Monetary and Fiscal Policies in Times of Large Debt: Unity is Strength*

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Abstract

We use a state-of-the-art estimated model augmented with a rich fiscal block and distortionary taxation to illustrate the policy trade-off that arises because of the large debt accumulation caused by the COVID recession. If policymakers implement fiscal adjustments, the economy could experience a prolonged period of economic stagnation. If instead policymakers give in to the temptation of correcting the large fiscal imbalance with higher inflation, a prolonged period of heightened macroeconomic volatility could follow. A coordinated strategy between the monetary and fiscal authorities to inflate away a fraction of the large debt mitigates this trade-off by separating the short-run need to stimulate the economy during the large recession from the issue of long-run fiscal sustainability. The coordinated strategy acts as an automatic stabilizer, mitigating the severity of the pandemic recession. Thus, in equilibrium, the rise in the debt-to-output ratio is contained and so is the increase in inflation needed to stabilize it.

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1 Introduction

An important legacy of the COVID–19 pandemic is a record-high U.S. government debt. Even before the onset of the pandemic, the U.S. fiscal imbalance was already quite large by historical standards and required fiscal adjustments. In January 2020 –before the severity of the Pandemic recession was known– the Congressional Budget Office (CBO) estimated that, under current law, federal debt at the end of this decade would be higher as a percentage of GDP than at any time since 1946. If no fiscal adjustment is made, debt would continue to increase, and in 2050 it would reach higher than the highest level ever recorded in the United States. The recent fiscal stimulus of $2.6 trillion and the recession caused by the restrictive measures taken by authorities in many states to contain the spread of COVID-19 are exacerbating the already strained fiscal situation. The debate over widening fiscal imbalances, and what to do about them, is likely to move toward the center of the political agenda soon.

We use a state-of-the-art dynamic general equilibrium model with a rich fiscal block (including distortionary taxation on labor and capital income and transfers) and estimated to U.S. data to study the macroeconomic consequences of this large and growing public debt. The model shows that in the post-pandemic period, policymakers risk facing a trade-off between economic stagnation and heightened macroeconomic instability. The former scenario arises if policymakers are expected to correct the large post-pandemic fiscal imbalance with higher distortionary taxes and with lower expenditures –a scenario we call *Fiscal Orthodoxy*. The latter scenario materializes if policymakers give in to the temptation of correcting the large fiscal imbalance with higher inflation– a scenario we call *Fiscal Inflation*.

This unpleasant trade-off can be mitigated by coordinating monetary and fiscal policies with the aim of inflating away the share of debt owing to the large pandemic recession and the associated $2.6T fiscal stimulus. To implement this coordinated strategy, the fiscal authority runs two separate budgets: a regular budget backed by future distortionary fiscal adjustments and an emergency budget needed to address the dire consequences of the pandemic recession. Crucially, no provision is made on how this emergency budget will be balanced. Concomitantly, the monetary authority clarifies that it will tolerate inflation running moderately above its long-run inflation target for some time.[1] The exact amount of tolerated inflation is the one needed to wear away the desired amount of debt. The concerted actions of the two authorities make such path for inflation credible because needed to stabilize the amount of debt in excess of the regular budget.

[1] In practice, this monetary policy framework may take the form of an asymmetric inflation target range, analyzed in Bianchi, Melosi, and Rottner (2019), or that of a temporary increase in the central bank's inflation target. In this paper, we consider the latter specification.

This coordinated strategy, which we call *Emergency Budget*, improves upon Fiscal Orthodoxy, which would cripple the economy by imposing a prolonged and costly period of fiscal adjustments. In contrast, adopting the Emergency Budget raises inflation expectations as agents understand that the fraction of nominal debt ascribed to the emergency budget will be worn away by higher future prices. These beliefs contribute to lowering the real interest rate, mitigating the pandemic recession. Furthermore, the new policy regime leads agents to anticipate less dramatic fiscal adjustments in the future. Expectations of faster economic growth during the recovery ameliorate even further the severity of the Pandemic recession.

The coordinated strategy also improves upon Fiscal Inflation for two main reasons. First, since policymakers are still committed to make the necessary fiscal adjustments to stabilize the pre-pandemic stock of government debt, the coordinated strategy does not bring about additional macroeconomic volatility. Second, while the $2.6 trillion 2020 stimulus bill is the largest U.S. fiscal stimulus on record, the decision of ascribing it to the emergency budget results in just a modest, controlled increase in inflation. A general equilibrium effect explains this result: the mitigation of the pandemic recession contributes to lowering the debt-to-GDP ratio and hence inflation does not have to rise exorbitantly to wear away the debt ascribed to the emergency budget. Indeed, after a rapid but contained increase, inflation falls, remaining slightly elevated for several years. Such a persistent effect on inflation raises nominal interest rates, reducing the risk for the economy to fall into a liquidity trap and corrects a two-decade-long period of below-target inflation for the central bank.

Two features of the Emergency Budget are essential for the strategy to work properly. First, the monetary and fiscal authorities have to coordinate their respective strategies, with the central bank raising temporarily its inflation target so as to allow prices to grow at the required pace to wear away the increase in the debt-to-GDP ratio due to the Pandemic recession. We consider a scenario in which the central bank explicitly refuses to do so and starts raising the interest rate to rein in inflation, including Fiscal Inflation. We show that this scenario may lead to sunspot-type dynamics of inflation and output as the private sector tries to guess which authority will emerge victorious from the institutional conflict.[2]

Second, the coordinated strategy is indeed an emergency strategy. And, as such, the reliance on this strategy must be strictly restricted to the need of addressing an economic emergency, such as the COVID-19 pandemic. The emergency budget is an emergency procedure and should not be interpreted as the standard approach to address all the recessions going forward. A recurrent and discretionary use of such a tool by policymakers could lead to heightened macroeconomic volatility as in the case of Fiscal Inflation and could bring about shifts in individual behaviors likely to undermine the effectiveness of the emergency-budget

[2] Bianchi and Melosi (2019) show this result in a calibrated, small-scale model.

strategy.

Bianchi and Melosi (2019) introduced the concept of shock-specific rules as a way to resolve a conflict between the monetary and fiscal authorities in the presence of a high fiscal burden that the fiscal authority is reluctant or unable to stabilize. This notion of shock-specific rules proves to be useful to solve general equilibrium models in which monetary and fiscal authorities adopt state-dependent targets, like in the case of the emergency budget studied in this paper. In this paper, we introduce an emergency budget into a state-of-the-art DSGE model with a rich fiscal block as a solution to a situation of impasse due to high distortionary taxation and a low interest rate environment.

An important historical precedent that shares some similarities with the approach studied in this paper is President Roosevelt's New Deal. In 1933, President Roosevelt openly argued that there were two separate budgets. A regular federal budget for which a pledge was made to cut specific outlays to guarantee its fiscal backing. An emergency budget, which was needed to defeat the depression and which was unbalanced. In April of the same year, the United States abandoned the gold standard, delinking the value of the dollar to gold and reclaiming autonomous monetary policy. Eggertsson (2008) and Jacobson, Leeper, and Preston (2019) show that the decision to abandon the Gold Standard created the conditions for an unbacked fiscal expansion that played an instrumental role in ending the Great Depression. More broadly, this paper is connected to the vast literature on monetary-fiscal policy interaction (Sargent and Wallace 1981; Leeper 1991; Sims 1994; Woodford 1994, 1995, 2001; Cochrane 1998, 2001; Schmitt-Grohe and Uribe 2000; Bassetto 2002; Reis 2016; among many others). Monetary-fiscal policy interaction is modeled based on monetary and fiscal policy rules as in Leeper (1991).

Our work is also related to Woodford (2003) and Benhabib, Schmitt-Grohe, and Uribe (2002) who show that liquidity traps can be made fiscally unsustainable. Furthermore, the shock-specific rule that we investigate shares some features with the policy interventions that Chris Sims advocated at the 2016 Jackson Hole meeting to replace ineffective monetary policy at the zero lower bound (Sims 2016). Concisely, Sims argues that policymakers should make clear that fiscal policy also aims at achieving a certain level of inflation. Unlike Sims' proposal, our shock-specific rule outlines the amount of debt that policymakers are planning to stabilize with inflation and links such amount to one particular event, the fiscal stimulus in response to the COVID-19 pandemic. This is an important distinction that limits the amount of inflation generated by the coordinated policy strategy analyzed in this paper. Once the shock is reabsorbed, the economy naturally reverts back to the pre-crisis policy framework.

Hall and Sargent (2011) show that historically most of US debt stabilization has been achieved through a combination of growth, revaluation effects, and low real interest rates, while changes in primary surpluses played a relatively modest role. Bianchi and Ilut (2017) link the high inflation of the 1970s to a fiscally-led regime in which the monetary authority accommodates the behavior of the fiscal authority. Bianchi and Melosi (2017) argue that the possibility of a return to such regime can explain the lack of deflation in the aftermath of the Great Recession. Leeper, Traum, and Walker (2017) find that monetary-led and fiscally-led regimes return similar fit when a DSGE model is estimated on post-WWII U.S. data. Thus, there is evidence that the post-Volcker monetary-led policy mix characterized by ample central bank independence has not always been the norm. The shock-specific rule studied in this paper can be seen as a way to remove the risk of a *tout court* return to a fiscally-led strategy, in which the monetary authority is required to systematically create inflation to stabilize government debt.[3] Such change would lead to very high levels of inflation and macroeconomic volatility.

Some scholars have recently advocated for *deficit monetization* or *helicopter money* to respond to the dreadful consequences of the pandemic recession (e.g., Galí 2019) In practice, the implementation of the emergency-budget strategy is similar to deficit monetization *commensurate* with the need to stimulate the economy during the COVID-19 pandemic. While the model we used in our analysis is cashless, we could assume that households derive utility from holding money and could expand the government budget constraint to include money growth. In this extended model, the emergency budget would lead to a persistent increase in the money supply to implement the passive monetary policy warranted by the increase in the temporary inflation target. However, the mechanism through which prices rise would be the same as in the cashless model. Whatever happens to money in equilibrium is not necessary to pinpoint the source of inflation, which lies in the agreement between the fiscal and the monetary authorities about how to finance an existing fiscal burden. Money is a tool, and its equilibrium behavior that is consistent with a given policy mix can be made explicit and traced, with no consequences for the equilibrium dynamics.

In this paper, we analyzed the effects of an immediate change to the fiscally-led policy mix, resulting in a sudden jump in inflation. The large increase in inflation could also materialize more gradually if agents slowly revise their expectations about the ability of the fiscal authority to stabilize debt. In that case, inflation could experience a run-up and accelerating behavior similar to what was observed in the 1970s (Bianchi and Melosi 2013).

The paper is organized as follows. Section 2 makes use of a stylized model to illustrate that unfunded government debt may lead to a rise in the inflation rate. In Section 3, we

[3]See Bassetto (2002) for a seminal study of the game theoretical aspects of the interaction between the monetary and fiscal authorities.

present a full-fledged, quantitative model. In Section 4 we explain how their parameters are estimated. Section 5 focuses on the unpleasant trade-off between persistent stagnation and heightened macroeconomic volatility that arises after the pandemic recession. In Section 6, we explain how the introduction of an emergency budget along with the introduction of an asymmetric inflation target can mitigate this trade-off. In Section 7, we show the point of contact of the strategy we call Emergency Budget with the literature on helicopter money. Section 8 contains our concluding remarks.

