Transfer Payments, Sacrifice Ratios, and Inflation in a Fiscal Theory HANK [1]

Noah Kwicklis[2]
July 2023
PRELIMINARY DRAFT

Abstract

The Fiscal Theory of the Price Level (FTPL) stipulates that fiscal policy can play an important role in determining prices and the path of inflation, potentially with significant effects on real variables in settings where the classical dichotomy does not hold. However, previous papers on FTPL have largely abstracted away from wealth and income inequality – leaving open questions about how active fiscal policy could affect and be affected by household heterogeneity. To bridge this gap, I numerically solve a calibrated canonical Heterogeneous Agent New-Keynesian (HANK) model that features nominal rigidities, incomplete markets, hand-to-mouth households, nominal long-term government debt, and active fiscal policy to consider how taxes and transfers to and from different members of the population can have markedly different consequences for both aggregate output and employment – and for the path of inflation, but not the cumulative amount of inflation overall. The numerical simulations thus indicate that taxes on low-marginal propensity to consume (MPC) high-income households can cool inflation at a lower cost to employment and output than the trade-off incurred by raising interest rates or by raising taxes more broadly. Conversely, the model predicts that stimulus checks to low-income high-MPC households generate more immediate inflation, but also a significantly stronger boom in real gross domestic product, both in absolute terms and in terms of GDP growth per percentage point of inflation accumulated. In general, spending programs of similar sizes can cause different responses to output depending on their recipients, but generate approximately the same cumulative amount of overall inflation, as they produce similar amounts of unbacked debt that must be inflated away in the FTPL environment. While there are forces that make transfers to high-MPC households less inflationary in the presence of automatic stabilizers, the model predicts that the differences are small.

Keywords: FTPL, HANK, sacrifice ratios, continuous time models
JEL Classification Codes: E63, E31, E12

[1]This version: July 31, 2023

[2]University of California, Los Angeles, Department of Economics, 8276 Bunche Hall, 315 Portola Plaza, Los Angeles, CA 90095.

1 Introduction

Recent theoretical work related to the Fiscal Theory of the Price Level (summarized in a 2023 book by John Cochrane of the same name) has highlighted the ways in which higher government deficits financed with nominally denominated bonds can raise the path of inflation and determine an economy's overall price level. If this perspective is accurate, it suggests that fiscal policy can also play an important role in bringing inflation back down – and that fiscal policy could potentially be an even more important inflationary or dis-inflationary force than monetary policy. However, unlike monetary policy, which deals with interest rates broadly in the economy, fiscal policy can be adapted to heterogeneously impact different parts of the population. The existing representative agent models of Fiscal Theory have therefore left a crucial question so far unanswered: if policy makers face a trade-off in which they can reduce economic activity using fiscal policy in order to cool inflation (or vice-versa), does it matter how the taxes and transfers are targeted, and could some policies lower inflation at a lower cost to output, employment, and social welfare than others? In other words, if a fiscal authority wanted to fight inflation in a way that inflicted the minimum human hardship necessary, who should it tax? And in the symmetric problem, if a government would like to boost output with minimal inflation, who should it send checks to? This paper attempts to answer these questions in stylized terms by extending a canonical heterogeneous-agent New Keynesian (HANK) model to an environment where the fiscal theory of the price level (FTPL) is active. The model's simulated output suggests that yes, in a fight against inflation or recession, some distributional policy choices are better than others.

Why might large deficits drive a substantial component of inflation? Fiscal theory, as laid out in Cochrane (2023), stipulates the budget constraint of a government may be integrated forward and combined with households' asset demand to write an ex-ante asset pricing equation for real government liabilities. If sovereign bonds act as a claim to future tax revenue, then the value of those outstanding bonds should be equal to the expected present value of future surpluses, assuming there is no bubble in the value of government debt. Mathematically, if T_t represents government transfers, r_t represents the real interest rate, G_t represents real expenditures, $\tilde{B}_t$ represents the nominal value of bonds in circulation, and P_t denotes the overall price level (whose changes are by definition inflation), then in an aggregate-risk-neutral or certainty-equivalent setting:

$$\frac{\tilde{B}_t}{P_t} = \mathbb{E}_t \left[\int_t^{\infty} e^{-\int_t^{\tau} r_s ds} [T_\tau - G_\tau] d\tau \right] \tag{1}$$

If nominal bonds outstanding $\tilde{B}_t$ are fixed upon the impact of a shock that lowers the present value right-hand side of the above expression, then P_t must rise on the left-hand side for the equation to still hold: new deficits not backed by future taxes necessitate an increase in the price level to devalue existing government liabilities like cash and outstanding government bonds in real terms. In a slightly more New-Keynesian tradition, we might also imagine that the price level cannot adjust instantaneously or only partially to changes in the macroeconomic environment. Then, the value of real bonds is fixed upon the impact of a policy change – such that a fall in current surpluses necessitates a relative decline in real rates in subsequent periods. If the central bank sets nominal rates and keeps them fixed (such as when the economy is at the zero lower bound (ZLB), or at least maintains passive monetary policy as in the sense of Leeper (1991)), these lower real rates can only be accomplished via inflation following deficits and a gradual increase in the price level. Put another way, FTPL suggests that if a government enacts deficit spending that is not backed by future primary surpluses (tax revenue in excess of its spending), then it must inflate its un-backed debt away by paying its future interest expense to bondholders with inflated dollars, implicitly eroding or defaulting on its real liabilities (as with a higher price level, a nominal government liability like a dollar or non-indexed bond represents a claim to fewer real resources than it did before). A key factor is that in FTPL models, fiscal policy is "active" (to again use the Leeper (1991) terminology), such that the government does not set budgets contingent on the price level, but rather sets budgets as it chooses and lets the price level adjust accordingly.

If we think of bonds as like money, FTPL thus takes on an almost monetarist-like intuition: increasing the amount of nominal assets in the economy without changing the real resources backing them leads to the real devaluation of the nominal assets; what the government spends but does not tax, it must inflate away. This acts like an invariance principle, which would suggest that a policy that spends 1% of GDP without introducing new taxes will add 1% to the debt if the debt-to-GDP ratio is close to 1 – such that this debt will have to be inflated away by a cumulative 1% rate of inflation over time. This further raises the possibility that some debt financed spending is a better "deal" than others, if some policies induce the same deficits and boost GDP to a greater extent than others, but cause the same inflationary impacts. However, fiscal theory also introduces further complications to this story, as the path of primary surpluses can be partially endogenous (as they are in the case of automatic stabilizers), such that if government spending leads to a boost in GDP, the government may be able to "tax the boom" to thereby restore confidence in the backing of its liabilities and partially counteract the inflationary force of its original policy. There is also a possibility that the timing of inflation and the adjustment real interest rates could be important for the overall inflationary impact of a policy. For instance, a debt-financed stimulus that leads to more inflation in the short-term may be able to generate less inflation in the long-term. This is because, taking the initial amount of new debt is given, if inflation is initially low and nominal interest rates are fixed, then government debt will grow at a higher real rate for a longer period of time, creating more debt that will eventually have to be inflated away, compared to a policy that produces a shorter burst of inflation that lowers real rates immediately. All of these factors could imply different trade-offs between inflation and output for different policies, which a full macroeconomic model can clarify. These trade-offs may be quantified in terms of "sacrifice ratios," the amount of cumulative GDP lost relative to the amount of total disinflation induced by a policy. Alternatively, one could assess the amount of cumulative GDP *added* per unit of inflation induced by a stimulus (in a setting where inflationary and dis-inflationary forces are symmetric, these two notions of the sacrifice ratio will of course be the same). A macroeconomic model exhibiting FTPL can help assess the relative strength and importance of these forces, and their implied impacts on the costs and benefits of different policy actions.

Why should two fiscal policies representing the same share of GDP affect the macroeconomy differently? Here, the growing HANK literature provides a natural explanation (as do the textbook "old Keynesian" models, albeit in a cruder form). One of the literature's seminal (and representative) papers is Kaplan, Moll, and Violante (2018), which re-examines the transmission mechanism of monetary policy to find that when a large fraction of agents lack liquid assets (and thus live largely hand-to-mouth, passing through changes in their income directly into their spending), monetary policy acts primarily through the automatic real fiscal adjustments that governments must make in standard models to balance their inter-temporal budgets, and through general equilibrium effects that change labor income. Transfers of resources toward agents with a high marginal propensity to consume (MPC) out of their current income thus jump-start an expansionary process wherein spending begets income begets production, in dynamic loop reminiscent of "old" Keynesian static models. Auclert, Rognlie, and Straub (2018 and 2023) discuss how these feedbacks continue until excess savings eventually "trickle up" to wealthier low-MPC households, attenuating the cycle. Such models can also be adapted to fit both macroeconomic and microeconomic data well simultaneously, as in Auclert, Rognlie, and Straub (2020), a task with which previous generations of representative agents struggled. They have also been shown to be useful in resolving some long-standing "puzzles" pertaining to monetary policy in the New Keynesian framework, as discussed in McKay, Nakamura, and Steinsson (2016). In the existing HANK literature, however, monetary and fiscal policy are generally assumed to be inseparably connected; models typically assume rules that require the government to passively adjust its fiscal surpluses to either continuously or inter-temporally balance its budget in response to changes in real interest rates, thereby inextricably connecting fiscal policy to monetary policy, with monetary policy playing the lead. In fiscal theory, however, fiscal policy is able to be active – a setting worth considering in a world where the United States' congress sets the federal budget for a host of reasons besides reactions to changes in the Federal Funds Rate.

It thus stands to reason that debt-financed government transfers (or printed money) to high-MPC, low-income, low-asset households might generate a larger economic expansion than transfers to low-MPC, high-income, high-asset households, holding the size of the spending programs equal. The logic of the standard forward-looking New-Keynesian Phillips Curve suggests that transfers to the former might induce a larger *immediate* increase in inflation, if marginal costs rise when output increases, potentially putting pressure on or compressing firms' or workers' margins. However, both programs (again, contingent on the spending programs being the same size) should generate roughly the same amounts of cumulative inflation, as per the Fiscal Theory equation (1), if both roughly add the same amount of un-backed debt to government balance sheets. The aforementioned effects of "taxing the boom" and the timing of inflation and real rates may complicate the picture, perhaps making cumulative inflation slightly lower when stimulus checks are sent to the poor rather than to the rich.

Which effects are the most important ones? Are they macroeconomically significant, if even in a stylized framework? It is in this spirit that this paper modifies a standard heterogeneous agent New-Keynesian (HANK) Bewley-Aiyagari model with incomplete markets, income risk, and borrowing constraints to include long-term nominal government debt and "active" fiscal policy. The model also features a proportional income tax in addition to lump-sum transfers, to capture how higher wages and employment can restore the government's coffers (and lower wages and employment can do the opposite). Long-term nominal government debt is incorporated as in the representative agent model described in Cochrane (2018b); as noted in that paper, fiscal theory with entirely short-term liquid government debt yields the counter-intuitive result that raising nominal rates *increases* inflation – but with long-term government debt (at least, with government debt long-term enough to match the U.S. government's weighted average maturity of roughly 7 years), contractionary monetary policy does indeed drive down the price level, at least temporarily. The rest of the New Keynesian model is kept relatively close to the rest of the literature, and closely resembles the one put forward in McKay, Nakamura, and Steinsson (2016); I include minimal ingredients to demonstrate the mechanism. To my knowledge, my model is the first to fully combine the HANK framework with the fiscal theory of the price level, and is also the first to discuss FTPL's implications for the trade-off between inflation and output's interactions with household heterogeneity under conditions of nominal rigidities.

