income under the two "extreme" DRS in $\Delta^{b/y}$ alongside with the basline..

We may then say that a delayed DRS tends to increase the financial wealth and to concentrate total assets in the hands of the older age groups. This process, that also induces a long-run increase in the real interest factor, strengthens the relative economic position of the older agents. Under such DRS, total labour input l_t (not shown here) tends to decline, magnifying the negative impact on labour income, i.e., the primary source of income of young agents. This process is reversed under a rapid DRS.

Summing up, the picture offered by the DRS simulation highlights a sharp generational distributive conflict over the way debt is to be repayed: the older agents favour a delayed DRS and the younger ones a faster one, as these are respectively the most aligned with their long-run economic interests. Clearly, this conflict must be cast in the context of the demograpic dynamics of the model, according to which the currently young agent progressively enter the older age group as time goes on.

4 Conclusions

This paper has examined the age-specific welfare consequences of the economic and social policies implemented in response to the COVID-19 pandemic, with a particular focus on the differential impacts of containment measures and debt-financed fiscal expansions. Using a tractable model adapted from Gertler (1999), we introduced the pandemic as a negative shock to survival probabilities and evaluated the welfare of young and old agents under various policy scenarios.

Our findings highlight a critical intergenerational trade-off. In the absence of containment measures, the welfare losses from increased mortality are concentrated among the elderly. However, when lockdown and social distancing policies are introduced, mortality is reduced at the cost of significant declines in output, with the resulting welfare burden disproportionately borne by younger agents. This asymmetry in the distribution of costs and benefits underscores the importance of explicitly considering the age dimension in both policy design and evaluation.

We further assessed the impact of expansionary fiscal measures, such as those included in the American Rescue Plan. While these policies marginally favored older agents, their overall effect on the relative welfare index was limited. Our analysis indicates that the primary determinant of intergenerational welfare differences lies in the containment measures themselves, not in the accompanying fiscal stimulus.

Finally, we explored how alternative public debt repayment schemes influence the long-term evolution of generational welfare. Our results show that delayed repayment plans tend to favor older cohorts by deferring the fiscal burden, while front-loaded repayment schemes disproportionately disadvantage the young. These findings suggest that ignoring the intergenerational distributional effects of debt repayment strategies risks exacerbating welfare inequities that were already intensified by the pandemic response.

In sum, our study emphasizes the necessity of incorporating generational analysis into macroeconomic policy assessments, especially in the context of the large-scale shocks due to pandemics. Future research should extend this framework to account for within-group heterogeneity and explore optimal policy issues.

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Appendix

A. Detrended equilibrium equations

The equilibrium system of stationary variables: $f(\mathbf{v}_{t+1};\mathbf{v}_t;\mathbf{v}_{t-1}) = \mathbf{0}$ includes the following equations:

$$\begin{aligned}
\Omega_t &= \omega + (1-\omega)\chi\left(\frac{\xi_t^o}{\xi_t^y}\right)^{\frac{1}{1-\sigma}}; \quad (1+n)(1+x)k_t = y_t - c_t - g_t + (1-\delta)k_{t-1};\\
\frac{1}{\xi_t^y} &= 1 + \gamma_{t+1}^y\left[\left(\frac{w_t}{(1+x)w_{t+1}}\right)^{(1-q)\rho}\beta\right]^\sigma \frac{(R_t\Omega_{t+1})^{\sigma-1}}{\xi_{t+1}^y};\\
\frac{1}{\xi_t^o} &= 1 + \gamma_{t+1}^o\left[\left(\frac{w_t}{(1+x)w_{t+1}}\right)^{(1-q)\rho}\beta\right]^\sigma \frac{R_t^{\sigma-1}}{\xi_{t+1}^o};\\
a_t &= \frac{\omega\left[(1-\xi_t^o)R_{t-1}\lambda_{t-1}a_{t-1} + e_t + w_t\eta l_t^o + a^o\psi_t(\theta_{Rt}-\theta_t) - \xi_t^o(h_t^o + d_t^o)\right]}{(1+n)(1+x)(\omega+\lambda_t-1)};
\end{aligned}$$