2 Fiscal Inflation in DSGE Models

Let us consider the simplest DSGE model to show that unfunded government debt may lead to inflation (Leeper 1991 and Sims 1994 and 2016). The economy is populated by a continuum of infinitely many households and a government. The representative household has concave and twice continuously differentiable preferences over non-storable consumption goods and is endowed each period with a constant quantity of these goods. The government issues one-period debt (liabilities) B_t to households who can trade them for consumption goods. There is no government spending. The representative household chooses consumption and government bonds so as to maximize:

$$\max \sum_{t=0}^{\infty} \beta^t U\left(C_t\right),$$

subject to the flow budget constraint

$$P_t C_t + Q_t B_t + P_t \tau_t = P_t Y + B_{t-1}, \tag{1}$$

where $\beta < 1$ is the households' discount factor, P_t denotes the price of consumption goods, Y is the fixed endowment of consumption goods, and τ_t denotes lump-sum taxes (in real terms). Government liabilities have purchase price $Q_t < 1$.

The government receives taxes $P_t \tau_t$ from households that are used to repay its maturing liabilities B_{t-1}. In symbols, the government budget constraint reads as follows:

$$Q_t B_t + P_t \tau_t = B_{t-1}. \tag{2}$$

Since there is no government spending, τ_t can be interpreted as the primary real surplus for the government. At this stage, we assume that the sequence of real primary surpluses and debt $\{\tau_t, B_t\}$ is deterministic and perfectly known by households.

Market clearing requires $C_t = Y$ in every period and the households' Euler equation implies the Fisher equation:

$$Q_t = \beta \frac{P_t}{P_{t+1}}. \tag{3}$$

We linearize the equations of the model around its steady-state equilibrium. Henceforth, hatted variables denote variables in deviation from their steady-state value.[4]

We linearize the government budget constraint (2) and obtain

$$\hat{b}_t = r_* \hat{b}_{t-1} - \hat{\tau}_t - b_* r_* \hat{\pi}_t + b_* \hat{\imath}_t, \tag{4}$$

where $\hat{b}_t$ denotes the deviations of *real* debt from its steady-state value. b_* is the steady-state real value of debt, which is normalized to unity, $r_* = \beta^{-1}$ denotes the real interest rate at steady state, and $\hat{\imath}_t = -\hat{Q}_t$ denotes the nominal returns to government bonds in deviations from its steady-state value (Q_*^{-1}.)

The Fisher equation is linearized and becomes:

$$\hat{\imath}_t = E_t \hat{\pi}_{t+1}. \tag{5}$$

We assume that the monetary authority controls the nominal interest rate on government bonds $i_t = Q_t^{-1}$ by using the rule $\hat{\imath}_t = \phi \hat{\pi}_t$, where the parameter ϕ governs how strongly the monetary authority responds to inflation.

The fiscal authority applies the following fiscal rule (expressed in real terms): $\hat{\tau}_t = \gamma \hat{b}_{t-1}$. Note that the parameter γ determines how strongly the fiscal authority adjusts primary surplus to fluctuations in its debt.

Plugging the monetary rule into the linearized Fisher equation leads to the following equation that describes the monetary block of this economy:

$$E_t \hat{\pi}_{t+1} = \phi \hat{\pi}_t. \tag{6}$$

We will refer to this equation as the *monetary block.*

Combining the linearized law of motion for the real debt with the fiscal rule yields

$$\hat{b}_t = \left(\beta^{-1} - \gamma\right) \hat{b}_{t-1} - b_* \beta^{-1} \hat{\pi}_t + b_* \hat{\imath}_t. \tag{7}$$

We will refer to equation (7) as the *fiscal block.*

The stability condition of the debt-to-output ratio depends on the terms in the brackets

[4] The fiscal variables B_t and τ_t are linearized around their steady state value whereas the other variables are log-linearized. The reason is that the value of fiscal variables can be negative.

of equation (7) and requires the government's response γ to be stronger than a threshold (specifically, $\gamma > \beta^{-1} - 1$). If the central bank satisfies the Taylor principle ($\phi > 1$), the monetary block becomes unstable. Higher inflation maps into even higher expectations of next period's inflation. Thus, the only stable Rational Expectations equilibrium is the one in which inflation expectations are anchored; that is, $E_t \hat{\pi}_{t+1} = 0$ all the time.

A corollary of this result is that if the government adjusts surpluses to stabilize debt, inflation is completely insulated from the fiscal block and fiscal imbalances are irrelevant for inflation determination in equilibrium (*Monetary and Fiscal Dichotomy*).[5]

If fiscal policy is non-Ricardian (i.e., $\gamma \leq \beta^{-1} - 1$), the fiscal authority is no longer committed to keep the debt-to-output ratio on a stable path and no stationary REE exists.[6] However, if the central bank forgoes its commitment to stabilize inflation by abandoning the Taylor principle ($\phi \leq 1$), inflation is now the variable that can adjust in equation (7) to keep government debt on a stable path. To see this, note that passive monetary policy makes the monetary block stable. Now inflation expectations are unanchored, meaning that $E\hat{\pi}_{t+1}$ does not have to be zero all the time to ensure the stability of the monetary block. It is the unstable fiscal block that now provides discipline to inflation expectations. The discipline comes from the need to stabilize government debt. Hence, if the monetary authority does not apply the Taylor principle, non-Ricardian fiscal policies can be compatible with a unique stable REE equilibrium.

However, the properties of this equilibrium for the dynamics of inflation are radically different from the other equilibrium where the Monetary and Fiscal Dichotomy holds. This is because the nature of the anchoring of inflation expectations is totally different. In fact, under passive monetary policy and non-Ricardian fiscal policy, inflation is determined in equilibrium by the need of stabilizing the government debt. Consequently, debt accumulation will affect inflation as well as all the other model's variables in equilibrium. This property holds in more sophisticated DSGE models as well.

3 The Model

We extend a version of the medium-scale general equilibrium model estimated by Leeper, Traum, and Walker (2017) to account for shock-specific rules along the lines of Bianchi and Melosi (2019). Namely, the environment consists of an economy a la Christiano, Eichenbaum, and Evans (2005), augmented with distortionary taxes on labor, capital and consumption, and a rich fiscal block. With respect to a typical model, both monetary and fiscal policy rules

[5] Leeper (1991) calls non-Ricardian fiscal policy rules passive fiscal policy rules.
[6] Leeper (1991) calls non-Ricardian fiscal policy rules active fiscal policy rules.

are specified with respect to a regular budget and an emergency budget. In what follows, we outline the model in detail.

3.1 Households

The economy is populated by a unit measure of households, of which a fraction μ are hand-to-mouth consumers. The remaining fraction, $1-\mu$, are savers and we indicate them with an S superscript. Hand-to-mouth households are assumed in the model as a simple way of breaking the Ricardian equivalence, making transfers relevant for a fraction of the population.

Savers A household of optimizing saving agents, indexed by j, derives utility from the consumption of a composite good, $C_t^{*S}(j)$, which comprises private consumption $C_t^S(j)$ and government consumption G_t such that $C_t^{*S}(j) = C_t^S(j) + \alpha_G G_t$. The parameter α_G governs the substitutability between private and government consumption. When negative, the goods are complements; when positive, they are substitutes. External habits in consumption imply that utility is derived relative to the previous period value of aggregate savers' consumption of the composite good θC_{t-1}^{*S}, where $\theta \in [0,1]$ is the habit parameter. Saver households also derive disutility from the supply of differentiated labor services from all its members, indexed by l, $L_t^S(j) = \int_0^1 L_t^S(j,l)\,dl$. The period utility function is given by $\mathcal{U}_t^S = u_t^b \left(\ln\left(C_t^{*S}(j) - \theta C_{t-1}^{*S}\right) - L_t^S(j)^{1+\xi} / (1+\xi) \right)$, where u_t^b is a discount factor shock and ξ is the Frisch elasticity.

Households accumulate wealth in the form of physical capital $\bar{K}_t^S$. The stock of capital depreciates at rate δ and accrues with investment I_t^S, net of adjustment costs. The law of motion for physical capital is: $\bar{K}_t^S(j) = (1-\delta)\bar{K}_{t-1}^S(j) + u_t^i \left[1 - s\left(\frac{I_t^S(j)}{I_{t-1}^S(j)}\right)\right] I_t^S(j)$, where u_t^i is a shock to the marginal efficiency of investment and s denotes a standard investment adjustment cost function that satisfies the properties $s(e^\gamma) = s'(e^\gamma) = 0$ and $s''(e^\gamma) \equiv s > 0$.

Households derive income from renting effective capital $K_t^S(j)$ to the intermediate firms. Effective capital is related to physical capital according to $K_t^S(j) = \nu_t(j)\bar{K}_{t-1}^S(j)$, where $\nu_t(j)$ is the capital utilization rate. The cost of utilizing one unit of physical capital is given by the function $\Psi(\nu_t(j))$. Given the steady-state utilization rate $\nu(j) = 1$, the function Ψ satisfies the following properties: $\Psi(1) = 0$, and $\frac{\Psi''(1)}{\Psi'(1)} = \frac{\psi}{1-\psi}$, where $\psi \in [0,1)$. We further denote the gross rental rate of capital as R_t^k and the tax rate on capital rental income as τ_t^K.

The household can also invest in the financial market by purchasing two types of zero-coupon bonds which differ in their maturity. One-period bonds promising a nominal payoff $B_{s,t}$ at time $t+1$ can be purchased at the present discounted value $R_t^{-1}B_{s,t}$, where R_t is the gross nominal interest rate set by the central bank. Long-term government bond B_t with a maturity decaying at a constant rate $\rho \in [0,1]$ and duration $(1-\beta\rho)^{-1}$, can be purchased at price P_t^B.

Each period, the household receives after-tax nominal labor income, after-tax revenues from renting capital to the firms, lump-sum transfers from the government Z_t^S and dividends from the firms D_t. These resources can be spent to consume and to invest in physical capital and bonds. The nominal budget constraint for the saver household is:

$$\begin{aligned} & P_t\left(1-\tau_t^C\right) C_t^S(j)+P_t I_t^S(j)+P_t^B B_t(j)+R_t^{-1} B_{s,t} \\ = & \left(1+\rho P_t^B\right) B_{t-1}(j)+B_{s,t-1}(j)+\left(1-\tau_t^L\right) \textstyle\int_0^1 W_t(l) L_t^S(j,l)\, dl \\ & +\left(1-\tau_t^K\right) R_t^k \nu_t(j) \bar{K}_{t-1}^S(j)-\psi\left(\nu_t\right) \bar{K}_{t-1}^S(j)+P_t Z_t^S(j)+D_t(j), \end{aligned} \tag{8}$$

where $W_t(l)$ denotes the wage rate that applies to all household members, and τ_t^C and τ_t^L denote the tax rates on consumption and labor income, respectively. The household maximizes lifetime discounted utility $\sum_{t=0}^{\infty} \beta^t \mathcal{U}_t^S$ subject to the sequence of budget constraints in equation (8).

Hand-to-mouth households Every period, hand-to-mouth households consume all of their disposable, after-tax income, which comprises revenues from labor supply and government transfers. It is assumed that the hand-to-mouth households supply differentiated labor services, and set their wage to be equal to the average wage that is optimally chosen by the savers, as described below. Using the superscript N to indicate the non-saving, hand-to-mouth households, their budget constraint can be written as follows:

$$\left(1+\tau_t^C\right) P_t C_t^N(j)=\left(1-\tau_t^L\right) \int_0^1 W_t(l) L_t^N(j,l)\, dl+P_t Z_t^N(j),$$

where it is assumed that both savers and non-savers face the same tax rates on consumption and labor income.

3.2 Firms and Price Setting

Final good producers A perfectly competitive sector of final good firms produces the homogeneous good Y_t at time t by combining a unit measure of intermediate differentiated inputs using the technology $Y_t=\left(\int_0^1 Y_t(i)^{\frac{1}{1+\eta_t^p}} di\right)^{1+\eta_t^p}$, where η_t^p denotes an exogenous mark-up shock to the prices of intermediate goods.. Profit maximization yields the demand function for intermediate goods $Y_t(i)=Y_t\left(P_t(i)/P_t\right)^{-\left(1+\eta_t^p\right)/\eta_t^p}$, where $P_t(i)$ is the price of the differentiated good i and P_t is the aggregate price of the final good.