One attractive feature of FTPL models is that their determinacy comes from the transversality condition on real government debt, and not from a Taylor Rule, which though popular in the modern New Keynesian literature instills local determinacy by ruling out hyperinflations and pre-committing the Fed to setting off a hyperinflationary loop if prices don't fall when interest rates rise, as discussed in Cochrane (2011). The Taylor Rule additionally fails to deliver determinacy in standard representative agent New Keynesian models when monetary policy is unable or unwilling to adjust interest rates at the zero lower bound (ZLB); Cochrane (2018a) takes the stability of inflation during the early 2010s (when the U.S. economy actually did have nominal interest rates of zero) as an indictment of Taylor Rule-provided determinacy. Acharya and Dogra (2020) note that the picture is yet more complicated in heterogeneous agent models, where determinacy additionally depends on the pro-cyclicality of income risk, where if the risk is procyclical, a Taylor Rule-type monetary response is not necessary for model determinacy, while if income risk is counter-cyclical (as it may well be in the real world, with unemployment risk rising sharply during recessions), raising nominal rates to just keep pace with inflation is actually insufficient for ruling out self-fulfilling-but-stable sunspot inflationary spells, such that monetary policy rules must be even more aggressive in some settings with realistic heterogeneity.

Hagerdorn et al (2019) also explores fiscal policy in a HANK and finds that fiscal multipliers in their simulations are higher when deficit-financed (1.31) than when paid for by contemporaneous taxes (0.61) in a scenario wherein nominal interest rates are fixed and monetary policy is passive. However, the paper's model again assumes that the government adjusts its transfers over time to inter-temporally, balancing the budget for all possible sequences of the price level and inflation (including off-path ones), making fiscal policy passive as well. The model's equilibrium selection mechanism, which is described in further detail in Hagerdorn (2018), is therefore one in which prices determine the tax process, as opposed to the one in FTPL wherein tax surpluses determine inflation. The price level realized in their simulation is the one that brings the agents' asset holdings back to their steady-state values – with the upshot that the economic dynamics essentially bring the price level (not just inflation) back to its pre-shock steady state following a change in economic conditions. Even so, the authors show that under a passive fiscal regime, hand-to-mouth agents (in addition to the existing non-Ricardian properties of the New Keynesian model) are enough generate substantial stimulus from fiscal policy, particularly if monetary policy does not constrict during the boom.

This paper is focused on the management of aggregate demand in the economy, rather than on supply-side factors. However, a host of supply chain disruptions accompanied the inflationary surge that followed 2021. How important were demand-driven factors for inflation in the past few years? Shapiro (2022) examines the movement of sub-categories of the Personal Consumption Expenditures (PCE) price index and finds that about half of the inflation that comprised the aggregate rate was associated with items where the quantities of goods sold co-moved with prices – such that consumers continued spending through price increases in many sectors of the economy, a trend that suggests a demand-side expansion in the economy. Di Giovanni et al (2022) calibrates a multi-sector network model to U.S. data and conclude that demand-side factors likely accounted for two-thirds of inflation in the past few years, with about half of that attributable to fiscal stimulus.

Is the FTPL perspective useful for understanding the time series data of the United States, particularly in the United States? Preliminary evidence suggests that it is. Bianchi et al (2023) solve and estimate a Bayesian DSGE model featuring an economy that switches between active-monetary and active-fiscal policy regimes (or "fiscally-led" and "monetary-led" regimes, in the authors' terms). The model output matches the historical record relatively well, and using real-time data from the time of the passage of the 2021 American Rescue Plan Act, the framework is able to successfully forecast persistent inflation and a strong macroeconomic recovery in hours worked and real GDP in the post-pandemic era, largely due to stimulus spending.

During inflationary periods, relative prices often change – but besides nominal assets being subject to an "inflation tax," the Fiscal Theory does not by itself make strong predictions as to who is relatively benefited or harmed during such times. As such, additional theory must be imposed to make markups pro-cyclical or counter-cyclical, just as in the rest of the New Keynesian literature; the HANK model in Kaplan, Moll, and Violante (2018) features pro-cyclical markups, while in a follow-up paper Alves et al (2020) the authors include nominal wage rigidities to achieve expanding profits and falling real wages during inflationary expansions. The latter specification appears to be more relevant in the current climate: from the first quarter of 2021 to the first quarter of 2023, the U.S. CPI index climbed by 13.9%, while the Bureau of Labor Statistics' Employee Compensation Index (private industry wages and salaries) rose by only 10.4% according to data readily accessible from the Federal Reserve Economic Data (FRED) database, suggesting a marked decline in real employee compensation. In Glover et al (2023a and 2023b), a pair of Kansas City Fed working papers, the authors document an increase in profits and markups in 2021 and in 2022, albeit with a much stronger rise in the former year than the latter (with profit margins mechanically accounting for 41% of inflation). They note that rising markups would be consistent with a demand-side forces pushing up prices in which firms, sensing an increase in customers' willingness-to-pay and being able to hold their labor costs down, are able to charge higher prices and capture higher profits without fear of losing market share.[3] However, the studies note that the timing of the markups is more consistent with firms expecting high future marginal costs and pricing those in an anticipatory manner, a pattern consistent with previous recessions and recoveries. Conlon et al (2023) finds a similar pattern in rising aggregate markups at the aggregate level – although little correlation for individual firms. To be consistent with the empirical evidence of rising profits and falling real wages during a demand-driven expansion, I therefore include nominal wage rigidity in excess of consumption good price rigidity in my theoretical model.

This paper is concerned with the numerical solution of a dynamic stochastic general equilibrium model with heterogeneous agents. To compute the approximate solution of the economy in its non-stochastic steady-state, I employ the continuous-time methods developed in Achdou et al (2021). To compute the model's dynamics outside of the steady-state, I use a continuous-time version of the discrete cosine transformation (DCT) dimension-reduction method used in Bayer and Luetticke (2020), which may be read as a modified version of the algorithm used in Reiter (2009), to solve a linearized rational expectations model using a Schur decomposition, as in Sims (2002). In continuous time, the Bayer and Lutticke (2020) solution is similar to the method used by Ahn et al (2018) – except the former uses a DCT transformation (instead of a spline-space basis as in the latter) to reduce the dimension of the value functions, and using a fixed copula to represent the distribution households in the economy (instead of projection onto a lower-dimensional Krylov subspace characterized by the transition matrix of aggregate prices and quantities). Bayer and Lutticke (2020) shows that their method is similar in terms of numerical accuracy to the classic Krusell and Smith (1998) method, but far faster.

[3] Extending this logic just a little further, owners of corporate equity would then be able to in capture part of the real value of government stimulus via raising prices relative to costs like employee wages.

The rest of this paper proceeds as follows: section 2 describes the incomplete-markets dynamic stochastic general equilibrium model. Section 3 details the model's calibration and moments from its non-stochastic steady-state. Section 4 describes the results of the simulations, including the impulse response functions for i) expansionary and contractionary monetary policy, ii) the impact of deficit-financed spending, iii) stimulus payments to high and low income households in particular, and iv) the implications of balanced-budget redistribution policy. Section 5 concludes.

2 The Model

The model consists of a block of heterogeneous households, who collectively organize to supply labor to intermediate goods firms in exchange for wages, who then supply their output to final goods firms, which produce consumer goods via a constant elasticity of substitution aggregator, as in McKay et al (2016). The government consists of a monetary authority (central bank) that sets nominal interest rates and a fiscal authority that determines taxes households via a proportional income tax and lump-sum transfers. The government can run deficits by spending in excess of its tax revenue; it finances those deficits by issuing long-term nominal debt at the rate set by the central bank, which households buy in the bond market (thereby foregoing their claim to private current consumption goods to the government, in return for future claims to consumption when their bonds mature). Aggregate exogenous shock processes are denoted with the vector ζ; the model first solved around its non-stochastic steady-state (NSS), where the aggregate shocks are $\zeta_t = 0$. It is then linearized around the NSS to approximate the dynamics of the economy in a business cycle when the shocks deviate from zero and then mean-revert.

2.1 The Households' Problem

The heterogeneous household block of this model is built around a standard Bewley-Aiyagari incomplete markets setting, wherein a measure-one continuum of agents can save and borrow in a single liquid asset and insure themselves against fluctuations in their personal income. The model does, however, include a new feedback from expectation errors regarding the price of nominal government debt into agents' wealth, which is necessitated by the fact that government debt is long-term.

Households discount the future at a rate ρ and maximize their time-separable expected lifetime utility V by choosing paths of consumption $(c_t)_{t\geq 0}$ and $(h_t)_{t\geq 0}$, given their liquid asset position a_t and their labor skills z_t (where a and z are *idiosyncratic* state variables specific to each household). The aggregate state of the economy is described by the distribution of households across idiosyncratic states $\mu_t(a, z)$ and a vector of *aggregate* shocks ζ to tax policy and the central bank's monetary policy rule. Since each household is infinitesimally small relative to the aggregate market, they take the distribution of the economy and the resultant prices (wages w and real interest rates r_t) as given. Inter-temporal discounting is set by the preference parameter ρ.

Households earn their income from the effective units of labor ($z_t h_t$) that they supply to the marketplace, and their log skills evolve according to an Ornstein-Uhlenbeck AR(1) process with mean reversion governed by θ_z and shocks driven by a Brownian motion W_t with a variance of σ_z^2.

Households must pay a fraction τ of their wage income to the government in taxes. They must also pay lump-sum taxes $T(a_t, z_t, \zeta)$ to the fiscal authority (although $T(a_t, z_t, \zeta)$ can also be negative, in which case it is a lump-sum transfer). Households can earn a prevailing real market rate of return of r_t on their asset holdings, denoted a_t. These assets are perfectly liquid, and are claims to government liabilities (which could be interpreted as interest-bearing reserves or near-cash instruments, literal government bonds, or shares of an investment firm or bank that owns government bonds). Borrowing is subject to first a soft constraint, and the a hard constraint: households' lending rates are $r(a) = r_t + \Delta_r \mathbf{1}_{\{a \leq 0\}}$, such that interest rates go up by a wedge $\mathbf{1}_{\{a \leq 0\}}$ for households with negative holdings. The hard borrowing constraint demands that $a \geq \underline{a}$ for every agent in the economy.

The total ex-post realized return on assets dR_t in an infinitessimal time increment dt will thus include the asset's ex-ante expected real realized return $r_t(a)$, plus whatever surprise capital gains $\delta_{a,t}$ the households make on their entire portfolio driven by the movement of asset prices. In a rational expectations equilibrium, these errors are mean-zero and endogenous to the model, as in Sims (2002).

In the absence of capital stock dynamics, all assets are purely financial in nature. Corporate profits are also remitted back to households, as in other HANK papers like Kaplan, Moll, and Violante (2018) and McKay, Nakamura, and Steinsson (2016), in payments $\Pi_t(a, z)$ contingent on the households' position in the state space.