$$\begin{aligned}
h_t^o &= w_t\eta l_t^o + a^o\psi_t(\theta_{Rt}-\theta_t) + \frac{(1+x)\gamma_{t+1}^o\psi_t}{\psi_{t+1}R_t}h_{t+1}^o;\\
h_t^y &= w_t l_t^y + \theta_{Rt} - \theta_t + \frac{(1+x)\omega}{\Omega_{t+1}R_t/\gamma_{t+1}^y}h_{t+1}^y + \frac{(1+x)(\Omega_{t+1}-\omega)}{\psi_{t+1}\Omega_{t+1}R_t/\gamma_{t+1}^y}h_{t+1}^o;\\
l_t &= l_t^y + \eta l_t^o; \qquad l_t^o = \psi_t - \frac{\varsigma}{w_t\eta}c_t^o; \qquad m_t^{RS} = \frac{\varsigma c_t^y}{1-l_t^y};\\
w_t &= \alpha\vartheta_t\left(\frac{y_t}{l_t}\right)^{1-\phi}; \quad y_t = \left[(1-\alpha)k_{t-1}^\phi + \vartheta_t\alpha l_t^\phi\right]^{\frac{1}{\phi}};\\
w_t &= \frac{(1-\rho_w)(1-\rho_w\beta)}{1+\rho_w^2\beta}m_t^{RS} + \frac{\rho_w\beta}{1+\rho_w^2\beta}E_t w_{t+1} + \frac{\rho_w}{1+\rho_w^2\beta}w_{t-1};\\
R_t &= (1-\alpha)\left(\frac{y_{t+1}}{k_t}\right)^{1-\phi} + 1 - \delta; \quad (1+n)\psi_t = \gamma_t^y(1-\omega) + \gamma_t^o\psi_{t-1};
\end{aligned}$$

$$\begin{aligned}
a_t &= k_t + b_t; \qquad (1+n)(1+x)b_t = g_t + e_t + (1+a^o\psi_t)(\theta_{Rt}-\theta_t) + R_{t-1}b_{t-1};\\
c_t &= \xi_t^y\left[(1-\lambda_{t-1})R_{t-1}a_{t-1} + h_t^y + d_t^y\right] + \xi_t^o(\lambda_{t-1}R_{t-1}a_{t-1} + h_t^o + d_t^o);\\
d_t^o &= e_t + \frac{(1+x)\psi_t\gamma_{t+1}^o}{\psi_{t+1}R_t}d_{t+1}^o; \qquad \frac{1}{1+x}d_t^y = \frac{\omega\gamma_{t+1}^y}{\Omega_{t+1}R_t}d_{t+1}^y + \left(\frac{\Omega_{t+1}-\omega}{\psi_{t+1}\Omega_{t+1}R_t/\gamma_{t+1}^y}\right)d_{t+1}^o\\
e_t &= \rho_e e_{t-1} + (1-\rho_e)r_t^e y_t; \quad g_t = \rho_g g_{t-1} + (1-\rho_g)r_t^g y_t;\\
\theta_{Rt} &= \rho_R\theta_{Rt-1} + (1-\rho_R)r_t^R y_t; \quad \theta_t = \rho_\theta\theta_{t-1} + (1-\rho_\theta)\left[r_t^\theta y_t + \delta_B\left(\frac{b_t}{y_t} - r^b\right)\right];\\
c_t^y &= \xi_t^y\left[(1-\lambda_{t-1})R_{t-1}a_{t-1} + h_t^y + d_t^y\right]; \qquad c_t^o = \xi_t^o(\lambda_{t-1}R_{t-1}a_{t-1} + h_t^o + d_t^o).
\end{aligned}$$

B. Benchmark simulation

Figure B.1 below shows the match between actual and simulated variables (y and fiscal ratios) in the first four years after the pandemic for the benchmark simultation:

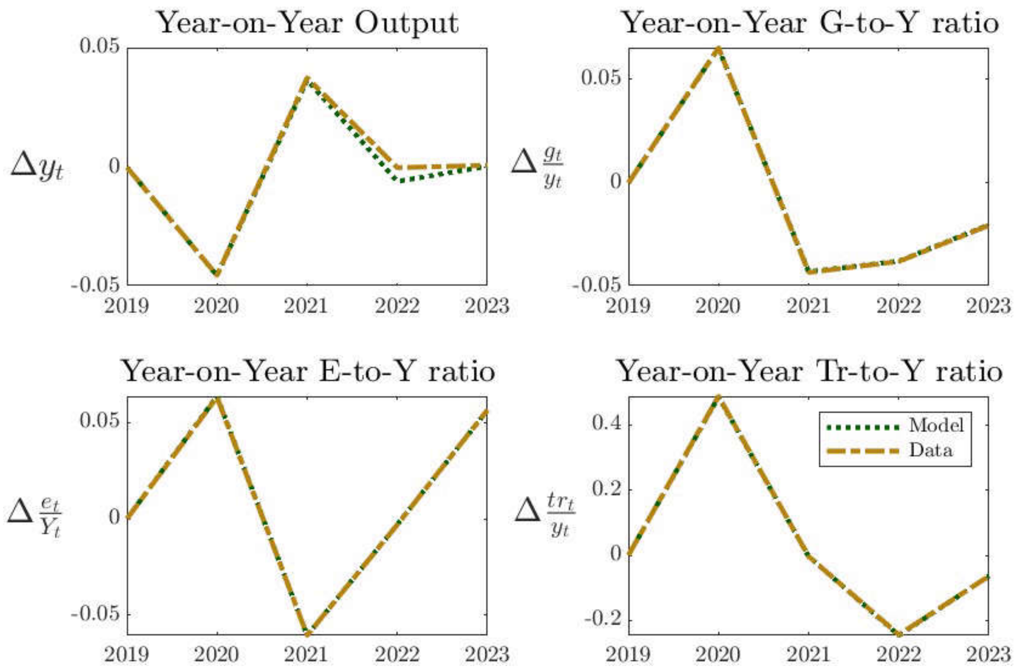

Figure B.1 – Benchmark simulation: matching with empirical measures from FRED database. Vertical axis show percentage change form one year to next.

C. Counterfactual simulation

As The first step is the determination of the overall value - in the period 2020-2023 - of the COVID-related fiscal programs which can be included into the three fiscal cathegories used in our model: G_t, E_t and Tr_t. To this aim we make use of the official data provided by U.S. government at: *https://www.usaspending.gov/disaster/covid-19?section=total_spending_by_budget_categories*, which allows us to compute the $COVID_t/Y_t$ ratio, where $COVID_t$ is the nominal value of the effective assignements and expenditures for COVID-related programs in year t (comprised into the cathegories G_t, E_t and Tr_t) and Y_t is nominal GDP from FRED database, as shown in Table C.1:

Table C.1 - Overall COVID-related fiscal programs

	$COVID_t$ (in billions \$)	Y_t (in billions \$)	$COVID/Y$
2020	1570	21400	7.37%
2021	1200	23700	5.09%
2022	547	26000	2.10%
2023	416	27700	1.50%
2024	299	29170	1.03%

The value of the $COVID_t/Y_t$ ratio must now be split into the ratios for the three cathegories, $\left(\frac{G_t}{Y_t}\right)^{COVID}$, $\left(\frac{E_t}{Y_t}\right)^{COVID}$ and $\left(\frac{Tr_t}{Y_t}\right)^{COVID}$. By adopting the decompostion proposed by Wilson (2020), we obtain the values shown in Table C.2:

Table C.2 - decomposition of Covid-Package intro specific fiscal variables

	$\frac{G}{y}$	$\frac{E}{Y}$	$\frac{Tr}{y}$	$\frac{T}{y}$31
% of tot. covid allocation	25%	5%	59%	11%

These figures are actually computed only for 2020, but lacking more detailed information we project them over the next three years, up to 2023.Furthermore, the ratio E/Y is computed as a residual from the figures for the other cathegories, and hence it is not a proper estimate of the real ratio. Yet, the small value of 5% can be reasonably adopted, being coherent with the very limited change of this ratio recorded in the four year of the pandemic.

These data allow us to compute the rate of change $\Delta\left(\frac{S}{Y}\right)_t^{COUNT} = \frac{(S/Y)_t^{COUNT} - (S/Y)_{t-1}^{COUNT}}{(S/Y)_{t-1}^{COUNT}}$ mentioned in the main text. By doing so, the match between the computed and the simulated values shown in following Figure C.1 is obtained:

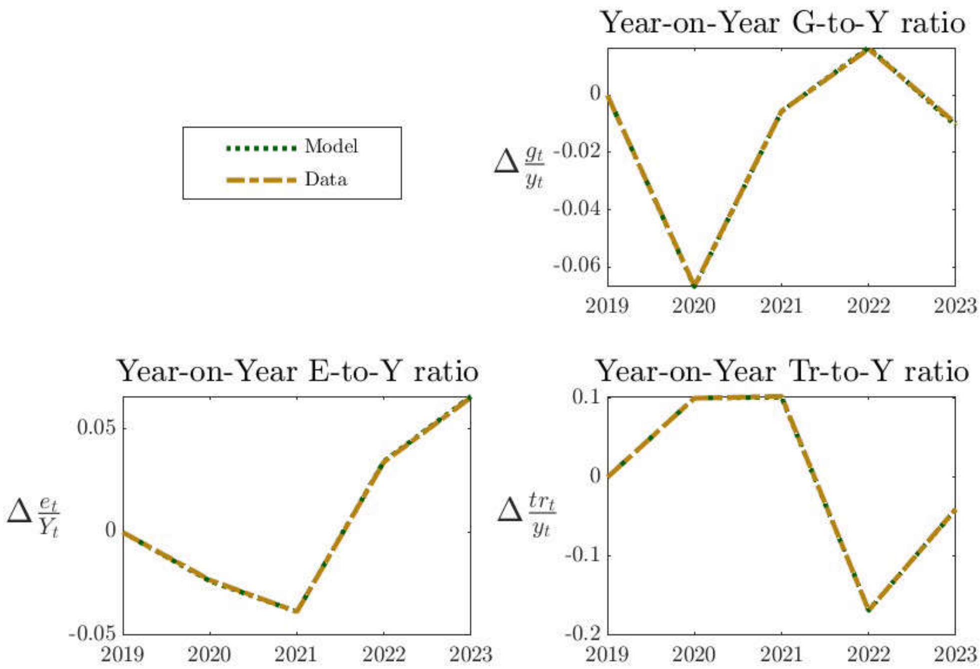

Figure C.1 – Counterfactual simulation: matching with computed values in the counterfactual scenario. Vertical axis show percentage change form one year to next.

D. Baseline Debt Repayment Scheme (DRS)

The simulation of the ratio b_t/y_t covers 31 years, from 2025 to 2055; in the first six years (from 2019 to 2024) we include the values for the transfer shock $(u_t^{\theta R})$ adopted in the Benchmark simulation for the the three first years, while for the remaining three years we set values for the transfer shocks so as to obtain a relatively smooth evolution of $\frac{b_t}{y_t}$ and a convergence to the value of 99.9 in 2025. All the steady state variables are uneffected by the choice of δ_B and are coherent with our calibrated/targeted values.

The baseline DRS simulation closely matches the evolution of the ratio r_t^b with the projections developed by the CBO, as shown by Figure D.1 below:

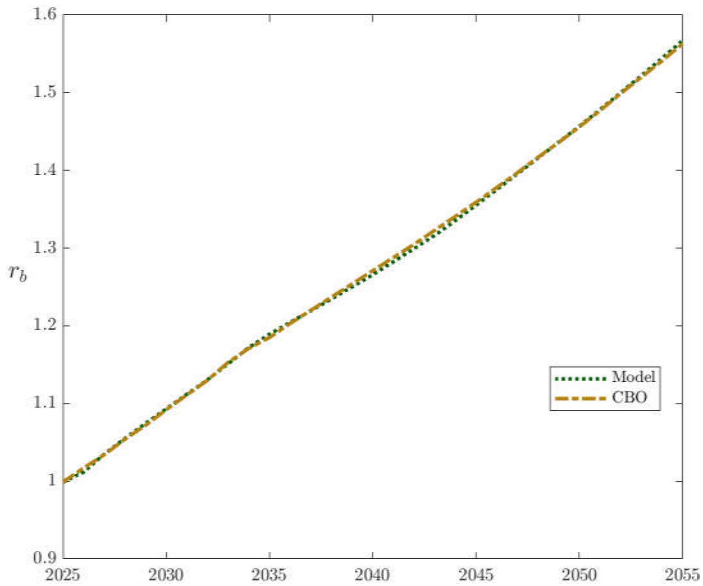

Figure D.1 – Baseline DRS simulation: matching with the long-run projections of $\frac{b_t}{y_t}$ provided by CBO: $\delta_B = 0.02$ and $u_t^{\theta R} \in \left\{u_t^{\theta R}\right\}_{\text{baseline}}$. Vertical axis show percentage values.

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