Intermediate good producers Intermediate firms produce using the technology $Y_t(i) = K_t(i)^{\alpha}(A_t L_t(i))^{1-\alpha} - A_t\Omega$, where Ω is a fixed cost of production that grows with the rate of labor-augmenting technological progress A_t.and $\alpha \in [0,1]$ a parameter. It is assumed that technological progress A_t follows an exogenous process that is stationary in the growth rate. Specifically, we assume that $u_t^a = (1-\rho_a\gamma) + \rho_a u_{t-1}^a + \varepsilon_t^a$, where γ is a drift parameter capturing the logarithm of the rate of technology growth in steady state. Intermediate firms rent capital and labor in perfectly competitive factor markets. It is assumed that L_t is a bundle of all the differentiated labor services supplied in the economy, which are aggregated into a homogeneous input by a labor agency, as described below. The nominal rental rate of capital is denoted by R_t^K and the wage rate by W_t. Cost minimization implies that all firms incur the same nominal marginal cost $MC_t = (1-\alpha)^{\alpha-1}\alpha^{-\alpha}\left(R_t^k\right)^{\alpha} W_t^{1-\alpha} A_t^{-1+\alpha}$.

When setting prices, intermediate producers face frictions *à la* Calvo, i.e., at time t a firm i can optimally reset its price with probability ω^p. Otherwise it adjusts the price with partial indexation to the previous period inflation rate according to the rule $P_t(i) = (\Pi_{t-1})^{\chi_p}(\Pi)^{1-\chi_p} P_{t-1}(i)$, where $\chi_p \in [0,1]$ is a parameter, $\Pi_{t-1} = \frac{P_{t-1}}{P_{t-2}}$ and Π denotes the aggregate rate of inflation at steady state.

Intermediate producers that are allowed to reset their price maximize the expected discounted stream of nominal profits:

$$\max E_t \sum_{s=0}^{\infty} (\beta\omega_p)^s \frac{\Lambda_{t+s}^S}{\Lambda_t^S}\left[\left(\prod_{k=1}^{s} \Pi_{t+k-1}^{\chi^p}\Pi^{1-\chi^p}\right) P_t(i) Y_{t+s}(i) - MC_{t+s} Y_{t+s}(i)\right]$$

subject to the demand function of the final good sector, where Λ^S denotes the marginal utility of the savers.

3.3 Wages

We assume that both savers and hand-to-mouth households are monopoly suppliers of a unit measure of differentiated labor service, indexed by l. Each period, a saver household gets an opportunity to optimally readjust the wage rate that applies to all of its workers, $W_t(l)$, with probability ω_w. If the wage cannot be reoptimized, it will be increased at the geometric average of the steady-state rate of inflation Π and of last period inflation Π_{t-1}, according to the rule $W_t(l) = W_{t-1}(l)(\Pi_{t-1}e^{\gamma})^{\chi_w}(\Pi e^{\gamma})^{1-\chi_w}$, where $\chi_w \in [0,1]$ captures the degree of nominal wage indexation. It is assumed that the hand-to-mouth households set their wage to be equal to the average wage that is optimally chosen by the savers.

All households, including both savers and non-savers, sell their labor service to a representative, competitive agency that transforms it into an aggregate labor input, according to the technology $L_t = \left(\int_0^1 L_t\left(l\right)^{\frac{1}{1+\eta_t^w}} dl\right)^{1+\eta_t^w}$, where η_t^w is an exogenous wage mark-up shock. The agency rents labor type $L_t\left(l\right)$ at price $W_t\left(l\right)$ and sells a homogeneous labor input to the intermediate producers at price W_t. The static profit maximization problem yields the demand function $L_t\left(l\right) = L_t\left(W_t\left(l\right)/W_t\right)^{-\left(1+\eta_t^w\right)/\eta_t^w}$.

3.4 Government Budget Constraint

Assuming that one-period government bonds are in zero net supply, the government nominal budget constraint can be written as:

$$P_t^B B_t + \tau_t^K R_t^k K_t + \tau_t^L W_t L_t + \tau_t^C P_t C_t = \left(1 + \rho P_t^B\right) B_{t-1} + P_t G_t + P_t Z_t, \tag{9}$$

where $C_t = \mu C_t^N + \left(1-\mu\right) C_t^S$ denotes aggregate consumption and $Z_t = \int_0^1 Z_t\left(j\right) dj = Z^S = Z^N$, following the assumption that lump-sum transfers are identical across households. The budget constraint in equation (9) implies that the fiscal authority finances government expenditures, transfers, and the rollover of expiring long-term debt by raising taxes on consumption, labor and capital, and by issuing new long-term debt obligations.

3.5 Monetary and Fiscal Policy

We rescale the variables entering the fiscal rules by defining $g_t = G_t/A_t$, $z_t = Z_t/A_t$ and we denote the debt-to-GDP ratio as the market value of outstanding debt divided by GDP $s_{b,t-1} = \frac{P_{t-1}^B B_{t-1}}{P_{t-1} Y_{t-1}}$. In what follows, for each variable x, we use $\widehat{x}$ to denote the percentage deviation from its own steady state.

We consider two cases. In the *Fiscal Orthodoxy* case, the fiscal authority is committed to repay the entirety of public debt with future fiscal adjustments and the monetary authority is engaged in responding aggressively to deviations of inflation from its fixed target. In the *Fiscal Inflation* case, the monetary authority gives in to the temptation of correcting the large fiscal imbalance with higher inflation.

Fiscal Orthodoxy Under fiscal orthodoxy, the fiscal authority adjusts government spending $\hat{g}_t$, transfers $\hat{z}_t$, and tax rates on capital income, labor income, and consumption $\hat{\tau}^J$, $J \in \{K, L, C\}$ as follows:

$$\hat{g}_t = \rho_G \hat{g}_{t-1} - \left(1-\rho_G\right)\ \gamma_G \hat{s}_{b,t-1} + u_t^G, \tag{10}$$

$$\hat{z}_t = \rho_Z \hat{z}_{t-1} - \left(1-\rho_Z\right)\ \gamma_Z \hat{s}_{b,t-1} + u_t^Z, \tag{11}$$

$$\hat{\tau}_t^J = \rho_J \hat{\tau}_{t-1}^J + (1-\rho_J)\ \gamma_J \hat{s}_{b,t-1} + u_t^J, \tag{12}$$

where $\hat{s}_{b,t-1}$ denotes the debt-to-GDP ratio, $u_t^s = \rho_{es} u_{t-1}^s + \varepsilon_t^s$, for $s = G, Z, J$ and $\varepsilon_t^s \sim N(0, \sigma_s^2)$. The fiscal authority is credibly committed to repay its obligations by raising taxes and cutting expenditures and this behavior is captured by the values for the reaction parameters γ_G, γ_Z, and $\gamma_J^* > 0$ that are consistent with Ricardian fiscal policy.

Under fiscal orthodoxy, the central bank is fully committed to respond strongly to inflation deviations from its *fixed* target $\hat{\pi}_t = \ln \frac{\Pi_t}{\Pi^*}$ with the nominal rate of interest, $\hat{R}_t$, on one-period bond. It follows the Taylor interest-setting rule with a non-negative constraint:

$$\hat{R}_t = \max\left[-\ln R_\star, \rho_r \hat{R}_{t-1} + (1-\rho_r)\left[\phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t\right]\right] + u_t^m.$$

where u_t^m is a monetary policy shock and the parameter $\phi_\pi > 1$ so that the Taylor principle is satisfied and monetary policy is active.

Fiscal Inflation In the second case, which we call Fiscal Inflation, policymakers believe that the fiscal adjustment needed to stabilize the large stock of debt is too costly for the economy and decide to resort to inflation to correct the large fiscal imbalance. To model this case, we set all the policy reaction parameters γ_G, γ_Z, and γ_J $J \in \{K, L, C\}$ to zero. This parameterization corresponds to a mix of passive monetary policy and non-Ricardian fiscal policy. Note that in this case the central bank abandons the objective of stabilizing inflation to endorse the objective of correcting the fiscal imbalance. This endorsement along with the fiscal authority disregarding the stock of debt brings about fiscal inflation for the reason discussed in the stylized model analyzed in Section 2.

Zero Lower Bound (ZLB) Constraint and Model Solution The model is log-linearized around the steady state (transfers and primary surplus are linearized). The zero lower bound constraint introduces a nonlinearity that prevents us from solving the model with standard solution methods. We develop a novel method to find the certainty-equivalence solution to these temporarily non-linear dynamics. Our method does not require us to assume that agents in the model have perfect foresight. Agents update their rational expectations about the duration of the zero lower bound over time after having observed past and current shocks.

Our method relies on appending a sequence of anticipated shocks (dummy shocks) to the unconstrained Taylor rule. Anticipated shocks are known by agents in the current period, but these shocks will hit the economy in future periods. The sequence of these shocks is computed so as to ensure that agents expect that the zero lower bound constraint will be satisfied for the next 60 quarters in every period.[7] When the constraint is never expected to become binding, these anticipated shocks are set to zero. Obviously, these shocks will have an effect on the expected duration of the ZLB and hence on equilibrium outcomes, requiring us to solve a fixed-point problem, as described in Faccini and Melosi (2020). This fixed-point problem does not turn out to be time consuming or computationally challenging in practice.

4 Calibration

The model is calibrated to the U.S. economy at quarterly frequency, relying largely on the estimates by Leeper, Traum, and Walker (2017) over the period 1955Q1 through 2014Q2. Calibrated parameter values, along with their description and source, are reported in Table 1. Starting with the parameters that characterize household preferences, we follow Leeper, Traum, and Walker (2017) in setting the inverse Frish elasticity ξ to 1.77, the external habit parameter θ to 0.99 and the coefficient governing the substitutability between private and public consumption α^G to -0.24. The discount factor β is set to 0.999 in order to match a real interest rate of 1.1%. We follow Kaplan, Violante, and Weidner (2014) and we set the share of hand-to-mouth households μ to match the poor hand-to-mouth consumers 0.11.[8]

The values of all parameters governing technology and the frictions in price and wage setting are also taken from Leeper, Traum, and Walker (2017). Namely, with regards to the technological parameters, the steady-state quarterly growth rate of technology $100 * e^{\gamma}$ is set to 0.25, the steady-state inflation rate is set to be equal to zero ($\Pi^* = 1$), the elasticity of output to capital in the production function α takes the value of 0.33, the rate of capital depreciation δ is set to 0.025, and the parameters governing the convexity of the investment adjustment cost function and of the capital utilization cost function are set to 5.46, and 0.16, respectively. As for the parameters related to the pricing frictions, the Calvo parameters for prices and wages are set to 0.92 and 0.91, respectively, the steady-state markups are both set to 0.14, and the parameters governing indexation are set to 0.06 for prices and 0.18 for wages, respectively.

Steady-state fiscal variables are also implied by the same parameterization as in Leeper, Traum, and Walker (2017). Specifically, the decay rate of the maturity of long-term bonds, ρ, is set to 0.9593 to match an average duration of six years estimated by the Congressional

[7]In none of the periods of our sample, the zero lower bound constraint binds for more than 36 months in expectation. If it did, we would need to add more anticipated shocks to the Taylor rule so as to cover a horizon longer than 36 months.

[8]As shown in that paper, including the wealthy hand-to-mouth consumers, who are people owning illiquid assets and short of cash, would increase this parameter to 0.33%. Results would not qualitatively change if we used this larger number.