All told, the household problem can be succinctly summarized mathematically as

$$V(a_0, z_0; \mu_0, \zeta_0) = \max_{\{c_t, h_t\}} \mathbb{E}_0 \int_0^\infty e^{-\rho t} \left[\frac{c_t^{1-\gamma}}{1-\gamma} - \frac{h_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right] dt$$

$$\begin{aligned}
\text{s.t. } & da_t = [(1-\tau) w_t z_t h_t + T_t(a_t, z_t; \zeta_t) + \Pi_t(a, z) - c_t] dt + a_t dR_t \\
& d\log(z_t) = -\theta_z \log(z_t) dt + \sigma_z dW_{t,z} \\
& dR_t = r_t(a_t) dt + \delta_{a,t} \\
& r_t(a) = r_t + \Delta_r \mathbf{1}_{a \leq 0} \\
& a_t \geq \underline{a}
\end{aligned}$$

Recursively, this value function can be reformulated as

$$\begin{aligned}\rho V(a,z;\mu,\zeta) = \max_{c,h} \Bigg\{ & \left[\frac{c^{1-\gamma}}{1-\gamma} - \frac{h^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}}\right] \\ & + \frac{\partial V}{\partial a}(a,z;\mu,\zeta)\big[(1-\tau)wzh + T_t(a_t,z_t;\zeta_t) + \Pi_t(a,z) - c + r(a)a\big] \\ & + \frac{\partial V}{\partial z}(a,z;\mu,\zeta) z\left[\frac{1}{2}\sigma_z^2 - \theta_z \log(z)\right] + \frac{\partial^2 V}{\partial z^2}(a,z;\mu,\zeta)\frac{1}{2}\sigma_z^2 z^2 + \frac{\mathbb{E}_t^{\mu,\zeta}[dV]}{dt}\Bigg\}\end{aligned} \tag{2}$$

Here, I write $\mathbb{E}_t^{\mu,\zeta}$ as the expectation operator taken over *only* the aggregate state variables, *not* the idiosyncratic ones. $\frac{\mathbb{E}_t^{\mu,\zeta}[dV]}{dt}$ is thus the aggregate variables' stochastic infinitessimal generator applied to the households' value function.

From the optimal choices of $\{c(a,z;\mu,\zeta), h(a,z;\mu,\zeta)\}$, the distribution of households then evolves according to a Kolmogorov forward equation:

$$\frac{\partial \mu_t}{\partial t}(a,z) = \overbrace{-\frac{\partial}{\partial a}\left(\frac{da}{dt}\mu_t(a,z)\right) - \frac{\partial}{\partial z}\left(\frac{\mathbb{E}_t[dz_t]}{dt}\mu_t(a,z)\right) + \frac{1}{2}\frac{\partial^2}{\partial z^2}\left(\sigma^2 z^2 \mu_t(a,z)\right)}^{\text{Idiosyncratic state drifts}} \tag{3}$$

Combining the evolution of the distribution with the market clearing conditions and the policy actions of the government is then sufficient to characterize the evolution of macroeconomic aggregates in the model environment.

2.2 Organization of Labor (Unions)

In order to rationalize nominal wage rigidities (and to generate real wages and firm profits that do not move significantly with business cycle fluctuations), I adapt the union approach of Auclert, Rognlie, and Straub (2018) to continuous time, which in turn is related to Schmitt-Grohé and Uribe (2005). Namely, I follow a stylized framework wherein small unions (or alternatively, workers collaborating informally in a workplace) indexed by k supply their work to labor-aggregating agencies. For simplicity, these unions each employ a slice of all workers in the economy, such that:

$$L_{kt} = \int\int z h_t(a,z) da\ dz$$

These employment agencies (or alternatively, hiring departments at production firms) transform the labor supplied by workers using a constant-elasticity-of-substitution aggregator into the mix of labor used by production firms by hiring at each union's nominal wage rate $\tilde{w}_{kt}$:

$$L_t = \left(\int_0^1 L_{kt}^{\frac{\varepsilon_\ell - 1}{\varepsilon_\ell}} dk\right)^{\frac{\varepsilon_\ell}{\varepsilon_\ell - 1}}$$

Intermediate firms thus desire to hire according to

$$\max_{\{L_{kt}\}_{k\in[0,1]}} \; w_t \left(\int_0^1 L_{kt}^{\frac{\varepsilon_\ell-1}{\varepsilon_\ell}} dk\right)^{\frac{\varepsilon_\ell}{\varepsilon_\ell-1}} - \int_0^1 \tilde{w}_{kt} L_{kt} dk$$

where $\tilde{w}_t$ is the prevailing nominal wage at time t. Employment is demand-determined in the economy, and labor unions internalize this demand when choosing the wages they demand, all the while maximizing the collective welfare of their members. Negotiating new wages, however, is subject to Rotemberg adjustment costs, making the objective of union k

$$\max_{\pi^w_{kt}} \mathbb{E}_0 \int_0^\infty e^{-\rho t} \left[\int\int \left\{ \frac{c_t(a,z)^{1-\gamma}}{1-\gamma} - \frac{h_t(a,z)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right\} \mu_t(a,z) da\ dz - \frac{\theta_w}{2} (\pi^w_{k,t})^2 \right] dt$$

$$\text{s.t.}\ \frac{d\tilde{w}_t}{dt} = \pi^w_{t,k} \tilde{w}_t, \quad L_{kt} = \int\int z h_t(a,z) \mu_t(a,z) da\ dz, \quad \frac{L_{kt}}{L_t} = \left(\frac{W_t}{W_{kt}}\right)^{\varepsilon_\ell}$$

Where $\pi^w_{t,k}$ is wage inflation. Further details and derivations are provided in the appendix; in a symmetric equilibrium, the resulting wage Phillips Curve is

$$\frac{\mathbb{E}_t[d\pi^w_t]}{dt} = \rho \pi^w_t - \frac{\varepsilon_\ell}{\theta_w} L_t \int\int \left(\frac{1}{Z} h_t(a,z)^\eta - \frac{\varepsilon_\ell - 1}{\varepsilon_\ell} (1-\tau) z w_t c_t(a,z)^{-\gamma} \right) da\ dz \tag{4}$$

and the real wage rate evolves according to

$$\frac{dw_t}{dt} = \pi^w_t - \pi_t \tag{5}$$

Unlike Auclert, Rognlie, and Straub (2018), I do not assume that households all supply the same amount of labor. Rather, I assume that in the steady-state households work hours according to

$$\frac{1}{Z} h(a,z)^\eta = \frac{\varepsilon_\ell - 1}{\varepsilon_\ell} (1-\tau) z w c(a,z)^{-\gamma}$$

where $Z = \int\int z\mu(a,z) da\ dz$ (and in my calibration, $Z \approx 1$). In other words, households in the steady-state work approximately what their labor-leisure choice would be in absence of the union, but with a wage markup commensurate with the elasticity of demand for their hours. Outside of the steady-state, I assume all members of the workplace increase their hours worked commensurate with the change in labor demand following a shock:

$$h_t(a,z) = h_{nss}(a,z) \frac{d\mu_{nss}}{d\mu_t}(a,z) + \frac{1}{Z}(L_t - L_{nss}) \tag{6}$$

where $\frac{d\mu_{nss}}{d\mu_t}(a,z)$ is the Radon-Nikodym derivative of the measure of workers in the steady state relative to the measure of workers at time t.[4]

2.3 The Government

2.3.1 Government Debt

The model's fiscal authority collects aggregate taxes (net of transfers) equal to T_t; real government expenditures G_t are included in the following equations for generality, but are set to be zero in equilibrium. The government is able to borrow using long-term nominal bonds, as in Cochrane (2018b). As such, it can pay off existing nominal debt $\tilde{B}$ maturing at time t by either running a primary surplus or by selling new bonds with a maturity of τ at a nominal price of $Q^B_{t,t+\tau}$, which pay off a unitary nominal return when they come due. The debt flow equation is thus

$$\underbrace{\tilde{B}_t dt}_{\substack{\text{Debt}\\\text{maturing}\\\text{at time } t}} = \underbrace{p_t(T_t - G_t)dt}_{\text{Surplus}} + \underbrace{\int_0^\infty Q^B_{t,t+\tau} d\tilde{B}_{t,t+\tau} d\tau}_{\substack{\text{Financing from}\\\text{new bond sales}}}$$

I denote the real value of total government debt outstanding at time t as B_t, such that

$$B_t \equiv \frac{\int_0^\infty Q^B_{t,t+\tau}\tilde{B}_{t,t+\tau}d\tau}{p_t}$$

I next assume that bonds are purchased and priced not directly by households, but rather by a risk-neutral profit-maximizing investment fund that buys debt from the government and sells shares to the public. The central fiscal theory equation from the introduction of this paper (equation (1)), therefore takes the form presented in Cochrane (2018b):

$$\underbrace{\frac{\int_0^\infty Q^B_{t,t+\tau}\tilde{B}_{t,t+\tau}d\tau}{p_t}}_{\substack{\text{Real debt}\\\text{outstanding}}} = \mathbb{E}_t\left[\int_t^\infty e^{-\int_t^\tau r_s ds}[T_\tau - G_\tau]d\tau\right]$$

Each household that holds liquid assets by holding shares in the fund thus effectively owns a cross-sectional slice of the entire government portfolio, and receives whatever interest payments are distributed and absorbs whatever capital gains and losses the government debt accrues.

Again as in Cochrane (2018b), I make the simplifying assumption that the government issues and rolls over debt such that the density of of government liabilities by maturity is always exponentially distributed with a rate of ω, such that the cumulative distribution of outstanding government treasury maturities τ is $CDF(\tau) = 1 - e^{-\omega\tau}$ and the density function is $PDF(\tau) = \omega e^{-\omega\tau}$. Additionally, I make the simplifying

[4] The rule stipulates that if firms want more hours worked, everyone in the workplace increases their hours by a the same amount, even if they were working different amounts before, adjusting for how the distribution of workers is also different relative to the non-stochastic steady-state.

assumption that in the non-stochastic steady-state of the model, all households hold the same slice of government debt, just in varying amounts. For an individual holding a unitary slice of the total government portfolio, their assets entitle them to a payment of ωdt almost immediately (this is the shortest-term debt coming being repaid), plus payments of $\omega e^{-\omega\tau}dt$ for all periods thereafter. The entire bond portfolio is then effectively a perpetuity which pays out a geometrically declining coupon $\omega e^{-\omega\tau}dt$ at each time $t+\tau$ for the rest of time. Note that as $\omega \to \infty$, government debt becomes instantaneously short-term and must be rolled over immediately with new bonds (analogous to the continuous-time equivalent of a one-period bond in discrete time), while as $\omega \to 0$, each new bond issued becomes a perpetuity.

Changes in the value of government debt outstanding can thus be influenced by both the price of government bonds. In the appendix, I follow similar steps as in Cochrane (2018b) to show that the evolution of real government debt will be

$$dB_t = -(T_t - G_t)dt + B_t\left[i_t - \pi_t\right]dt + \frac{\delta_{qB,t}}{q_t^B}B_t \tag{7}$$

Here, $\delta_{qB,t}$ denotes the endogenous expectation error on the nominal price of government debt. Expected nominal bond prices are in turn governed by

$$E_t[dq_t^B] = q_t^B\left(i_t + \omega - \frac{\omega}{q_t^B}\right)dt \tag{8}$$

and so bond prices evolve according to

$$dq_t^B = q_t^B\left(i_t + \omega - \frac{\omega}{q_t^B}\right)dt + \delta_{qB,t}$$

as derived in the Appendix. Notably, since the bonds offer nominal payments, the nominal interest rate determines the evolution of nominal bond prices.

2.3.2 Taxes

As a baseline, the fiscal authority in the model taxes labor income at a rate of τ, such that if total effective labor employment in the economy is L_t and real wages are w_t, total income taxes are $\tau w_t L_t$ within the time increment. Households are additionally subject to lump-sum transfers, which aggregate to total lump-sum taxes $T_t(\zeta_t)$ (where if this tax is negative, it is instead a lump-sum transfer). These taxes aggregate naturally from taxes on households:

$$T_t(\zeta_t) = \int_0^\infty \int_{\underline{a}}^\infty T_t(a, z; \zeta_t)\mu_t(a, z)da\ dz$$

In the steady-state, these transfers are assumed to balance the budget; after paying for the interest expense on the debt, the government rebates its tax revenue evenly to the rest of society, such that

$$T_{nss} + \tau w_{nss} L_{nss} - r_{nss} B_{nss} = 0$$

Since more tax revenue is collected from high-earners, but the rebate is evenly distributed, the result is a progressive net transfer scheme. Outside of steady-state, however, the government does *not* necessarily balance the budget. Rather, it adjusts lump-sum transfers according to exogeneous aggregate processes:

$$T_t(a, z; \zeta_t) = T_{nss} + 4Y_{nss} \times \left(T_t^{\text{All}}(a, z; \zeta_t^{\text{All}}) + T_t^{\text{High}}(a, z; \zeta_t^{\text{High}}) + T_t^{\text{Low}}(a, z; \zeta_t^{\text{Low}}) + T_t^{\text{BB}}(a, z; \zeta_t^{\text{BB}}) \right)$$

These tax policies (driven by aggregate "shocks" ζ_t) may all be viewed as programs that send out or demand transfers of varying kinds. All of them are shocks expressed relative to annual GDP in the non-stochastic steady-state (which is $4 \times Y_{nss}$, since the model is quarterly). The first, T_t^{All}, denotes a mean-reverting increase in lump-sum taxes (or cut in benefits) on all members of society:

$$T_t^{\text{All}}(a, z; \zeta_t^{\text{All}}) = \zeta_t^{\text{All}}$$

A negative shock to $T_t^{\text{All}}(a, z; \zeta_t^{\text{All}})$ is analogous to the government printing or borrowing stimulus checks and sending them out to everyone in society. A positive shock is its (somewhat less realistic) opposite, in which the government demands its citizens to pay it flat fees.

The $T_t^{\text{High}}(a, z; \zeta_t^{\text{High}})$ is similar, but in this case, the tax is levied only on households whose wages are above the median in the population. If $\bar{z}$ is the median skill level z, it therefore follows that

$$T_t^{\text{High}}(a, z; \zeta_t^{\text{High}}) = \mathbf{1}_{\{z \geq \bar{z}\}} \zeta_t^{\text{High}}$$

The $T_t^{\text{Low}}(a, z; \zeta_t^{\text{Low}})$ is the same, but only levied on households with wages below the median:

$$T_t^{\text{Low}}(a, z; \zeta_t^{\text{Low}}) = \mathbf{1}_{\{z < \bar{z}\}} \zeta_t^{\text{Low}}$$

Naturally, if both $T_t^{\text{High}}(a, z; \zeta_t^{\text{High}})$ and $T_t^{\text{Low}}(a, z; \zeta_t^{\text{Low}})$ are active at the same time and are of the same magnitude in a linearized model, they are additively equivalent to a change in $T_t^{\text{All}}(a, z; \zeta_t^{\text{All}})$. Conversely, changes in the economy in reactions to the paths of $T_t^{\text{High}}(a, z; \zeta_t^{\text{High}})$ and $T_t^{\text{Low}}(a, z; \zeta_t^{\text{Low}})$ may be seen as a decomposition of the effects of $T_t^{\text{All}}(a, z; \zeta_t^{\text{All}})$ in the effect driven by taxes on the lower-income and the effect driven by taxes on the higher-income.

$T_t^{BB}(a,z;\zeta_t^{BB})$ is a slightly different policy than the preceding ones, in that it leaves net lump sum surpluses unchanged, and only acts through redistribution. It imagines a change in tax policy that taxes those above median income and remits those transfers to those below median income. The policy is thus set up such that

$$T_t^{BB}(a,z) = \frac{z}{Z_t}\zeta_t^{BB}\mathbf{1}_{\{z\geq\hat{z}\}} - \kappa_t^{BB}\mathbf{1}_{\{z<\bar{z}\}}$$

Where ζ_t^{BB} is the tax shock, here now scaled by $\frac{z}{Z_t}$ to make the tax yet more progressive on higher above-median earners, and where κ_t^{BB} is the flat remittance to lower-income households. If $T_t^{BB}(a,z)$ aggregates to zero to leave the federal budget unchanged (aside from the feedbacks from automatic taxes τ), it must then be that

$$\kappa_t^{BB} = \zeta_t^{BB}\frac{\int_{\bar{z}}^{\infty}\int_{\underline{a}}^{\infty}\frac{z}{Z_t}\mu_t(a,z)\;da\;dz}{\int_0^{\bar{z}}\int_{\underline{a}}^{\infty}\mu_t(a,z)\;da\;dz}$$

2.3.3 Monetary Block

The central bank directly sets nominal interest rates in the economy according to

$$i_t = r^* + \phi_\pi\pi_t + \zeta_{\mathrm{MP},t} \tag{9}$$

where r^* is the interest rate that would prevail in equilibrium in the absence of any aggregate shocks. The baseline specification sets $\phi_\pi = 0$, such that interest rates are nominally fixed. For all specifications, I maintain $\phi_\pi < 1$, such that the economy is in a "passive" monetary regime.

2.4 Firms

Intermediate and final goods firms in the model behave as in Kaplan et al (2018), although in this version of the model labor is the only input factor used in production. Final output Y_t is produced by final goods firms at the end of the supply chain using a constant elasticity of substitiution (CES) production and the output of a continuum of monopolistically competitive intermediary firms indexed by i, denoted $y_t(i)$:

$$Y_t = \left(\int_0^1 y_t(i)^{\frac{\varepsilon-1}{\varepsilon}}di\right)^{\frac{\varepsilon}{\varepsilon-1}}$$

These monopolistically competitive intermediate goods firms hire labor and produce output via the linear production function

$$y_t(i) = e^{\zeta_t^{\mathrm{tfp}}}h_t(i)$$

such that their marginal costs are simply their wage costs divided by their total factor productivity (TFP).

$$m_t = \exp(-\zeta_{\text{TFP},t})w_t$$

These intermediaries are subject to Rotemberg (1982) quadratic adjustment costs when changing their prices. As such, intermediate firms set their prices by solving the profit-maximization problem:

$$\begin{aligned} J(p_0;\zeta_0) = &\max_{\pi_t(i)} \mathbb{E}_0 \int_0^\infty e^{-\int_0^t r_s ds}\left[\frac{p_t(i)}{P_t}y_t(i) - w_t h_t(i) - \frac{\theta}{2}\pi_t(i)^2 Y_t\right]dt \\ \text{s.t. } & dp_t(i) = \pi_t(i)dt \\ & y_t(i) = e^{\zeta_t^{\text{tfp}}}h_t(i) \\ & y_t(i) = \left(\frac{p_t(i)}{P_t}\right)^{-\varepsilon} Y_t \end{aligned}$$

whose recursive formulation is

$$rJ(p;\zeta) = \max_{\pi}\left\{\left(\frac{p_t(j)}{P_t} - m_t\right)\left(\frac{p_t(j)}{P_t}\right)^{-\varepsilon} Y_t - \frac{\theta}{2}\pi^2 Y + \partial_p J(p;\zeta)\pi p + \underbrace{\frac{\mathbb{E}^{\zeta}[dJ(p,\zeta)]}{dt}}_{\mathcal{D}_\zeta J(p;\zeta)}\right\}$$

As shown in Kaplan, Moll, and Violante (2018), the solution to this problem yields the New-Keynesian Phillips Curve

$$\frac{\mathbb{E}[d\pi_t]}{dt} = \left(r_t - \frac{\mathbb{E}[dY_t]}{dt}\frac{1}{Y_t}\right)\pi_t - \frac{\varepsilon}{\theta}\left(m_t - m^*\right) \tag{10}$$

where $m^* = \frac{\varepsilon - 1}{\varepsilon}$ is a firms' marginal cost in the absence of shocks.

2.5 The Distribution of Monopoly Profits

Firms in the economy collect monopoly profits, which are in total equal to

$$\Pi_t^F = (1 - m_t)Y_t - \frac{\theta_\pi}{2}\pi_t^2 Y_t$$

To abstract away from the price adjustment costs, I assume that these are rebated back to households as the income of a separate firm, such that profits from the entire corporate sector are $\Pi_t = \Pi_t^F + \frac{\theta_\pi}{2}\pi_t^2 Y_t = (1 - m_t)Y_t$.

Like in McKay, Nakamura, and Steinsson (2016), households are rebated these profits directly; this allows the model to avoid a discussion of the evolution of equity markets outside of the steady-state. However, as in Kaplan, Moll, and Violante (2018), households receive these profits as "bonuses," with higher-income households receiving a larger share, to keep the redistribution scheme from significantly changing the income inequality features of the economy. As such, the profit flows to households take the simple form

$$\Pi_t(a,z) = \frac{z}{Z_t}\Pi_t \tag{11}$$

2.6 Aggregate Exogenous Stochastic Processes

The aggregate exogenous stochastic process vector is $\zeta_t = (\zeta_t^{\text{MP}}, \zeta_t^{\text{All}}, \zeta_t^{\text{High}}, \zeta_t^{\text{Low}}, \zeta_t^{\text{BB}})'$. The first entry pertains to a monetary policy shock, while the latter four refer to perturbations to tax policy, as discussed in Section 2.3.2. Collectively, the shocks evolve according to the Ornstein-Uhlenbeck process

$$d\zeta_t = -\Theta_\zeta \zeta_t dt + dW_{\zeta,t} \tag{12}$$

where $dW_{\zeta,t}$ is a vector of mean-zero independent stochastic innovation terms. The model considers shocks to each of the vectors independently, one at a time. As such, the model numerical simulation assumes the mean-reversion matrix component of the process to be diagonal:

$$\Theta_\zeta = \begin{bmatrix} \theta_{\text{MP}} & 0 & 0 & 0 & 0 \\ 0 & \theta_{\text{Tax}} & 0 & 0 & 0 \\ 0 & 0 & \theta_{\text{Tax}} & 0 & 0 \\ 0 & 0 & 0 & \theta_{\text{Tax}} & 0 \\ 0 & 0 & 0 & 0 & \theta_{\text{Tax}} \end{bmatrix}$$

such that the exogenous shocks to tax policies all share the same mean-reversion parameter.

2.7 Market Clearing and Equilibrium

Note that in a symmetric equilibrium, total output is

$$Y_t = \exp(\zeta_t^{\text{tfp}})L_t \tag{13}$$

And if the inflation adjustment costs $\frac{\theta}{2}\pi_t^2 Y_t$ is rebated back to households, then in the absence of government spending and physical investment

$$Y_t = C_t + \underbrace{\int_0^\infty \int_{\underline{a}}^\infty \mathbf{1}_{\{a<0\}} \Delta_r a \mu_t(a,z) da\ dz}_{\text{Financial Fees}} \tag{14}$$

where aggregate consumption is

$$C_t = \int_0^\infty \int_{\underline{a}}^\infty c_t(a,z)\mu_t(a,z)da\ dz$$

and the aggregate labor demand is equal to the total effective hours worked by households:

$$L_t = \int_0^\infty \int_{\underline{a}}^\infty zh_t(a,z)\mu_t(a,z)da\ dz \tag{15}$$

The total amount of assets also further be equal to the total amount of government debt

$$A_t = \int_0^\infty \int_{\underline{a}}^\infty a\mu_t(a,z)da\ dz$$
$$A_t = B_t \tag{16}$$

A equilibrium in the mean field game given a sequence of aggregate shocks $(\zeta_t)_{t\geq 0}$ is therefore

i. a set of household decisions for consumption across idiosyncratic states and over time $(c_t(a,z))_{t\geq 0}$ that solves (2) given the path of prices prices, transfers, profits, and aggregate shocks

ii. a distribution of idiosyncratic household states μ_t that evolves over time according to (3)

iii. A sequence of aggregate effective hours $(L_t)_{t\geq 0}$ worked determined by firms' labor demand (which is in turn determined by output and the demand for consumer goods), and idiosyncratic hours worked $h_t(a,z)$ determined by unions' labor rules (6)

iii. A sequence of inflation consistent with firms' profit maximization problem given prices, i.e. the Phillips Curve (10) (where marginal cost is determined by wages)

iv. A sequence of nominal wage inflation consistent with the unions' maximization problem and resulting wage Phillips Curve (4)

iv. A sequence of nominal government bond prices $(q_t^B)_{t\geq 0}$ consistent with the dynamic equation (8)

v. Profit disbursal to households $(\Pi_t(a,z))_{t\geq 0}$ in accordance with (11)

vi. Sequences of macro aggregates $(Y_t, C_t, L_t, A_t, B_t)_{t\geq 0}$ consistent with their definitions (and therefore the household decision rules and distribution equations and the production functions)

vii. Sequences of real wages and real rates of return $(w_t, r_t)_{t\geq 0}$, where w_t evolves according to (5) and r_t obeys the Fisher equation $r_t = i_t - \pi_t$

viii. Government taxes and transfers across the population and over time $(T_t(a,z))_{t\geq 0}$

such that

1. Total output is produced as in (13)
2. the asset market clears, as in (16)
3. the labor market clears (and so by Walras' law, the goods market clears) (15 and 14)
4. interest rates ($(i_t)_{t\geq 0}$) are set according to the central bank's policy rule (9)
5. tax policy is consistent with the government's fiscal rules (summarized in section 2.3.2).