Calibration			
Parameters	Description	Value	Target/source
Preferences			
β	Discount factor	0.999	Real rate 1.4%. (FOMC SEP)
ξ	Inverse Frisch elasticity	1.770	Leeper et al. (2017)
θ	Habit formation	0.990	Leeper et al. (2017)
α^G	Substitutability of private vs. gov. consumption	-0.240	Leeper et al. (2017)
Frictions and technology			
100γ	Steady-state log growth rate of technology	0.250	Leeper et al. (2017)
μ	Share of hand-to-mouth households	0.11	Kaplan et al. (2014)
α	Elasticity in production function	0.330	Leeper et al. (2017)
δ	Capital depreciation rate	0.025	Leeper et al. (2017)
s	Investment adjustment cost	5.460	Leeper et al. (2017)
	Capital utilization cost	0.160	Leeper et al. (2017)
ω_p	Price Calvo parameter	0.920	Leeper et al. (2017)
ω_w	Wage Calvo parameter	0.910	Leeper et al. (2017)
χ_p	Price indexation	0.060	Leeper et al. (2017)
χ_w	Wage indexation	0.180	Leeper et al. (2017)
η_p	Price markup	0.140	Leeper et al. (2017)
η_w	Wage markup	0.140	Leeper et al. (2017)
Monetary authority			
ϕ_π	Interest rate response to inflation	2.000	See Section 4
ϕ_y	Interest rate response to output	0.100	See Section 4
ρ_r	Interest rate smoothing	0.710	Leeper et al. (2017)
Fiscal authority			
ρ	Debt maturity decay rate	0.959	CBO (2020)
τ^L	Steady-state tax rate on labor	0.186	Leeper et al. (2017)
τ^K	Steady-state tax rate on capital	0.218	Leeper et al. (2017)
τ^C	Steady-state tax rate on consumption	0.023	Leeper et al. (2017)
ρ_i	Persistence of G, and tax rates $i = G, K, L$	0.980	Estimated
ρ_Z	Persistence of transfers rule	0.500	Calibrated
γ_G	Debt response with G	0.190	Calibrated
γ_Z	Debt response with transfers	0.190	Calibrated
γ_i	Debt response, for $i = \tau^K, \tau^L$	0.190	Calibrated
γ_C	Debt response with consumption taxes	0.000	See Section 4
Steady-state calibration targets			
s_{gc}	Government expenditures to GDP ratio	0.110	Leeper et al. (2017)
s_b	Debt to annualized GDP ratio	0.600	

Table 1: Calibrated values for model parameters and steady-state targets.

Budget Office (2020). We also assume a steady-state debt to GDP ratio of 60% (240% with respect to quarterly GDP). This number is above the historical average. The conclusions of our paper would not be affected by lower values because the emergency budget does not apply to the pre-existing debt. The share of government consumption in GDP is set to the value of 0.11. The steady-state tax rates on capital, labor and consumption are set to 0.218, 0.186 and 0.023, respectively.

Moving to the coefficients that characterize the behavior of the monetary authority, we set the interest rate response to inflation in the monetary regime ϕ_π to the conventional value

Calibration of shocks			
Parameters	Description	Value	Target/source
Standard deviations			
σ_a	Technology	1.05	Leeper et al. (2017)
σ_b	Discount factor	81.88	Leeper et al. (2017)
σ_m	Monetary policy	0.22	Leeper et al. (2017)
σ_i	Efficiency of investment	0.75	Leeper et al. (2017)
σ_w	Wage markup	0.35	Leeper et al. (2017)
σ_p	Price markup	0.09	Leeper et al. (2017)
σ_{gc}	Government consumption	1.83	Leeper et al. (2017)
σ_z	Transfers	3.20	Leeper et al. (2017)
Autocorrelation			
ρ_a	Technology	0.23	Leeper et al. (2017)
ρ_b	Discount factor	0.40	Leeper et al. (2017)
ρ_m	Monetary policy	0.70	Leeper et al. (2017)
ρ_i	Efficiency of investment	0.69	Leeper et al. (2017)
ρ_w	Wage markup	0.18	Leeper et al. (2017)
ρ_p	Price markup	0.74	Leeper et al. (2017)
ρ_{gc}	Government consumption	0.98	Leeper et al. (2017)
ρ_z	Transfers	0.00	Leeper et al. (2017)

Table 2: Calibrated values for model parameters and steady-state targets.

of 2, the response to output ϕ_y to 0.1 and the smoothing coefficient ρ_r to 0.71 as estimated by Leeper, Traum, and Walker (2017).

The debt responses of transfers, as well as capital and income tax rates, γ_Z, γ_K, and γ_L, are set so as to drive the debt-to-GDP ratio to its steady-state value of 60% in twenty years in the case of fiscal orthodoxy in the post-COVID-19 scenario, which is analyzed in the next section. In doing this, we assume that the adjustment (in deviation from the steady-state value) to achieve this objective is the same across these three fiscal tools. This yields a coefficient for γ_Z, γ_K, and γ_L equal to 0.19. The response of government consumption to the evolution of the debt-to-GDP ratio, γ_G, is set to equal the value estimated by Leeper, Traum, and Walker (2017). The consumption tax rate τ_t^C is assumed to be constant, so the coefficient γ_C is set to zero. We estimate the serial correlation coefficients in the fiscal rule using the time series constructed by Leeper, Traum, and Walker (2017) and described in their online appendix.

Finally, the persistence and the standard deviation of all the shocks are set following the estimates in Leeper, Traum, and Walker (2017) as reported in Table 2.

5 Post-COVID-19 Scenario

We use the model to show that in the post-pandemic period policymakers might face a trade-off between economic stagnation and heightened macroeconomic instability. The former scenario might arise if the private sector expects the policymakers to make the necessary fiscal adjustments to correct the large post-pandemic fiscal imbalance estimated by the Congressional Budget Office (CBO). The latter scenario might materialize if policymakers will give in to the temptation of correcting the large fiscal imbalance with higher inflation.

To illustrate this trade off, we initialize the model economy at its steady-state equilibrium with the only exception of government debt, which is set so that the debt-to-output ratio is 120% after the Pandemic Recession. We consider two cases that differ in how the monetary and fiscal authorities intend to deal with this large debt.

In the first case, which we call *Fiscal Orthodoxy*, the government remains credibly committed to carry out the massive fiscal adjustments needed to stabilize its debt in the future. This can be modeled by restricting the values for the fiscal authority's reaction parameters γ_g, γ_z, γ_L, and γ_K to be Ricardian; that is, to satisfy the stability condition of the debt-to-output ratio Specifically, we set these rates to 0.19, which ensure the large stock of debt is stabilized in 20 years.[9] This strong commitment by the fiscal authority allows the monetary authority to effectively stabilize inflation around its target by applying the Taylor principle (i.e., $\phi_\pi > 1$). Specifically, we set $\phi_\pi = 2$.

In the second case, which we call *Fiscal Inflation*, policymakers believe that the fiscal adjustment needed to stabilize the large stock of debt is too costly for the economy and decide to resort to inflation to correct the large fiscal imbalance. To model this case, we set all the policy reaction parameters γ_g, γ_z, γ_L, and γ_K and ϕ_π to zero. This parameterization corresponds to a mix of passive monetary policy and non-Ricardian fiscal policy. Note that in this case the central bank abandons the objective of stabilizing inflation to endorse the objective of correcting the fiscal imbalance.[10]

This post-COVID scenario is shown in Figures 1 and 2. Figure 1 shows the dynamics of the fiscal variables. In the case of Fiscal Inflation, the debt-to-GDP ratio contracts as the policymakers embrace this policy that spurs a sudden rise in the inflation rate, as shown in Figure 2. In the case of Fiscal Orthodoxy instead, the debt-to-GDP ratio remains persistently elevated for the first few quarters, as fiscal adjustments are delayed. However, when fiscal consolidation begins, the debt-to-GDP ratio improves at a faster pace than in the case of Fiscal Inflation. The entity of the fiscal adjustments is also shown in Figure 1. In the case of Fiscal Inflation, tax rates, government spending, and transfers do not vary. Because GDP rises, consumption and government spending fall when expressed as a fraction of GDP, as

[9] I set these parameter values so that the government debt is back to its its long-run level, which I assume to be 60%.

[10] The case in which the central bank does not cooperate with the fiscal authority and refuses to endorse the new objective is studied by Bianchi and Melosi (2019) and will be briefly discussed at the end of this section.

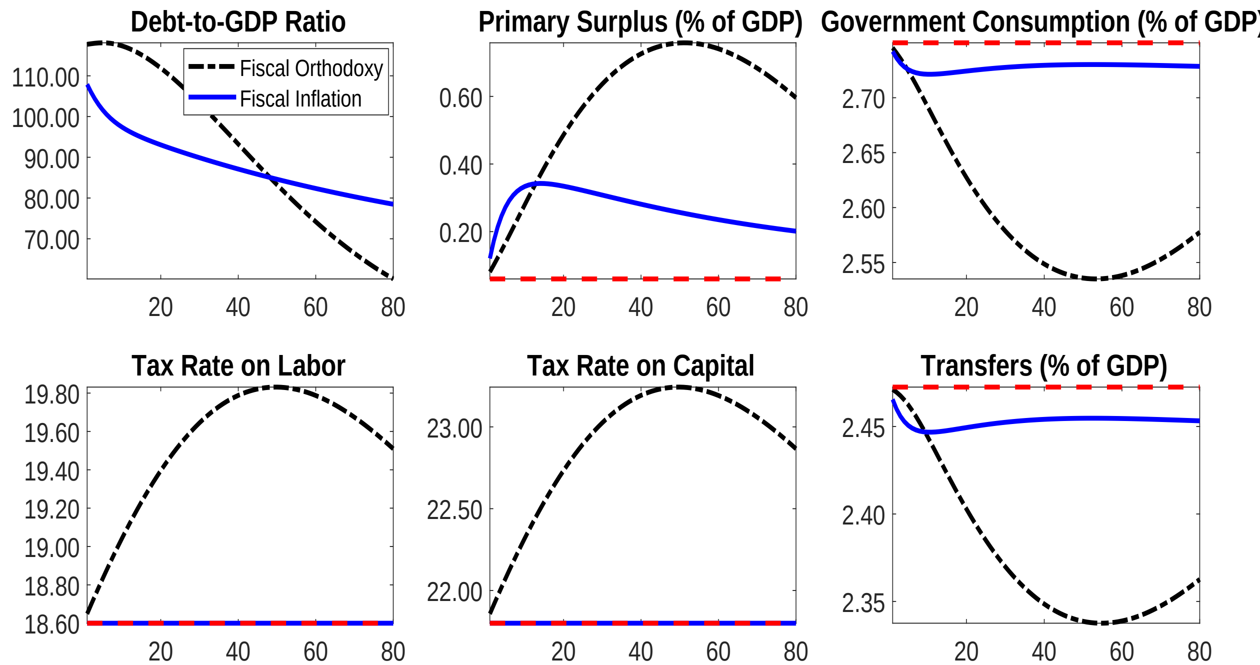

Figure 1: Post-COVID-19 Recession Scenario. Fiscal aggregates in the case of Fiscal Orthodoxy is adopted and in the case Fiscal Inflation is adopted. Debt-to-GDP ratio is total nominal debt at the end of the quarter divided by the annualized GDP in the quarter. Primary surplus, goverment consumption, and transfers are expressed as percentage of GDP. The periods on the x-axis are quarters.

shown in Figure 1. In the case of Fiscal Orthodoxy instead, the fiscal authority slowly but steadily raises tax rates and decreases both government spending and transfers over the next 15 years, so as to stabilize the debt-to-GDP ratio. In particular, transfers reduce sharply in the case of Fiscal Orthodoxy, making a dramatic impact on the consumption decisions of the non-savers. Concurrently, the increase in the distortionary tax rates on labor and capital income negatively affect the consumption of the savers.