Computationally, the model is first solved around its non-stochastic steady-state (NSS) using a finite difference scheme similar to the kind put forward by Achdou et al (2021). To generate the impulse response functions of the economy in response to aggregate shocks, the system is subjected to a dimension reduction routine demonstrated in Bayer and Luetticke (2020) and linearized around its NSS and perturbed as in Ahn et al (2018). In doing so, the value function is projected down onto a hierarchical Chebychev polynomial basis via a discrete cosine transform (DCT), where only the Chebychev polynomials that explain the largest amount of variation in the value function are perturbed from their steady-state values. Additionally, the distribution function is projected onto a fixed copula, where the idiosyncratic variables' joint distribution is assumed to be characterized by the evolution of the idiosyncratic marginal distributions.[5] The entire process treats the differential equations in the model (like the Hamilton-Jacobi-Bellman equations and the Kolmogorov Forward Equation) as a large system of inter-related stochastic ordinary differential equations. Once this discretization and dimension reduction has been completed, the model is then solved using methodologies standard to the solution of linear rational expectation models, namely a QZ (Schur) decomposition, as in Klein (2001) and Sims (2002). For the model to have a uniquely determined stochastic solution, its Jacobian must have exactly as many explosive (positive) generalized eigenvalues as the system has jump variables (which here include the discretized value function, inflation, and the bond and equity prices); I verify that this is indeed the case for my system. Further details are provided in the appendix.

One may note that among the equations that I have listed, one of them is actually redundant: the aggregate law of motion (7) can be used to track the evolution of the market value of government debt, but since households hold the government's bonds as assets, the private sector's total bond position may be calculated by using the Kolmogorov forward equations (3) and aggregating using (16). In all of my numerical simulations, I calculate the evolution of the stock of government debt both ways, and then observe the percentage difference as a test of my model's numerical accuracy. Overall, the errors in the simulated time series are on the order of 5×10^{-6}.

[5] Bayer and Luetticke (2020) note that this will be a good approximation if the rank correlations of the distributions are not strongly affected by the shocks, which they observe to be the case in models like the one in Krusell and Smith (1998), to which my model's household sector is highly similar.

3 Calibration

3.1 Model Parameters

For this paper, I target the same income process moments used in McKay, Nakamura, and Steinsson (2016), except for the continuous-time analogue of their discrete-time process. I similarly calibrate ρ to achieve a an annual interest rate of 2% (the selected value, $\rho = 0.01575$, is equivalent to an annual discount rate of $e^{-4\rho} = 0.938$). I retain the same relative risk aversion coefficient of $\gamma = 2$ – although coefficients ranging from between 1 and 2 are common in the HANK literature (for example, log utility is used in Kaplan, Moll, and Violante (2018)). The parameters, along with their rationals, targets, or sources, are displayed in Table 1.

Like Kaplan, Moll, and Violante (2018), I target a slope of the Phillips Curve of 0.10. However, Auclert, Bardoczy, and Rognlie (2021) suggest that nominal wage rigidities capture several important features of the micro data, like low marginal propensities to earn in the micro data, than conventional final goods price rigidities do. As such, I set final goods price nominal rigidities to be very low (1% of the wage rigidities), and make the nominal wage Phillips Curve to have a slope of 0.10. This allows the model to capture similar overall inflation dynamics as other calibrations in the literature: with more flexible prices, monopolistically competitive firms are better able to completely pass changes to their marginal costs along to households, keeping their markups relatively constant. Workers, in contrast, face a compressed surplus due to nominal wage rigidities during an economic expansion, due to the time and effort that it takes to change their wages. Since they are not on their competitive labor supply curves, workers still increase their hours to meet their employers' demands, but their surplus per hour worked falls.

Table 1: Baseline Parameters

Parameter	Symbol	Value	Source or Target
Relative Risk Aversion	γ	2.0	McKay et al (2016)
Quarterly Time Discounting	ρ	0.01575	$r = 2\%$ annually
Borrowing Limit	$\underline{a}$	-1.0	$\approx$30% of avg income
Frisch Elasticity of Labor	η	0.5	Chetty (2012)
Borrowing Wedge Rate	Δ_r	0.02	Kaplan et al (2018)
Idiosyncratic Shock Variance	σ_z^2	0.017	McKay et al (2016)
Idiosyncratic Shock Mean Reversion	θ_z	0.034	McKay et al (2016)
Intermediary Elasticity of Substitution	ε	10	10% profit share of GDP
Rotemberg price adjustment cost	θ_π	1% of wage rigidities	
Labor Elasticity of Substitution	ε	10	Philips Curve slope of 0.10
Rotemberg wage adjustment cost	θ_w	100	Phillips curve slope of 0.10
Steady-state government debt	B_{nss}	5.26	Debt/GDP of 1.33
Geometric maturity structure of debt	ω	0.043	Avg. maturity of 70 months
Income Tax Rate	τ	0.20	
Mean reversion of monetary shock	θ_{MP}	0.175	4-quarter shock half-life
Mean reversion of fiscal shocks	θ_{Tax}	1.0	

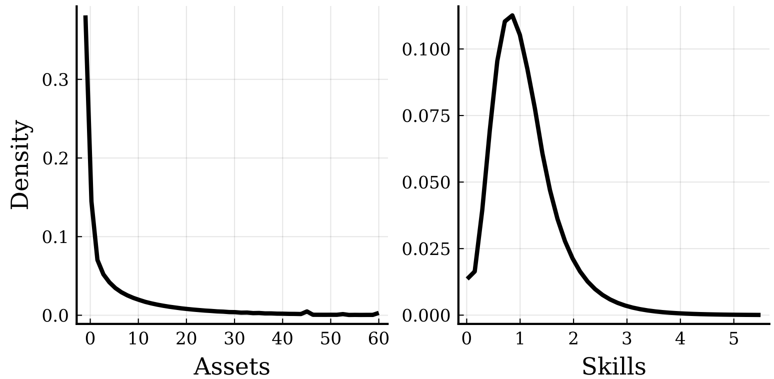

Figure 1: Distribution of assets and income (skills) in the non-stochastic steady-state.

For the mean reversion of the shocks, a monetary policy shock is assumed to have a half-life of 4 quarters. In contrast, the mean reversion of fiscal shocks is made to be much stronger with $\theta_{\text{Tax}} = 1.0$. This is intended to better reproduce the speed with which stimulus checks may be sent out; after 4 quarters, the fiscal shocks almost entirely dissipate. Since the path of the shock in the absence of further perturbations may be described with

$$\zeta_t^{\text{All}} = e^{-\theta_{\text{Tax}} t}$$

this also means that the cumulative effect of an initial shock of $\zeta_0^{\text{All}} = -0.01$ has the interpretation of a 1%-of-annual-GDP disbursal of lump-sum stimulus checks, which in the United States would have implied a spending program of roughly \$210 billion dollars if 2019's GDP and prices represented the steady-state.

3.2 Non-Stochastic Steady-State

The non-stochastic steady state is solved by setting all aggregate shocks $\zeta_t = 0$. The model is not able to match the United States income Gini coefficient, which the Census Bureau reported as around 0.48 (before taxes) in 2018. The model also slightly undershoots measures of liquid wealth inequality, which Kaplan, Moll, and Violante estimate to be roughly 0.98. Even so, the model generates a large mass of households with little-to-no savings; 38% of the households have a net worth of zero or less. Both the distribution of assets a and skills z (which mechanically matches the model's distribution of pre-tax wages) are depicted in Figure 1.

Table 2: Non-Stochastic Steady-State Moments

Moment	Model Value
Debt/GDP Ratio	1.33
Earnings Gini	0.30
Wage Gini	0.31
Wealth Gini	0.859
Wage and Asset Correlation	0.520

4 Results

In simulating the economy's response to various shocks, I consider the contemporaneous and cumulative effects of the policy perturbations. To calculate the cumulative inflation rate, I simply calculate the price level over time as

$$p_t = e^{\int_0^t \pi_\tau d\tau}$$

and normalize the pre-shock price level to 1. For the growth of GDP, I similarly accumulate

$$\Delta Y_t = \frac{\int_0^t (Y_\tau - Y_{nss}) d\tau}{Y_{nss}}$$

to gauge the percentage growth of the economy following the shock relative to the non-stochastic steady-state. I define my measure of the sacrifice ratio as the average decline in GDP required to bring prices down by a cumulative 1%. If I truncate the cumulative changes to time horizon t, then this means the sacrifice ratio observed in the economy as of time t is

$$SR_t = \frac{\Delta Y_t}{p_t}$$

The first simulation I conduct is a 1% decrease to the nominal interest rate by the country's central bank. Since government bonds are nominally denominated, this mechanically means a jump in nominal bond prices; a slow-to-adjust price level means that real bond prices rise, while real interest rates fall. In the typical intertemporal substitution mechanism, new debt becomes more expensive to finance and saving becomes more attractive. This force is added to by the fact that the jump in bond prices induces a positive wealth effect amongst savers, causing their consumption to slightly rise as well. The increase in labor demand then means more hours worked and slightly higher wages across the economy. Agents without any savings (who otherwise would have taken on debt, had it not been for the borrowing limit or higher borrowing interest rates) pass the transitive shock into consumption increase, further amplifying the rise in demand. The end result is a transitory expansion and inflation in the short term, as shown in Figure 2. The model is linearized with respect to aggregate shocks, so the effects of instead *raising* interest rates can be deduced by flipping the sign of the impulse response functions, with low-asset high-MPC households facing little choice other than to ride out the fall in their labor incomes with cutbacks to their own consumption when demand falls, exacerbating the contraction.