Figure 2 shows that if policymakers stick to Fiscal Orthodoxy to manage the post-COVID-19 situation, the expectations of future fiscal adjustments weigh considerably on economic activity for the next 20 years. This outcome is shown by the black dashed-dotted line. The model predicts that the level of GDP will stay 1.0 percent below its long-run trend on average for the next ten years. It also predicts that the economy will lose cumulatively 57.50 percentage points of GDP during the 20-year-long period of fiscal consolidation. Interestingly, the model sees moderately inflationary pressure because the increase in marginal tax rates raises expected marginal costs.

In the case of Fiscal Inflation, inflation suddenly shoots up to almost 5 percent and remains above 3 percent for 20 years, as shown by the solid blue line in Figure 2. The economy's output will stay above potential for a prolonged period of time as the high inflation

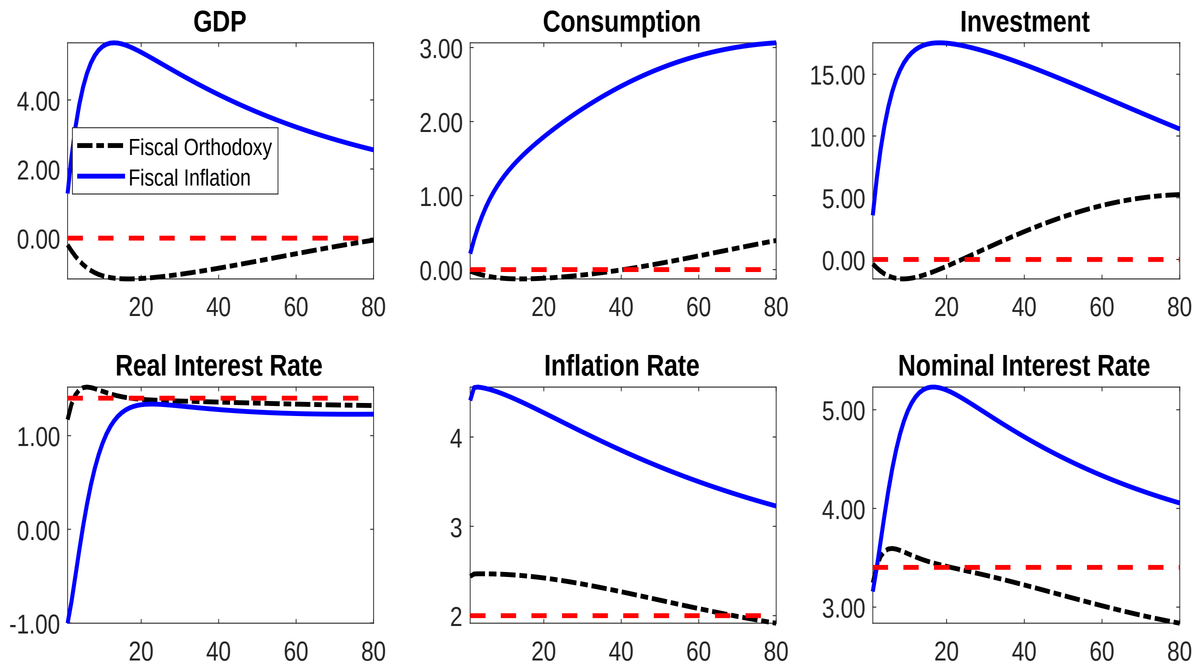

Figure 2: Post-COVID-19 Recession Scenario. Macroeconomic dynamics in the case of Fiscal Orthodoxy is adopted and in the case Fiscal Inflation is adopted. GDP is real output expressed in percentage logdeviations from its stochastic trend. Inflation and the interest rates are expressed in percentage of annualized rates. The periods on the x-axis are quarters.

accommodated by the central bank lowers the real interest rate, boosting consumption and investment.

In sum, Figure 2 shows that a large public debt may lead policymakers to face a trade-off between the crippling effects on economic growth of raising distortionary taxes and the inflationary consequences of the unfunded debt.

It should be noticed that the *deterministic simulations* reported in Figures 1 and 2 are likely to underestimate the real costs of resorting to inflation to correct the large fiscal imbalance. The case of Fiscal Inflation most likely implies an institutional reform that overhauls the objectives assigned to the monetary authority. As shown in Section 2, such structural changes of the monetary and fiscal policy mix significantly alter how shocks propagate in the economy, potentially affecting macroeconomic volatility. Hence, to correctly evaluate the negative consequences of adopting Fiscal Inflation, we need to consider a stochastic environment in which the standard set of business cycle shocks buffet the model economy.

This stochastic exercise shows that resorting to inflation to wear away the large public debt is very costly. As shown in Table 3, the model predicts a drastic increase in macroeconomic volatility with respect to Fiscal Orthodoxy. Indeed, the volatility of inflation almost doubles its size and the volatility of real output becomes almost three times larger than that under Fiscal Orthodoxy. The case of Fiscal Inflation produces such a dramatic impact

	Unconditional Volatility	
	Fiscal Orthodoxy	Fiscal Inflation
Inflation	0.1561	0.2605
Output	0.7641	2.0778

Table 3: Unconditional standard deviation of inflation and output under the assumption that the fiscal and monetary policy mix is monetary led (Fiscal Orthodoxy) and fiscally led (Fiscal Inflation).

on macroeconomic volatility because the monetary authority's objective accommodates all fluctuations in the debt-to-GDP ratio instead of stabilizing inflation and the macroeconomy. While resorting to fiscal inflation allows the fiscal authority to pay off its debt without crippling economic performance, the results in Table 3 suggest that the welfare consequences of this choice might be very serious.

To sum up, we have shown that large and growing fiscal imbalances may bring about an unpleasant trade-off between economic stagnation and heightened macroeconomic instability. In the next section, we study a coordinated monetary and fiscal strategy that mitigates this trade-off by separating the need of stimulating the economy during the pandemic recession from the issue of long-run fiscal sustainability.

The Case of Lack of Coordination So far we have only considered scenarios in which the monetary and fiscal authorities agree on whom should control inflation and act accordingly. However, the private sector may fear the outbreak of an institutional conflict between the monetary and fiscal authority over the control of inflation. This worrying scenario might arise if the fiscal authority's commitment to pay its debt with fiscal instruments weakens in the eyes of the private sector and, at the same time, the central bank explicitly refuses to abandon its objective of inflation stabilization and start raising the interest rate to rein in the fiscal inflation.

6 A Coordinated Strategy to Mitigate the Post-COVID Macroeconomic Trade-Off and Reflate the Economy

In the previous section, we showed that in the post-pandemic period policymakers might face a trade-off between economic stagnation and heightened macroeconomic instability. The former scenario would arise if the private sector expects the policymakers to make the necessary fiscal adjustments to correct the large post-pandemic fiscal imbalance estimated by the Congressional Budget Office (CBO). The latter scenario would instead materialize if policymakers give in to the temptation of correcting the large fiscal imbalance with higher inflation. In this section, we show that a coordinated strategy between the monetary and fiscal authorities ameliorates the trade-off between economic stagnation and heightened macroeconomic instability analyzed in the previous section. Under this coordinated strategy, the fiscal authority runs two separate budgets: a *regular budget* backed by future distortionary fiscal adjustments and an *emergency budget* needed to combat the pandemic recession. Crucially, no provision is made on how this emergency budget will be balanced. The monetary authority temporarily raises its inflation target to clarify it will tolerate inflation above its long-run two-percent objective for some time.

Modeling the Pandemic Recession We initialize the model's debt-to-GDP ratio to match the CBO estimate for the fiscal year 2019. The other model's variables are assumed to be at steady state at the beginning of the simulation exercise. We model the COVID shock using a combination of shocks to the discount factor and to the marginal efficiency of investment. We set the value of these shocks so as to get a fall in real GDP of about 6 percent within the first four quarters under the benchmark case of Fiscal Orthodoxy.[11] We set the persistence of these shocks to 0.25 so that the model predicts a sharp contraction in GDP in the first two quarters, followed by a recovery. At the same time, we calibrate the positive shock to transfers, ε_t^Z, so as to match an increase in transfers of \$2.6 trillion, consistently with the official numbers of the CARES package.

The Emergency-Budget Rules Under the emergency budget strategy, the fiscal authority is committed to repay only a fraction of debt $\hat{s}_{b,t}^T < \hat{s}_{b,t}$ by raising taxes and cutting expenditures. No provision is made about how the residual part of debt, $\hat{s}_{b,t} - \hat{s}_{b,t}^T$, the emergency budget, will be stabilized:

$$\hat{g}_t = \rho_G \hat{g}_{t-1} - (1-\rho_G)\,\gamma_G \hat{s}_{b,t-1}^T + u_t^G, \tag{13}$$

$$\hat{z}_t = \rho_Z \hat{z}_{t-1} - (1-\rho_Z)\,\gamma_Z \hat{s}_{b,t-1}^T + +u_t^Z, \tag{14}$$

$$\hat{\tau}_t^J = \rho_J \hat{\tau}_{t-1}^J + (1-\rho_J)\,\gamma_J \hat{s}_{b,t-1}^T + u_t^J, \tag{15}$$

where $J \in \{K, L, C\}$. The parameters $\gamma_G > 0$, $\gamma_Z > 0$, and $\gamma_J > 0$ are consistent with Ricardian fiscal policy. The restrictions on these parameters imply that the government is committed to raise enough fiscal resources to cover the amount of debt $\hat{s}_{b,t-1}^T$. On the other hand, the fiscal authority is not committed to move primary surpluses to cover the amount of debt exceeding the target amount $\hat{s}_{b,t-1}^T$.

We consider a situation in which the fiscal authority introduces an emergency budget to finance the change in the debt-to-GDP ratio *resulting from the pandemic recession.* This

[11] The *Survey of Professional Forecasters* forecast a contraction in the U.S. real GDP of 5.6% in 2020.

share of debt is abscribed to the emergency budget and is denoted by $\hat{s}_{b,t-1} - \hat{s}^T_{b,t-1}$ in the emergency-budget rules (13)-(15). The target debt $\hat{s}^T_{b,t-1}$ denotes the debt-to-output ratio that would have arisen if the COVID-19 pandemic never happened. This counterfactual debt-to-output ratio is pinned down by introducing a shadow or parallel economy, which is characterized by the same set of equations as the actual model economy except for (i) the shadow economy is not affected by the two shocks that caused the pandemic recession (i.e., the discount factor shocks and the shock to the marginal efficiency of investment); (ii) it is not affected by the fiscal stimulus, captured by the shock to transfers; and (iii) the policy rules are given by equations (13)-(15) instead of (10)-(12), with γ_G, γ_Z, and γ_J parameterized as under the case of Fiscal Orthodoxy. Details on how to implement the model with the shadow economy are provided below. Note that the fiscal rules (13)-(15) require the fiscal authority to raise primary surpluses to cover its pre-pandemic recession debt as the Ricardian policy prescribes.

The monetary authority fully cooperates with the fiscal authority by allowing inflation to temporarily increase above the long-term target. This can be done by introducing a temporary time-varying inflation target $\hat{\pi}^T_t$ to accommodate the inflation needed to stabilize the share of debt ascribed to the emergency budget ($\hat{s}_{b,t} - \hat{s}^T_{b,t}$), i.e., the fraction of the debt-to-GDP ratio that is not fiscally backed. The monetary authority responds to deviations of inflation from this temporarily higher target $\hat{\pi}^T_t$. Thus, movements in the nominal interest rate $\hat{R}_t$ will be commensurate with the deviations of inflation from the temporary inflation target, and not to the deviations from the fixed long-term target as in the fiscal orthodoxy case. This leads us to a Taylor rule modified to account for the presence of the emergency budget:

$$\hat{R}_t = \max\left[-\ln R_\star, \rho_r \hat{R}_{t-1} + (1-\rho_r)\left[\phi_\pi\left(\hat{\pi}_t - \hat{\pi}^T_t\right) + \phi_y \hat{y}_t\right]\right] + u^m_t, \tag{16}$$

where $\phi_\pi > 1$ implies active monetary policy. This monetary rule implies that the central bank reacts only to inflation deviations from the time-varying target $\hat{\pi}^T_t$. In equilibrium, this target is larger than the fixed inflation objective used in the fiscal orthodoxy case, implying that *on average* the central bank will tolerate a higher level of inflation. This strategy is justified by the need to let inflation rise by the exact amount necessary to stabilize the debt ascribed to the emergency budget $\hat{s}_{b,t} - \hat{s}^T_{b,t}$. At the same time, the central bank retains the commitment to fight excessively high levels of inflation and to return to the long-term target once the emergency budget is reabsorbed. In the next section, we will discuss how to characterize these temporary inflation targets.