All of this so far looks like the typical RANK or HANK story. However, without active monetary policy to adjust interest rates to respond to inflation and force it back toward zero immediately, the model begins to exhibit the neo-Fisherian properties documented by the representative agent model in Cochrane (2018b). Namely, because money is neutral in the economy, the economy begins to adjust to the low nominal interest

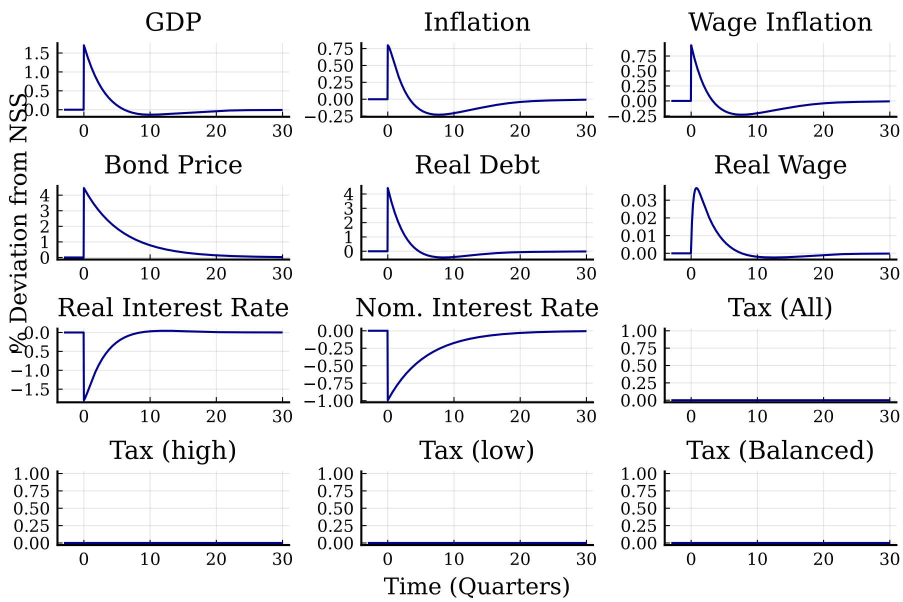

Figure 2: Impulse response functions to a 1% decrease in nominal interest rates.

rates with a decrease in the inflation rate and the price level in order to bring the real rate back toward its value in the absence of shocks. This deflation begins to counteract the initial inflationary impulse, generating a "stepping-on-a-rake" effect, as discussed in Sims (2011) and Cochrane (2018b). For example, a year after the *contractionary* version of the shock (a 1% *increase* in rates), for instance, the price level is 1.06% lower, but after 8 quarters the price level has already returned to and exceeded its pre-shock value. After that, the high rates become inflationary, to the point that after 30 quarters (long after the shock has played out), prices are 1.34% *higher* in response to the persistent monetary tightening. As such, the sacrifice ratio appears to be 2.92 to the agents living in the economy for the first quarter following the shock. However, it appears almost twice as large after a year has elapsed, and becomes unbounded before flipping its sign entirely (when on net, the price level begins to inflate). As such, in the model economy, fiscal theory stipulates that interest rates can achieve disinflation in the short-term, only to have inverse effects in the long-term.

Returning to the case plotted in the impulse response functions, wherein interest rates were lowered by the central bank, this means that the low rates eventually drive the price level *lower*, as documented in the first four columns of Panel A of Table 3.

How much does the federal government's ability to "tax the boom" matter for the amount of inflation or deflation generated by the shock? To assess this, I repeat the same experiment, but instead have the government spend its automatic stabilizer revenue instead of using it to back and pay down the debt. The government thus purchases

$$G_t = \tau(w_t L_t - w_{nss} L_{nss}) \tag{17}$$

from firms directly, modifying the goods market clearing equation to

$$Y_t = C_t + G_t + \int_{\underline{a}}^{\infty} \mathbf{1}_{\{a<0\}} \Delta_r a \mu_t(a,z) da \, dz \tag{18}$$

The resulting cumulative changes in GDP and inflation after 30 quarters are reported in the fifth column of Table 3. The governments' new purchases act to yet further stimulate the economy during the monetary policy-driven expansion, causing output to grow by even more than it did in the baseline experiment. The government forsaking the use of the new revenue for debt repayment does produce a slight inflationary force, as more debt must instead be inflated away in equilibrium. However, the effect is very small, on the order of adding 0.07 percentage points to the overall amount of inflation generated by monetary policy.

Table 3: Monetary Policy Shock: Cumulative Inflation and Real GDP

	Quarters After Shock				Government Spends New Revenue
Cumulative Variable	1	4	8	30	30 Quarters
Monetary Expansion					
Real GDP (%)	3.42	3.63	3.17	2.29	3.07
Inflation (%)	1.17	0.64	-0.21	-1.34	-1.27
Sacrifice Ratio	2.92	5.64	-	-	-

Note: Since the the sacrifice ratio for monetary policy blows up and flips sign at around 10 quarters due to neo-Fisherian effects, I do not calculate it for monetary policy's 8 and 30 quarter horizons.

Proceeding to the next simulation, I generate the impulse response functions reported in Figure 3. A 1% of steady-state GDP lump-sum payment to all households leads to a sharp increase in GDP as relatively hand-to-mouth households pass the increase in income into lower spending, which in turn causes a jump in hiring and further increases in income and spending. Inflation ensues to diminish the real amount of government debt outstanding, as the expenditure was not backed by new taxes, although automatic stabilizers are able to partially offset the effect by providing more net income to the government's coffers. Surprisingly, despite the tax increase, the real value of the debt temporarily *falls*.[6] This is largely because the inflation response is strong enough to move real rates into negative territory; this occurs as the supply side of the economy struggles to mobilize productive factors to support the boom and marginal costs rise.

All told, sending stimulus checks to all agents in the economy in an expenditure equal to 1% of GDP ends up growing the economy by 1.88% over time at the cost of an additional 0.61 percentage points of inflation (where in the very short-term, the rate of additional inflation experienced by agents in the first year is over 1.14%). If the government had gone the other way, and demanded fees from the public instead of distributing checks, the sacrifice ratio would thus have amounted to 2.44 by the end of the simulation window.

[6] Note that in the previous experiment with monetary policy, this dynamic was masked by the surge in bond prices. Since the central bank keeps the interest rate constant in the tax policy experiment, nominal bond prices do not move.

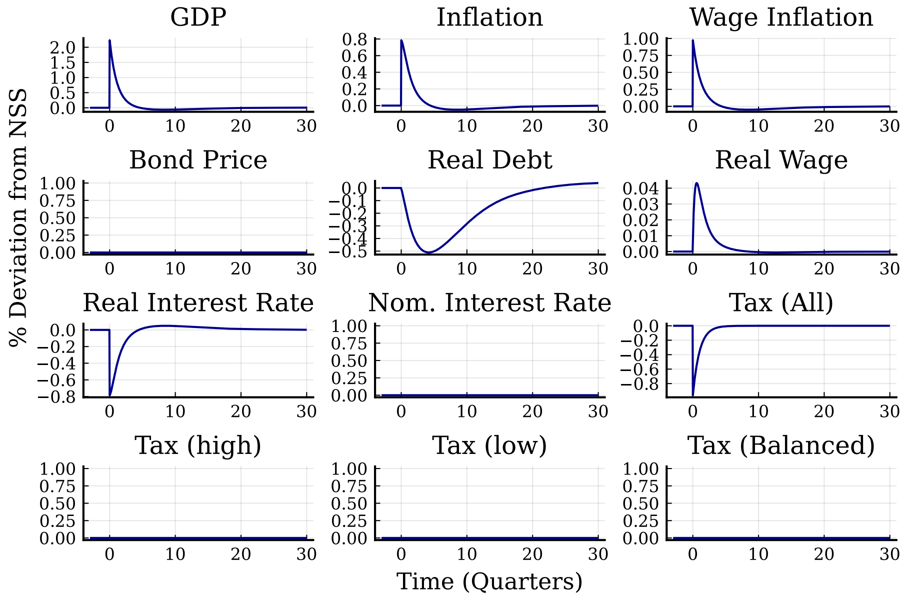

Figure 3: Impulse response functions to a mean-reverting decrease in lump-sum taxes on all households.

Table 4: Fiscal Policy Shocks: Cumulative Inflation and Real GDP

	Quarters After Shock				Government Spends New Revenue
Cumulative Variable	1	4	8	30	30 Quarters
Panel A: Tax Shock (All)					
Real GDP (%)	2.47	2.38	2.14	1.88	2.54
Inflation (%)	1.14	1.06	0.88	0.61	0.67
Sacrifice Ratio	2.17	2.29	2.24	2.44	3.78
Panel B: Tax Shock (High Income)					
Real GDP (%)	1.74	1.79	1.60	1.30	1.74
Inflation (%)	1.02	1.07	0.93	0.63	0.68
Sacrifice Ratio	1.71	1.68	1.72	2.04	2.56
Panel C: Tax Shock (Low Income)					
Real GDP (%)	3.32	3.09	2.77	2.58	3.49
Inflation (%)	1.28	1.06	0.81	0.58	0.66
Sacrifice Ratio	2.61	2.91	3.42	4.47	5.28

Note: All tax shocks are equal to stimulus transfers amounting to 1.0% of GDP, while the monetary shock is a 1.0% nominal interest rate decrease. The cumulative effects in Panel A may be recovered by averaging the cumulative effects in Panels B and C with the weights 0.54 and 0.44, respectively. Since the the sacrifice ratio for monetary policy blows up and flips sign at around 10 quarters due to neo-Fisherian effects, I do not calculate it for monetary policy's 8 and 30 quarter horizons.

I next decompose the overall fiscal shock into two components: the stimulus check rebate to high-wage agents (who are on average wealthier), and the stimulus check rebate to low-wage agents (who are on average poorer). Note that now, since each of the shocks fall on only half of the population, I adjust the size of the tax shocks to keep the implied expenditure plans equal to 1.0% of annual steady-state GDP (and thus comparable to the earlier simulations); averaging the results of the two shocks yields the effects of Figure 3 composite shock.[7] I

[7] Due to the coarseness of the income space grid, however, the upper-income group is actually divided at those making more than the 46th percentile, as opposed to the 50th. As such, the weights for averaging the high-income tax simulation with the low income tax to obtain the Figure 3 are 0.56 and 0.44, respectively. The initial tax shocks are similarly scaled accordingly to keep the total expenditure shock the same across simulations.

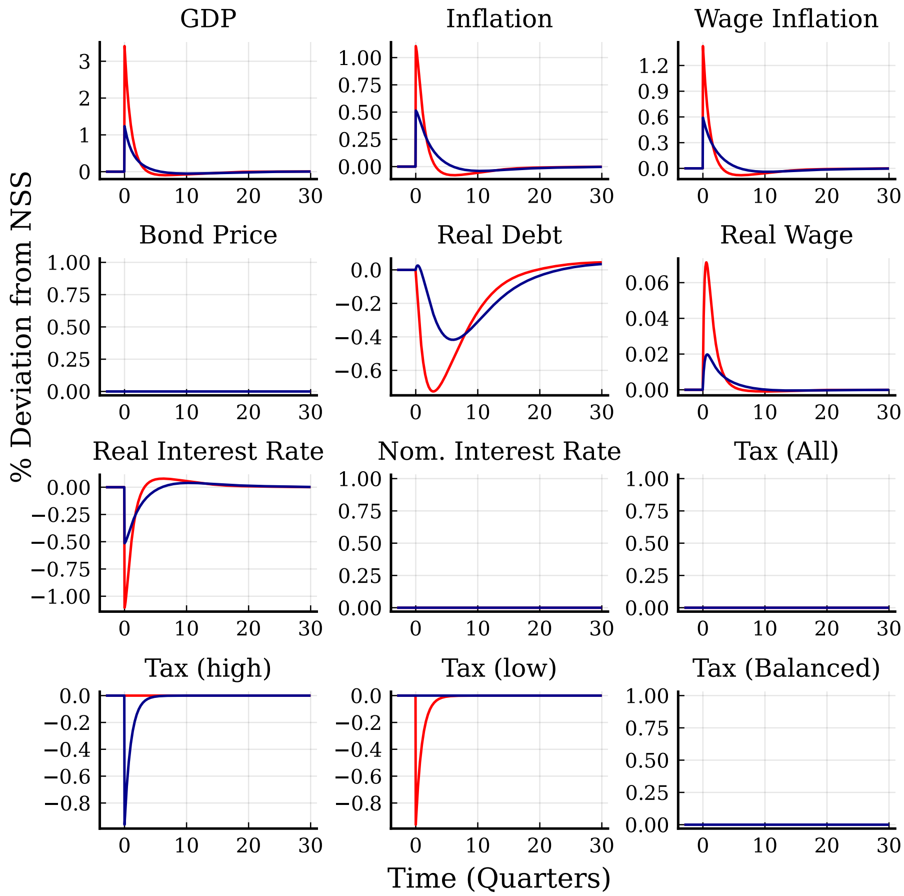

Figure 4: Impulse response functions to mean-reverting stimulus check payments to high-income and low-income households. The policy that sends checks to high-income households is plotted in dark blue, while the policy that sends checks to low-income households is plotted in bright red.

plot both sets of impulse response functions in Figure 4; the policy where checks are sent out to low-income households is plotted in bright red, while the policy that sends checks out to high-income households is depicted in dark blue.

Looking first at the effects of sending checks to the high-wage agents, the economy still expands upon impact, but only by 1.2% instead of delivering the 3.8% output boom experienced immediately in the world where the equivalent value of checks are sent out to lower-income households. Automatic stabilizer revenue from proportional income taxes (not depicted) surge by similar amounts, as real wages are highly stable (companies defend their markups almost completely, passing along the increase in labor costs directly to consumers, resulting in little change to wages' overall purchasing power) and hours worked go up. Debt, too, falls even faster in the simulation where the low-income receive the stimulus checks, as it is devalued even more by the stronger initial inflation response. In the first quarter, the differences in inflation are large; the scenario in which the low-income receive checks experiences 1.28% inflation, while in the case where the higher-income households received checks, the inflation rate in the first quarter reached only 1.02%. By the end of the year, however, the difference in the cumulative amount of inflation experienced in the two different scenarios becomes almost zero, as the inflation endured when the high income receive checks is more sustained. Over a longer time horizon (30 quarters), it is actually the case that total inflation endured in the setting where the low-income received checks is actually slightly *lower* than the amount endured when the high-income were the recipients, as shown the fourth column of panels B and C in Table 4. The gap is about 0.05 percentage points of inflation, a tiny amount. The last column of Table 4, panels B and C indicates that the tax-the-boom effect to balance the budget contributed about 0.03 percentage points to this difference; when the government simply spends its new labor income tax revenue instead of saving it, inflation (and output) rise in both scenarios, but the difference in inflation between the low-income stimulus checks and high-income stimulus check scenarios falls to 0.02. Either way, the restoration of the government's balance sheet and the exact timing of the fall in real interest rates does not appear to significantly bear on the total amount of inflation generated by the policies over time. By contrast, the difference in the implied ratios of additional GDP growth to additional inflation in the scenarios where the recipients of the checks are different is striking. When the high-income receive the checks, the economy goes on to grow by roughly 2.04% for every percentage point of inflation. When the low-income get the checks, the ratio is more than double (4.47) after all of the shocks have played out by the end of the 30th quarter. As recounted in the first 3 columns of Table 4, the pattern of higher cumulative GDP relative to inflation induced when checks are distributed to the low-income is present at all of the intermediate time horizons as well.

Going in the other direction, toward fiscal contraction, taxing the low-income carries a dramatically higher sacrifice ratio. The new revenue restores confidence that the government will not partially default by inflating away its obligations, restoring faith in the currency and the government's debt, but at a grievous cost to real output. The same dis-inflationary effect is roughly accomplished by taxes higher-income households, but with a far less severe economic downturn.

All of the cumulative responses to the different policies are depicted in Figure 5.

What happens when the government pursues a policy wherein it taxes the rich and rebates the proceeds back to the poor? The aftermath of such a policy is presented in Figure 6. The movement of resources from low-MPC to high-MPC households generates an immediate economic boom, slightly lower than that experienced when checks were distributed to low-income households alone, but still larger than when they were distributed to high-income households. The increase in economic activity drives wage inflation as households negotiate higher wages to work more hours, which companies pass on to end consumers to protect their profits. However, since no deficits are actually incurred by the policy redistribution policy, FTPL implies that the cumulative amount of inflation experienced should be zero; there is no new unbacked debt to inflate away. Figure 7 shows that this is the case as the time horizon under consideration grows longer. After the first year following the policy, the economy experiences a mild deflation, raising interest rates as households buy back bonds that were cheaper

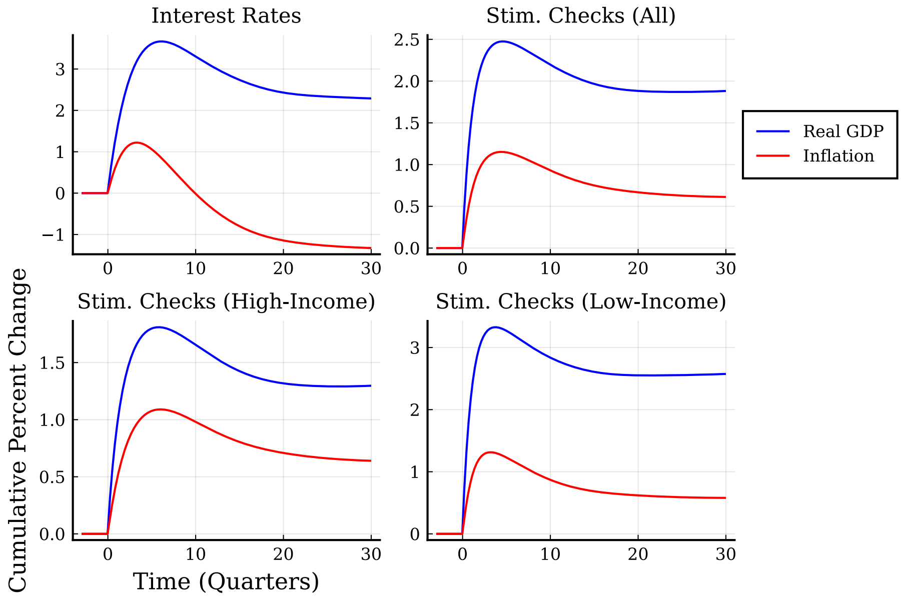

Figure 5: Cumulative responses of real GDP and inflation to expansionary shocks.

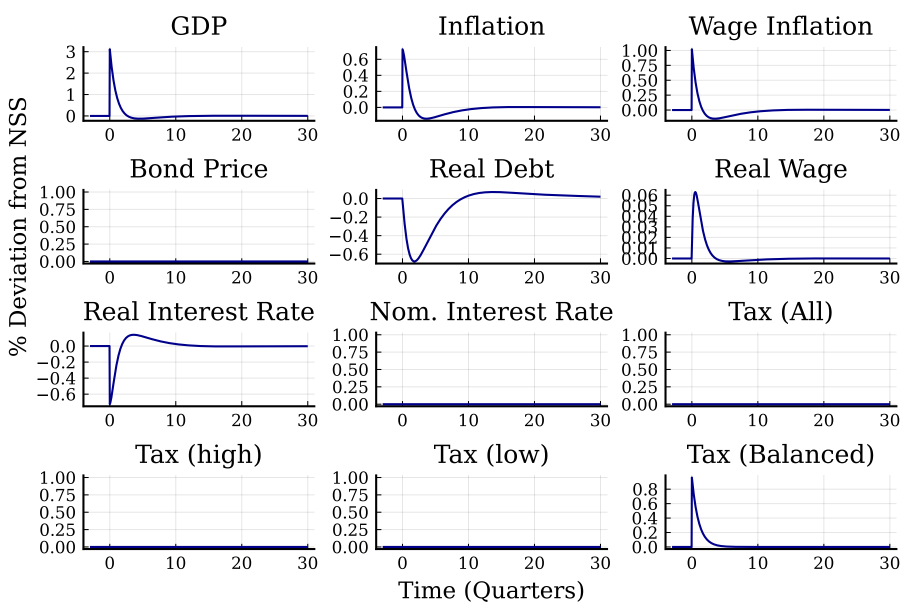

Figure 6: Impulse response functions to a mean-reverting increase in lump-sum taxes on high-income households with the proceeds remitted to low-income households.

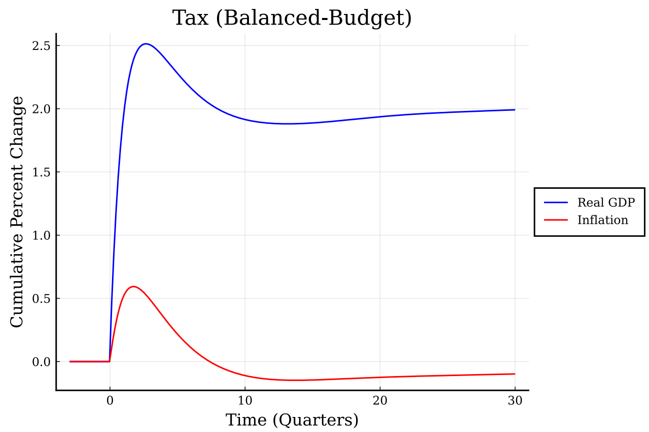

Figure 7: Cumulative effects on inflation and output following a balanced-budget transfer from high-to-low income households.

during the boom. Over time, the price level (not just the rate of inflation) converges back to where it started, before the fiscal transfers were made (the surge in automatic revenues also makes the government debt more valuable, making the transfer scheme slightly *deflationary* in the long-run, but the magnitude of the effect is small).

5 Discussion

The model presented in this paper drives to a few simple conclusions. First, the accounting of fiscal theory makes it look as though the main determinant of a fiscal policy's overall net inflationary force is mainly determined by the overall size of the fiscal spending shock to the economy. Automatic stabilizers and the timing of inflation and real rates can potentially complicate this picture – but ultimately the simulations suggest that these complications are small. Thus, if a government sends out stimulus checks unbacked by future taxes, the model predicts that when it comes to the total cumulative amount of inflation sparked by a policy, the amount denominated by the checks matters much more than who gets them.[8]

The intuition of this result might be somewhat surprising, in that it is contrary to the intuition that one might have about giving money to "high-velocity" versus "low-velocity" consumers having different consequences for inflation, wherein the average speed of subsequent spending might determine how inflationary a transfer ultimately is. However, in the framework of fiscal theory, the result is straightforward: if inflation is about markets participants' confidence in the government's ability to pay its debts, or the currency's usefulness as a means of settling taxes with the fiscal authority, then the size of unfunded deficits is what is of first-order importance.

The second implication in this paper is similarly straightforward. The HANK literature suggests that

[8]Of course, if acute inflation is more painful to consumers than a protracted but more moderate inflation, the exact path of inflation may matter more. However, in all of the simulations, the majority of inflation is over by the end of the first year following the policy shock.

transfers to people who of varying liquid asset positions generates heterogeneous effects on aggregate expenditure, income, and output. Namely, transfers to the poor who must spend their income almost as soon as they receive it start feedback loops that cause larger economic expansions than transfers to wealthier people do. If wealth is correlated to income, which governments can observe more easily, then transfers to low-income people make sense if policymakers are seeking to stimulate the economy. Taking resources away from poor people, by contrast, provides a steeper contraction in economic activity, all else equal.

The upshot of these two points is that if a government is trying to stimulate the economy with the least amount of inflation possible, it should set the overall size of the program first and then tilt its stimulus efforts toward those it believes have a high marginal propensity to consume. If fiscal theory is correct, then the amount of inflation is relatively insensitive to the payments' recipients, but the amount of economic activity generated is larger when the recipients go out and spend their income relatively quickly. An insensitive denominator and a sensitive numerator combine to suggest that stimulus checks to those without liquid savings represent a superior GDP-to-inflation trade-off than alternative policies.