The idea of the emergency budget presents some similarities with President Roosevelt's New Deal. President Roosevelt ran his presidential campaign as fiscally conservative, but in 1933, he openly argued that there were two separate budgets. A regular federal budget for which a pledge was made to cut specific outlays. An emergency budget, which was needed to defeat the depression and which was unbalanced. In April of the same year, the United States abandoned the gold standard, disanchoring the value of the dollar from gold in a way to gain leeway in the conduct of monetary policy.

Temporary Targets of Debt-to-Output Ratio and Inflation The fiscal and monetary rules under the emergency budget strategy require policymakers to provide temporary targets for the debt-to-GDP ratio and inflation, which we denoted by $s_{b,t}^{T}$ and π_t^T. These targets allows us to define the amount of the debt-to-GDP ratio not backed by future fiscal adjustments and the amount of inflation that the central bank needs to forgo to stabilize such amount. We construct a shadow economy to characterize these targets.

The same equations that characterize the equilibrium of the actual economy also govern the shadow economy. The only point of departure is that the shadow economy is not affected by the shocks that caused the COVID-19 recession and the transfer shock. In the shadow economy, fiscal and monetary policies are Ricardian and respond to inflation and the previous period's debt-to-GDP ratio of this economy. Hence, by construction, the shadow economy returns the dynamics of inflation and debt-to-GDP ratio in the counterfactual scenario in which the pandemic recession did not happen and the fiscal stimulus was not carried out and so the monetary and fiscal policy mix would be Ricardian.

It also follows that the debt-to-GDP ratio in the shadow economy precisely isolates the portion of debt that does not depend on the pandemic recession and the fiscal stimulus and hence is not financed with the emergency budget. Thus, the target debt-to-GDP ratio $\hat{s}_{b,t-1}^{T}$ in the fiscal rules (13)-(15) corresponds to the debt-to-GDP ratio in the shadow economy, which we denote by $\hat{s}_{b,t}^{*}$.

We now turn our attention to the temporary state-dependent inflation target in the monetary rule (16). The central bank needs to choose this temporary target so that inflation can rise just by the amount necessary to stabilize the emergency budget, $(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^{T})$. Again, the shadow economy comes in handy. Indeed, the difference between the equilibrium inflation in the actual economy and the equilibrium inflation in the shadow economy can be shown to give us the right amount of inflation needed to wear away the fraction of the debt financed with the emergency budget. Therefore, we write the temporary inflation target π_t^T in the rule of the actual economy as the difference between the equilibrium inflation rates of the two economies; that is, $\hat{\pi}_t^T \equiv \hat{\pi}_t - \hat{\pi}_t^*$, where π_t^* denotes the equilibrium inflation rate in the shadow economy.

Endowed with these intuitions, we can then rewrite the monetary and fiscal rules (13)-(16)

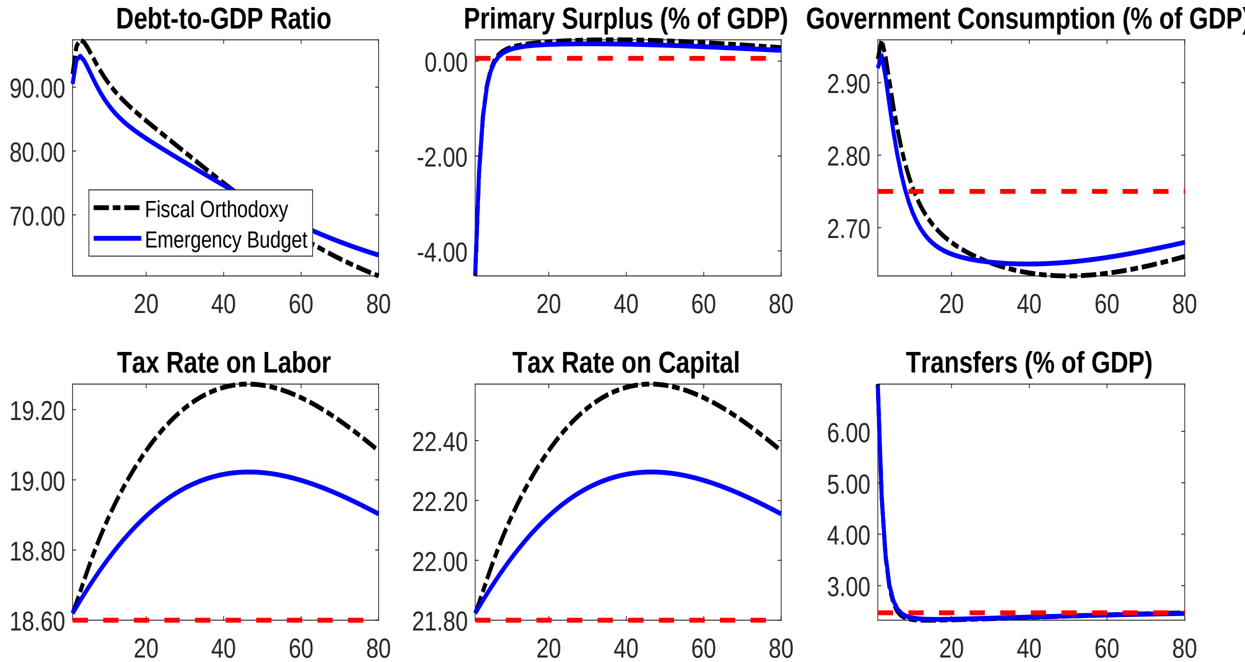

Figure 3: COVID-19 Recession. Fiscal aggregates in the case of Fiscal Orthodoxy is adopted and in the case the Emergency Budget is adopted. Debt-to-GDP ratio is total nominal debt at the end of the quarter divided by the annualized GDP in the quarter. Primary surplus, governmt consumption, and transfers are expressed as percentage of GDP. The periods on the x-axis are quarters.

as follows:

$$\hat{g}_t = \rho_G \hat{g}_{t-1} - (1-\rho_G)\,\gamma_G \hat{s}^*_{b,t-1} + u^G_t, \tag{17}$$

$$\hat{z}_t = \rho_Z \hat{z}_{t-1} - (1-\rho_Z)\,\gamma_Z \hat{s}^*_{b,t-1} + u^Z_t, \tag{18}$$

$$\hat{\tau}^J_t = \rho_J \hat{\tau}^J_{t-1} + (1-\rho_J)\,\gamma_J \hat{s}^*_{b,t-1} + u^J_t, \tag{19}$$

with $J \in \{K, L, C\}$ and

$$\hat{R}_t = \rho_r \hat{R}_{t-1} + (1-\rho_r)\left[\phi_\pi \hat{\pi}^*_t + \phi_y \hat{y}_t\right] + u^m_t, \tag{20}$$

where the starred variables are defined in the shadow economy described earlier.

Note that these rules belong to the broader class of shock-specific rules introduced by Bianchi and Melosi (2019). To see this, note that policymakers respond with different strength to the changes in debt, inflation, and output resulting from the pandemic recession and the large fiscal stimulus shock. The introduction of the emergency budget to finance the massive fiscal stimulus at the onset of the pandemic is accompanied with an increase in the temporary inflation target $\hat{\pi}^T_t$. Such increase in the target would lead the central bank to respond more aggressively when inflation is *below* the fixed long-term target and to be more

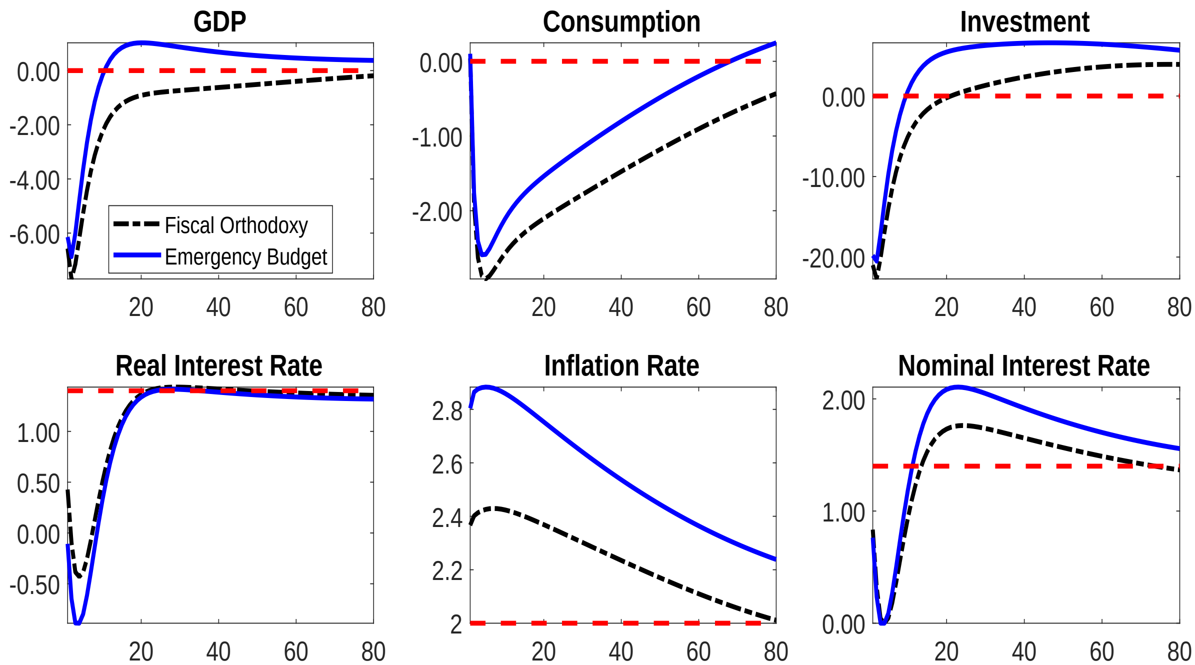

Figure 4: COVID-19 Recession. Macroeconomic dynamics in the case of Fiscal Orthodoxy is adopted and in the case the Emergency Budget is adopted. GDP is real output expressed in percentage logdeviations from its stochastic trend. Inflation and the interest rates are expressed in percentage of annualized rates. The periods on the x-axis are quarters.

accommodative when inflation runs *above* the fixed long-term inflation target. Interestingly, the FOMC discussed the suitability of a similar asymmetric approach to inflation stabilization at its meeting of 28 and 29 January 2020 as reported by the minutes of that meeting on page 10. Bianchi, Melosi, and Rottner (2019) show that this type of asymmetric monetary rule re-anchors inflation expectations to the long-term inflation objective and corrects the deflationary bias arising in a low interest rate environment.

Fiscal orthodoxy We first describe the response of the model economy in the case of fiscal orthodoxy (black dashed line). Figure 3 shows the dynamics of the fiscal variables during the pandemic crisis and its aftermath. The large fiscal debt keeps growing during the recession and then contracts as the fiscal authority carries out the necessary fiscal adjustments to bring the debt-to-GDP ratio to steady state in twenty years.