Alternatively, if a government is trying to *lower* inflation, fiscal theory stipulates that inflation from a one-time fiscal shock is eventually transitive, even without strong intervention from monetary policy; once the excess nominal debt is inflated away, the inflationary pressure will subside. Monetary policy is also not necessary for determinacy, as Cochrane (2023) discusses at length, and higher interest rates may assist in the fight against inflation in the short-term, only to become counter-productive in the longer-term. If a country wants to tamp down on inflation and end it earlier than later, however, FTPL suggests that fiscal policy and reform can play a greater role in restoring faith in a country's currency. However, from the logic of the previous paragraph, a fiscal reform accomplished by transferring resources away from those with low assets and low income likely carries with it a much high sacrifice ratio. Markets can still get the message that the debt and currency will be honored from a fiscal reform that raises taxes on agents whose spending is less sensitive to their income, with less of a hit to employment and consumption.

But for all of its mathematical coherence, is fiscal theory right, in the sense that it is the the correct model of inflation out in the real world? In another sense, this paper broaches an interesting empirical test for those interested in fiscal theory. For countries in inflationary episodes, particularly following deficit spending or new currency issuance with a signal of little willingness or ability to raise future surpluses, is the amount of ensuing inflation at all related to who gets the spending, or is it just a matter of how much spending or currency is issued? Finding clear examples of such cases in the real world is likely difficult (much less finding enough of them to conduct statistical inference), but if the relative size of the spending program appears to matter for inflation in the data, then that may be interpreted as evidence in support of fiscal theory. If this is not the case, however, then FTPL may have to be reconsidered, amended, or ultimately rejected. Until then, FTPL's interaction with heterogeneity and demand-determined economies with nominal rigidities opens interesting opportunities for new theory and its implications for policy.

References

Acharya, Sushant and Keshav Dogra (2020). "Understanding HANK: Insights From a PRANK". In: *Econometrica* 88.3, pp. 1113–1158. DOI: 10.3982/ECTA16409. URL: https://ideas.repec.org/a/wly/emetrp/v88y2020i3p1113-1158.html.

Achdou, Yves, Jiequn Han, Jean-Michel Lasry, Pierre-Louis Lions, and Benjamin Moll (2021). "Income and Wealth Distribution in Macroeconomics: A Continuous-Time Approach". In: *The Review of Economic Studies* 89.1, pp. 45–86. ISSN: 0034-6527. DOI: 10.1093/restud/rdab002. eprint: https://academic.oup.com/restud/article-pdf/89/1/45/42137446/rdab002.pdf. URL: https://doi.org/10.1093/restud/rdab002.

Ahn, SeHyoun, Greg Kaplan, Benjamin Moll, Thomas Winberry, and Christian Wolf (2018). "When Inequality Matters for Macro and Macro Matters for Inequality". In: *NBER Macroeconomics Annual* 32, pp. 1–75. DOI: 10.1086/696046. eprint: https://doi.org/10.1086/696046. URL: https://doi.org/10.1086/696046.

Alves, Felipe, Greg Kaplan, Benjamin Moll, and Giovanni L. Violante (2020). "A Further Look at the Propagation of Monetary Policy Shocks in HANK". In: *Journal of Money, Credit and Banking* 52.S2, pp. 521–559. DOI: https://doi.org/10.1111/jmcb.12761. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/jmcb.12761. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/jmcb.12761.

Auclert, Adrien, Bence Bardóczy, and Matthew Rognlie (2023). "MPCs, MPEs, and Multipliers: A Trilemma for New Keynesian Models". In: *The Review of Economics and Statistics* 105.3, pp. 700–712. ISSN: 0034-6535. DOI: 10.1162/rest_a_01072. eprint: https://direct.mit.edu/rest/article-pdf/105/3/700/2089959/rest_a_01072.pdf. URL: https://doi.org/10.1162/rest%5C_a%5C_01072.

Auclert, Adrien, Matthew Rognlie, and Ludwig Straub (2018). *The Intertemporal Keynesian Cross*. Working Paper 25020. National Bureau of Economic Research. DOI: 10.3386/w25020. URL: http://www.nber.org/papers/w25020.

— (2020). *Micro Jumps, Macro Humps: Monetary Policy and Business Cycles in an Estimated HANK Model*. Working Paper 26647. National Bureau of Economic Research. DOI: 10.3386/w26647. URL: http://www.nber.org/papers/w26647.

— (2023). *The Trickling Up of Excess Savings*. Working Paper 30900. National Bureau of Economic Research. DOI: 10.3386/w30900. URL: http://www.nber.org/papers/w30900.

Autor, David, David Cho, Leland D. Crane, Mita Goldar, Byron Lutz, Joshua Montes, William B. Peterman, David Ratner, Daniel Villar, and Ahu Yildirmaz (2022). "The $800 Billion Paycheck Protection Program: Where Did the Money Go and Why Did It Go There?" In: *Journal of Economic Perspectives* 36.2, pp. 55–80. DOI: 10.1257/jep.36.2.55. URL: https://www.aeaweb.org/articles?id=10.1257/jep.36.2.55.

Bayer, Christian and Ralph Luetticke (2020). “Solving discrete time heterogeneous agent models with aggregate risk and many idiosyncratic states by perturbation”. In: *Quantitative Economics* 11.4, pp. 1253–1288. DOI: https://doi.org/10.3982/QE1243. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.3982/QE1243. URL: https://onlinelibrary.wiley.com/doi/abs/10.3982/QE1243.

Bianchi, Francesco, Renato Faccini, and Leonardo Melosi (2023). *A Fiscal Theory of Persistent Inflation*. NBER Working Papers 30727. National Bureau of Economic Research, Inc. URL: https://ideas.repec.org/p/nbr/nberwo/30727.html.

Chetty, Raj (2012). “BOUNDS ON ELASTICITIES WITH OPTIMIZATION FRICTIONS: A SYNTHESIS OF MICRO AND MACRO EVIDENCE ON LABOR SUPPLY”. In: *Econometrica* 80.3, pp. 969–1018. ISSN: 00129682, 14680262. URL: http://www.jstor.org/stable/41493842 (visited on 07/04/2023).

Cochrane, John H. (2011). “Determinacy and Identification with Taylor Rules”. In: *Journal of Political Economy* 119.3, pp. 565–615. DOI: 10.1086/660817. eprint: https://doi.org/10.1086/660817. URL: https://doi.org/10.1086/660817.

— (2018a). “Michelson-Morley, Fisher, and Occam: The Radical Implications of Stable Quiet Inflation at the Zero Bound”. In: *NBER Macroeconomics Annual* 32, pp. 113–226. DOI: 10.1086/696050. eprint: https://doi.org/10.1086/696050. URL: https://doi.org/10.1086/696050.

— (2018b). “Stepping on a rake: The fiscal theory of monetary policy”. In: *European Economic Review* 101, pp. 354–375. ISSN: 0014-2921. DOI: https://doi.org/10.1016/j.euroecorev.2017.10.011. URL: https://www.sciencedirect.com/science/article/pii/S001429211730199X.

Conlon, Christopher, Nathan H. Miller, Tsolmon Otgon, and Yi Yao (2023). “Rising Markups, Rising Prices?” In: *AEA Papers and Proceedings* 113, pp. 279–83. DOI: 10.1257/pandp.20231098. URL: https://www.aeaweb.org/articles?id=10.1257/pandp.20231098.

Giovanni, Julian di, Şebnem Kalemli-Özcan, Alvaro Silva, and Muhammed A. Yıldırım (2023). “Quantifying the Inflationary Impact of Fiscal Stimulus under Supply Constraints”. In: *AEA Papers and Proceedings* 113, pp. 76–80. DOI: 10.1257/pandp.20231028. URL: https://www.aeaweb.org/articles?id=10.1257/pandp.20231028.

Glover, Andrew, Jose Mustre-del-Rio, and Alice von Ende-Becker (2023). “How Much Have Record Corporate Profits Contributed to Recent Inflation?” In: *Economic Review* 0.no.1, pp. 1–13. DOI: 10.18651/ER/v108n1GloverM. URL: https://ideas.repec.org/a/fip/fedker/95477.html.

Glover, Andrew, Jose Mustre-del-Rio, and Jalen Nichols (2023). “Corporate Profits Contributed a Lot to Inflation in 2021 but Little in 2022—A Pattern Seen in Past Economic Recoveries”. In: *Economic Bulletin*, pp. 1–4. URL: https://ideas.repec.org/a/fip/fedkeb/96344.html.

Hagedorn, Marcus (2018). *Prices and Inflation when Government Bonds are Net Wealth*. CEPR Discussion Papers 12769. C.E.P.R. Discussion Papers. URL: https://ideas.repec.org/p/cpr/ceprdp/12769.html.

Hagedorn, Marcus, Iourii Manovskii, and Kurt Mitman (2019). *The Fiscal Multiplier*. NBER Working Papers 25571. National Bureau of Economic Research, Inc. URL: https://ideas.repec.org/p/nbr/nberwo/25571.html.

Kaplan, Greg, Benjamin Moll, and Giovanni L. Violante (2018). "Monetary Policy According to HANK". In: *American Economic Review* 108.3, pp. 697–743. DOI: 10.1257/aer.20160042. URL: https://www.aeaweb.org/articles?id=10.1257/aer.20160042.

Klein, Paul (2000). "Using the generalized Schur form to solve a multivariate linear rational expectations model". In: *Journal of Economic Dynamics and Control* 24.10, pp. 1405–1423. URL: https://ideas.repec.org/a/eee/dyncon/v24y2000i10p1405-1423.html.

Krusell, Per and Anthony A. Smith Jr. (1998). "Income and Wealth Heterogeneity in the Macroeconomy". In: *Journal of Political Economy* 106.5, pp. 867–896. DOI: 10.1086/250034. eprint: https://doi.org/10.1086/250034. URL: https://doi.org/10.1086/250034.

Leeper, Eric M. (1991). "Equilibria under 'active' and 'passive' monetary and fiscal policies". In: *Journal of Monetary Economics* 27.1, pp. 129–147. ISSN: 0304-3932. DOI: https://doi.org/10.1016/0304-3932(91)90007-B. URL: https://www.sciencedirect.com/science/article/pii/030439329190007B.

McKay, Alisdair, Emi Nakamura, and Jón Steinsson (2016). "The Power of Forward Guidance Revisited". In: *American Economic Review* 106.10, pp. 3133–58. DOI: 10.1257/aer.20150063. URL: https://www.aeaweb.org/articles?id=10.1257/aer.20150063.

Reiter, Michael (2009). "Solving heterogeneous-agent models by projection and perturbation". In: *Journal of Economic Dynamics and Control* 33.3, pp. 649–665. ISSN: 0165-1889. DOI: https://doi.org/10.1016/j.jedc.2008.08.010. URL: https://www.sciencedirect.com/science/article/pii/S0165188908001528.

Shapiro, Adam Hale (2022). "Decomposing Supply and Demand Driven Inflation". In: *Federal Reserve Bank of San Francisco Working Paper* 2022-18. URL: https://doi.org/10.24148/wp2022-18.

Sims, Christopher A (2002). "Solving Linear Rational Expectations Models". In: *Computational Economics* 20.1-2, pp. 1–20. URL: https://ideas.repec.org/a/kap/compec/v20y2002i1-2p1-20.html.

— (2011). "Stepping on a rake: The role of fiscal policy in the inflation of the 1970s". In: *European Economic Review* 55.1, pp. 48–56. URL: https://ideas.repec.org/a/eee/eecrev/v55y2011i1p48-56.html.

6 Appendix

(Forthcoming.)