Figure 4 depicts the dynamics of macroeconomic aggregates. Again the case of fiscal orthodoxy is marked by the black dashed line. We observe that even though the policymakers carry out a massive \$2.6T fiscal stimulus, the pandemic recession is still quite severe. As discussed in the post-COVID-19 scenario, the expected fiscal adjustments weigh on heavily and persistently on economic performance; especially on consumption. This crippling effects are chiefly explained by the increase in the tax rates on capital and labor income. The central

	Unconditional Volatility	
	Fiscal Orthodoxy	Emergency Budget
Inflation	0.1561	0.1561
Output	0.7641	0.7641

Table 4: Unconditional standard deviation of inflation and output under the assumption that the fiscal and monetary policy mix is monetary led (Fiscal Orthodoxy) and fiscally led (Fiscal Inflation).

bank's commitment to fight inflation implies a higher real interest rate and investment falls as capital taxes rise. The nominal interest rate is constrained by the ZLB for one year and half.

The main take-away from this exercise is that under fiscal orthodoxy, expectations of future tax rises and spending cuts generate a negative wealth effect which bears negatively on the consumption decision of savers during the pandemic recession and in the years that follow. The positive impact of the expansionary fiscal policy dies out as the direct effect of transfers on hand-to-mouth consumption fades away.

Emergency budget In the case where the fiscal and monetary authorities coordinate to stabilize the amount of government debt that directly relates to the emergency budget, the real interest rate falls more compared to the case of fiscal orthodoxy (blue solid line in Figure 4). This is because the emergency budget brings about a controlled increase in inflation that pushes the real interest rate down even though the nominal rate is stuck at the ZLB. The initial contraction in GDP, consumption, and investment is much less severe if policymakers adopt the Emergency-Budget strategy. Furthermore, the moderate rise in fiscal inflation needed to stabilize the share of debt ascribed to the emergency budget mitigates the fiscal adjustment in the form of raising taxes and cutting spending. As shown in Figure 3, the fiscal adjustment is much less severe compared to the Fiscal-Orthodoxy case because the controlled rise in inflation contributes to stabilize the share of debt accumulated during the pandemic recession.

While the $2.6 trillion 2020 stimulus bill is the largest U.S. fiscal stimulus on record, the decision of ascribing it to the emergency budget results in just a modest, controlled increase in inflation. A general equilibrium effect explains this result: the mitigation of the pandemic recession contributes to lowering the debt-to-GDP ratio and hence inflation does not have to rise exorbitantly to wear away the debt ascribed to the emergency budget. Indeed, after a rapid but contained increase, inflation falls, remaining slightly elevated for several years. Such a persistent effect on inflation raises nominal interest rates, reducing the risk for the economy to fall into a liquidity trap and corrects a two-decade-long period of below-target inflation for the central bank.

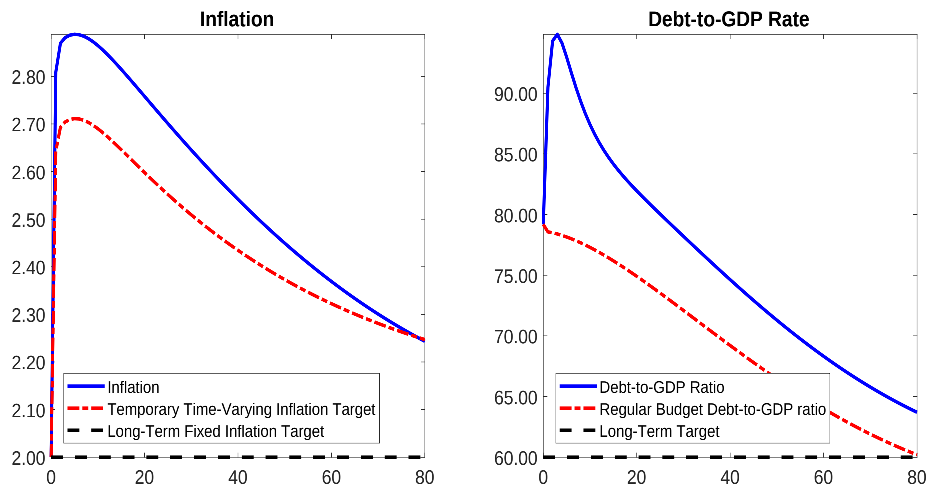

Figure 5: Monetary and Fiscal Policy Targets Under an Emergency Budget. Under the Emergency budget scenario, the COVID fiscal stimulus is ascribed to an emergency budget with no fiscal backing. The emergency budget is given by the difference between the total debt-to-GDP ratio (solid blue line) and the amount of debt-to-GDP ratio backed by future primary surpluses (dashed-dotted red line). The red dashed-dotted line in the left panel corresponds to the temporary state-dependent inflation target.

Since policymakers are still committed to making the fiscal adjustments that are necessary to stabilize the pre-pandemic stock of government debt, the coordinated strategy does not bring about additional macroeconomic volatility. Table 4 shows that the adoption of the Emergency Budget does not bring about any increase in macroeconomic volatility, unlike the adoption of Fiscal Inflation (see Table 3).

Figure 5 illustrates the targets of the coordinated monetary and fiscal policy mix which we call Emergency Budget. The right panel of the figure plots the actual behavior of the debt-to-GDP ratio in the case of a coordinated response (solid blue line), together with the debt-to-GDP ratio that the fiscal authority is committed to cover with future fiscal adjustments (dotted-dashed red line). As explained above, this corresponds to the debt-to-GDP ratio of the shadow economy. The difference between the two lines is the amount of debt in the emergency budget which at any point in time remains to be stabilized by the concerted action of the monetary and fiscal authorities. The monetary strategy that achieves this goal is plotted in the left panel of the figure, which depicts the actual rate of inflation (solid blue line) along with the announced temporary time-varying target (dotted-dashed red line).

It is important to notice that the peak-rise in the temporary target is about 70 basis points above the two-percent long-term inflation target. After rising a few quarters the target inflation rate converges back to the long-term two-percent goal sluggishly. This result can be effectively interpreted as a modest increase in the inflation objective. By raising the target in combination with the adoption of the emergency budget by the fiscal authority, the central bank achieves the joint objective of enhancing the effectiveness of the fiscal stimulus and correcting a two-decade-long period of below-target inflation. Arguably, the fact that the increase in inflation is necessary in order to stabilize the emergency budget adds credibility to the coordinated policy, unlike a unilateral decision of the central bank that agents might see as easily reversible.

7 Helicopter Money

In the case of the emergency budget, the coordinated action of the fiscal and monetary authorities wears away a well-defined and limited portion of the debt-to-GDP ratio by causing a gradual rise in inflation that the central bank accommodates. What sparks inflation is the announcement of a new monetary and fiscal policy mix, which is reflected in the projected paths of the fiscal instruments, i.e. tax rates, transfers and government expenditures, and of the temporarily asymmetric inflation target. Inflation expectations jump upon the implementation of the coordinated policy mix, leading to an immediate decline in real interest rates.

The model abstracts from money, as the monetary policy rule is defined in terms of an interest rate policy. Nevertheless, it can be interesting to understand how our analysis relates to the discussion of helicopter money, i.e., the assumption of a fiscal transfer of cash to households financed by an increase in money growth. The policy we analyze clearly shares some elements of commonality with the discussion of helicopter money. However, whatever happens to money in equilibrium is not necessary to pinpoint the source of inflation, which lies in the agreement between the fiscal and monetary authorities about how to finance an existing fiscal burden. Money is a tool, and its equilibrium behavior that is consistent with a given policy mix can be made explicit and traced, with no consequences for the equilibrium dynamics reported in the previous sections.

The simplest way to introduce money in the model is to assume it in the utility function. For instance, we could postulate the function:

$$\mathcal{U}_t^S = \left(\ln \left(C_t^{*S}(j) - \theta C_{t-1}^{*S} \right) - L_t^S(j)^{1+\xi} / (1+\xi) + \zeta \ln \left(\frac{M_t}{P_t} \right) \right),$$

where M_t denotes money and $\zeta > 0$. At the same time, seigniorage revenues derived from money creation would need to be added to the government budget constraint, yielding:

$$\tau_t^K R_t^k K_t + \tau_t^L W_t L_t + \tau_t^C P_t C_t + \left[P_t^B B_t - \left(1 + \rho P_t^B \right) B_{t-1} \right] + M_t - M_{t-1} = P_t G_t + P_t Z_t, \quad (21)$$

which implies that nominal government expenditures or transfers can be financed by an increase in the stock of money. Assuming for simplicity that no utility is derived from government consumption such that $C_t^{*S} = C_t^S$, that there are no habits in consumption ($\theta = 0$), that there is no growth in steady state ($\gamma = 0$), utility maximization yields the following demand function for real money balances, after substituting for the Euler equation:

$$\frac{M_t}{P_t} = \zeta \left[\frac{1}{C_t} \left(1 - \frac{1}{R_t} \right) \right]^{-1}, \tag{22}$$

which shows the standard result that real money demand is positively related to consumption and negatively related to the interest rate. Equation (22) implies that for a given interest rate set by the central bank, and for a given level of aggregate consumption and prices at time t, the supply of money M_t has to adjust to satisfy the demand for real money balances. In the case of the emergency budget, the path of the price level and of consumption relative to the case of fiscal orthodoxy, implies that the supply of money has to increase to satisfy the demand function in equation (22). This increase in the stock of money generates seigniorage revenue for the government, which can be used to finance cash transfers to the households in equation (21) or alleviate the fiscal burden. In both cases, the analysis presented above would not significantly change given that the equilibrium path is pinned down by the interaction between the fiscal rules and the Taylor rule, and not by the precise path of money supply.

In a related paper, Galí (2019) compares the effectiveness of fiscal policy under debt financing vs. money financing, finding larger multipliers in the latter case. Galí (2019) also finds that the relative effectiveness of money financing relative to debt financing is reduced in the presence of the zero lower bound (ZLB). In our analysis of the emergency budget reported in Figure 4, the presence of the ZLB is not a constraint on the effectiveness of the coordinated policy mix analyzed in this paper. Rather, the coordination between the fiscal and monetary authorities turns out to be helpful to escape the ZLB by creating expectations of higher inflation, which is immediately reflected in higher nominal interest rates. The difference stems from the assumption in Galí (2019) that while dropping money from the helicopter, the monetary authority keeps the inflation target at zero. In our analysis, the inflation target is instead temporarily raised with the explicit intent of reducing the burden of the debt.

8 Conclusions

A likely legacy of COVID-19 is a large stock of public debt. In this paper, we have discussed some of the challenges that a large public debt poses to macroeconomic stability and have analyzed an approach that could potentially turn these challenges into an opportunity. This approach requires the fiscal authority to adopt a separate emergency budget to finance the fiscal stimulus needed to combat the pandemic recession. This fiscal strategy is backed by a modest upward revision of the central bank's inflation objective. We evaluate the implications of this coordinated strategy through the lens of a state-of-the-art DSGE model estimated to U.S. data. In the short run, this coordinated approach is showed to mitigate the COVID recession and the risk of a post-recession stagnation owing to expectations of massive fiscal adjustments. In the longer run, the strategy may lead to a reflation of the economy that could mitigate the deflationary bias and reduce the risk of liquidity traps.

References

Bassetto, M. (2002): "A Game-Theoretic View of the Fiscal Theory of the Price Level," *Econometrica*, 70(6), 2167–2195.

Benhabib, J., S. Schmitt-Grohe, and M. Uribe (2002): "Avoiding Liquidity Traps," *Journal of Political Economy*, 110(3), 535–563.

Bianchi, F., and C. Ilut (2017): "Monetary/Fiscal Policy Mix and Agents' Beliefs," *Review of Economic Dynamics*, 26, 113–139.

Bianchi, F., and L. Melosi (2013): "Dormant Shocks and Fiscal Virtue," in *NBER Macroeconomics Annual 2013, Volume 28*, NBER Chapters, pp. 1–46. National Bureau of Economic Research, Inc.

——— (2017): "Escaping the Great Recession," *American Economic Review*, 107(4), 1030 – 58.

——— (2019): "The dire effects of the lack of monetary and fiscal coordination," *Journal of Monetary Economics*, 104, 1–22.

Bianchi, F., L. Melosi, and M. Rottner (2019): "Hitting the Elusive Inflation Target," NBER working paper.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005): "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 113(1), 1–45.

Cochrane, J. H. (1998): "A Frictionless Model of U.S. Inflation," in *NBER Macroeconomics Annual 1998*, ed. by B. S. Bernanke, and J. J. Rotemberg, pp. 323–384. MIT Press, Cambridge, MA.

——— (2001): "Long Term Debt and Optimal Policy in the Fiscal Theory of the Price Level," *Econometrica*, 69, 69–116.

Congressional Budget Office (2020): "Federal Debt: a Primer," (CBO Publication No. 56165). Washington, DC: Congressional Budget Office.

Eggertsson, G. B. (2008): "Great Expectations and the End of the Depression," *American Economic Review*, 98(4), 1476–1516.

Faccini, R., and L. Melosi (2020): "Bad Jobs and Low Inflation," CEPR Working Paper DP 13628.

Galí, J. (2019): "The effects of a money-financed fiscal stimulus," Journal of Monetary Economics, forthcoming.

Hall, G. J., and T. J. Sargent (2011): "Interest Rate Risk and Other Determinants of Post-WWII U.S. Government Debt/GDP Dynamics," *American Economic Journal: Macroeconomics*, 3(3), 192–214.

Jacobson, M. M., E. M. Leeper, and B. Preston (2019): "Recovery of 1933," NBER Working Papers 25629, National Bureau of Economic Research, Inc.

Kaplan, G., G. Violante, and J. Weidner (2014): "The Wealthy Hand-to-Mouth," *Brookings Papers on Economic Activity*, 44(1), 77–138.

Leeper, E. M. (1991): "Equilibria Under Active and Passive Monetary and Fiscal Policies," *Journal of Monetary Economics*, 27, 129–147.

Leeper, E. M., N. Traum, and T. B. Walker (2017): "Clearing Up the Fiscal Multiplier Morass," *American Economic Review*, 107(8), 2409–2454.

Reis, R. (2016): "QE in the future: the central bank's balance sheet in a financial crisis," Discussion Papers 1620, Centre for Macroeconomics (CFM).

Sargent, T., and N. Wallace (1981): "Some Unpleasant Monetarist Arithmetic," *Federal Reserve Bank of Minneapolis Quarterly Review*, Fall, 1–17.

Schmitt-Grohe, S., and M. Uribe (2000): "Price level determinacy and monetary policy under a balanced-budget requirement," *Journal of Monetary Economics*, 45(1), 211–246.

Sims, C. A. (1994): "A Simple Model for Study of the Determination of the Price Level and the Interaction of Monetary and Fiscal Policy," *Economic Theory*, 4, 381–399.

Sims, C. A. (2016): "Fiscal policy, monetary policy and central bank independence," in *Kansas City Fed Jackson Hole Conference*.

Woodford, M. (1994): "Monetary Policy and Price Level Determinacy in a Cash-in-Advance Economy," *Economic Theory*, 4, 345–389.

——— (1995): "Price Level Determinacy without Control of a Monetary Aggregate," *Carnegie-Rochester Series of Public Policy*, 43, 1–46.

——— (2001): "Fiscal Requirements of Price Stability," *Journal of Money, Credit, and Banking*, 33, 669–728.

——— (2003): *Interest and prices: Foundations of a theory of monetary policy*. Princeton University Press, Princeton, New Jersey.

A The Log-Linear Model

This model features a trend in the state of labor-augmenting technological progress. In order to make the model stationary, we define the following variables: $y_t = \frac{Y_y}{A_t}$, $c_t^{*S} = \frac{C_t^{*S}}{A_t}$, $c_t^S = \frac{C_t^S}{A_t}$, $c_t^N = \frac{C_t^N}{A_t}$, $k_t = \frac{K_t}{A_t}$, $g_t = \frac{G_t}{A_t}$, $z_t = \frac{Z_t}{A_t}$, $b_t = \frac{P_t^B B_t}{P_t A_t}$, $w_t = \frac{W_t}{P_t A_t}$, and $\lambda_t^S = \Lambda_t^S A_t$. We list below the equations of the log-linear model, starting with those that characterize the actual-economy block.

Production function:

$$\hat{y}_t = \frac{y + \Omega}{y}\left[\alpha \hat{k}_t + (1-\alpha)\hat{L}_t\right]. \tag{23}$$

Capital-labor ratio:

$$\hat{r}_t^K - \hat{w}_t = \hat{L}_t - \hat{k}_t. \tag{24}$$

Marginal cost:

$$\widehat{mc}_t = \alpha \hat{r}_t^k + (1-\alpha)\hat{w}_t. \tag{25}$$

Phillips curve:

$$\hat{\pi}_t = \frac{\beta}{1+\chi_p\beta} E_t\hat{\pi}_{t+1} + \frac{\chi_p}{1+\chi_p\beta}\hat{\pi}_{t-1} + \kappa_p \widehat{mc}_t, \tag{26}$$

where $\kappa_p = \left[(1-\beta\omega_p)(1-\omega_p)\right] / \left[\omega_p\left(1+\beta\chi_p\right)\right]$.

Saver household's FOC for consumption:

$$\hat{\lambda}_t^S = -\frac{e^\gamma}{e^\gamma - \theta} c_t^{*S} + \frac{\theta}{e^\gamma - \theta} c_{t-1}^{*S} - \frac{\tau^C}{1+\tau^C}\hat{\tau}_t^C. \tag{27}$$

Public/private consumption in utility:

$$\hat{c}_t^* = \frac{c^S}{c^S + \alpha_G g}\hat{c}_t^S + \frac{\alpha_G g}{c^S + \alpha_G g}\hat{g}_t. \tag{28}$$

Euler equation:

$$\hat{\lambda}_t^S = \hat{R}_t + E_t\hat{\lambda}_{t+1}^S - E_t\hat{\pi}_{t+1}. \tag{29}$$

Maturity structure of debt:

$$\hat{R}_t + \hat{P}_t^B = \frac{\rho}{R} E_t \hat{P}_{t+1}^B. \tag{30}$$

Saver household's FOC for capacity utilization:

$$r_t^k - \frac{\tau^K}{1-\tau^K}\tau_t^K = \frac{\psi}{1-\psi}\hat{\nu}_t. \tag{31}$$

Saver household's FOC for capital:

$$\hat{q}_t = E_t\hat{\pi}_{t+1} - \hat{R}_t + \beta e^{-\gamma}\left(1-\tau^K\right) r^k E_t\hat{r}^k_{t+1} - \beta e^{-\gamma}\tau^K r^k E_t\hat{\tau}^K_{t+1} + \beta e^{-\gamma}\left(1-\delta\right) E_t\hat{q}_{t+1}. \quad (32)$$

Saver household's FOC for investment:

$$\hat{\imath}_t + \frac{1}{\left(1+\beta\right) s e^{2\gamma}}\hat{q}_t - \frac{\beta}{1+\beta}E_t\hat{\imath}_{t+1} = \frac{1}{1+\beta}\hat{\imath}_{t-1}. \quad (33)$$

Effective capital:

$$\hat{k}_t = \hat{\nu}_t + \hat{\bar{k}}_{t-1}. \quad (34)$$

Law of motion for capital:

$$\hat{\bar{k}}_t = \left(1-\delta\right) e^{-\gamma}\hat{\bar{k}}_{t-1} + \left[1 - \left(1-\delta\right) e^{-\gamma}\right]\hat{\imath}_t. \quad (35)$$

Hand-to-mouth household's budget constraint:

$$\tau^C c^N \hat{\tau}^C_t + \left(1+\tau^C\right) c^N \hat{c}^N_t = \left(1-\tau^L\right) wL\left(\hat{w}_t + \hat{L}_t\right) - \tau^L wL\hat{\tau}^L_t + z\hat{z}_t. \quad (36)$$

Wage equation:

$$\begin{aligned}\hat{w}_t \;=\; & \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{\beta}{1+\beta}E_t\hat{w}_{t+1} - \kappa_w\left[\hat{w}_t - \xi\hat{L}_t + \hat{\lambda}^S_t - \frac{\tau^L}{1-\tau^L}\hat{\tau}^L_t\right] \\ & + \frac{\chi^w}{1+\beta}\hat{\pi}_{t-1} - \frac{1+\beta\chi^w}{1+\beta}\hat{\pi}_t + \frac{\beta}{1+\beta}E_t\hat{\pi}_{t+1}. \quad (37)\end{aligned}$$

Aggregate households' consumption

$$c\hat{c}_t = c^S\left(1-\mu\right)\hat{c}^S_t + c^N\mu\hat{c}^N_t. \quad (38)$$

Aggregate resource constraint:

$$y\hat{y}_t = c\hat{c}_t + i\hat{\imath}_t + g\hat{g}_t + \psi'\left(1\right) k\hat{\nu}_t. \quad (39)$$

Government budget constraint:

$$\begin{aligned}& \frac{b}{y}\hat{b}_t + \tau^K r^k\frac{k}{y}\left[\hat{\tau}^K_t + \hat{r}^k_t + \hat{k}_t\right] + \tau^L w\frac{L}{y}\left[\hat{\tau}^L_t + \hat{w}_t + \hat{L}_t\right] + \tau^C\frac{c}{y}\left(\hat{\tau}^C_t + \hat{c}_t\right) \\ = \; & \frac{1}{\beta}\frac{b}{y}\left[\hat{b}_{t-1} - \hat{\pi}_t - \hat{P}^B_{t-1}\right] + \frac{b}{y}\frac{\rho}{e^{\gamma}}\hat{P}^B_t + \frac{g}{y}\hat{g}_t + \frac{z}{y}\hat{z}_t. \quad (40)\end{aligned}$$

Monetary policy rule under fiscal orthodoxy:

$$\hat{R}_t = (1 - \rho_r) \left[\phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t \right]. \tag{41}$$

In the case of the emergency budget, the rule above is replaced by:

$$\hat{R}_t = (1 - \rho_r) \left[\phi_\pi \hat{\pi}_t^* + \phi_y \hat{y}_t \right],$$

where $\hat{\pi}_t^*$ refers to the rate of inflation in the shadow economy, which is characterized below.

The fiscal rules under the case of orthodoxy are:

$$\hat{g}_t = \rho_G \hat{g}_{t-1} - (1 - \rho_G)\ \gamma_G \hat{s}_{b,t-1}, \tag{42}$$

$$\hat{z}_t = \rho_Z \hat{z}_{t-1} - (1 - \rho_Z)\ \gamma_Z \hat{s}_{b,t-1} + \varepsilon_t^Z, \tag{43}$$

$$\hat{\tau}_t^J = \rho_J \hat{\tau}_{t-1}^J + (1 - \rho_J)\ \gamma_J \hat{s}_{b,t-1}. \tag{44}$$

In the case of the emergency budget, they are replaced by

$$\hat{g}_t = \rho_G \hat{g}_{t-1} - (1 - \rho_G) \gamma_G \hat{s}_{b,t-1}^*, \tag{45}$$

$$\hat{z}_t = \rho_Z \hat{z}_{t-1} - (1 - \rho_Z) \gamma_Z \hat{s}_{b,t-1}^* + \varepsilon_t^Z, \tag{46}$$

$$\hat{\tau}_t^J = \rho_J \hat{\tau}_{t-1}^J + (1 - \rho_J) \gamma_J \hat{s}_{b,t-1}^*. \tag{47}$$

The block of equations that characterize the shadow economy consists in an additional set of equations (23) to (40) plus the rule for the monetary authority (41) and the rules for the fiscal authority (42) to (44), where any variables that refer to the actual economy x_t are replaced by the same variable in the shadow economy x_t^*.