Gini in the Taylor Rule: Should the Fed Care About Inequality?*

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Abstract

This study investigates whether the Federal Reserve (Fed) should care about inequality. We develop a Heterogeneous Agent New Keynesian (HANK) model, which generates empirically realistic inequalities and business cycle properties observed in the U.S. data. We consider the income Gini coefficient in a monetary policy rule to see how an inequality-targeting monetary policy affects aggregate and disaggregate outcomes, as well as economic welfare. We find that a monetary policy rule with an explicit inequality target can be welfare improving, even if inequality becomes volatile. In particular, the policy reform can improve the welfare of the poorest the most. Finally, we demonstrate the feasibility of a subgroup targeting monetary policy as a tool for an implementable inclusive monetary policy.

JEL classification: E52, D31, D52, D63, J21

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1 Introduction

Should central bankers care about inequality when conducting monetary policy? This question arouses the attention of policy makers and academics as economic inequality deteriorates. Historically, concerns about inequality have been out of table for central banks mainly because inequality concerns are outside central banks' legal mandates. Modern central banking has been conducted based on so-called flexible inflation targeting. Under this monetary policy framework, central banks try to maintain stable prices and full employment, so naturally inequality has not been a first-order issue for them. Recently, the impacts of monetary policy on inequality and the intermediary role of various inequalities on the transmission of monetary policy have received a lot of attention, as inequality is gradually widening. There have been a number of articles that explore how *unsystematic* components of monetary policy (or monetary policy *shocks*) have distributional consequences (Kaplan, Moll and Violante, 2018; Auclert, 2019; Ma, 2021). In addition to the short-term casual relationship between inequality and monetary policy, asking whether central banks should *systematically* consider inequality is central to public debates these days (Powell, 2020; Daly, 2020). Calls for a more inclusive monetary policy, which puts more weight on the economic well-being of disadvantaged households, have spread in various forms. For instance, there are widespread arguments that the Federal Reserve (Fed) should play a role in addressing racial inequality in the United States, as racial tensions have heighten.[1] However, there has been little research that conducts a welfare analysis on implementing monetary policy rules that react to economic inequalities.[2] The main objective of this paper is to fill this gap.

In this paper, we investigate whether central banks need to systematically care about inequality when conducting monetary policy in a version of Heterogeneous Agent New Keynesian (HANK) model. Households in our economy are subject to the aggregate productivity shock and to the idiosyncratic labor efficiency and preference shocks. In particular, they cannot perfectly insure against idiosyncratic shocks, implying that asset markets are incomplete, as in Aiyagari (1994). Owing to

[1] See speeches by Joseph Biden, president of the United States (https://www.rev.com/blog/ transcripts/joe-biden-racial-equity-plan-speech-transcript-july-28), Jerome Powell, chair of the Board of Governors of the Federal Reserve System (Powell, 2020), Raphael Bostic, president of the Federal Reserve Bank of Atlanta (https://www.frbatlanta.org/about/feature/2020/06/12/bostic-a-moral-and-economic-imperative-to-end-racism), and Mary Daly, president of the Federal Reserve Bank of San Francisco (Daly, 2020).

[2] There are recent papers, e.g., Baek (2021) and Hansen, Lin and Mano (2020), that derive the welfare gains of alternative monetary policy rules that account for inequality. However, ours differs from those, as we use a full-scale Heterogeneous Agent New Keynesian (HANK) model that can account for realistic heterogeneity comparable to the data across various dimensions, including income, earnings and wealth.

market incompleteness and to limited borrowing conditions, the model can produce substantial cross-sectional heterogeneity across individual households, including assets, earnings, consumption, and income. In addition, the model distinguishes between the extensive and intensive margins of labor supply, as the extensive margin is known to be an important driver of inequality over the business cycle (Castañeda, Díaz-Giménez and Ríos-Rull, 1998; Kwark and Ma, 2021). We follow Chang et al. (2019) and embed a nonconvexity into the mapping from time devoted to work to labor services to generate an operative intensive and extensive margin of labor supply. Rich *ex-post* household heterogeneity and the nonconvexity mapping will lead to heterogeneous responses of individual households to business cycle fluctuations and will, in turn, affect their welfare differently depending on how well they are insured against aggregate shocks.

We compute welfare gains across economies with different monetary policy rules. To be more specific, we analyze whether caring about inequality is welfare-improving by incorporating the Gini coefficient as a representative variable for economic inequality into the benchmark monetary policy rule. Then, we assess the aggregate and disaggregate welfare implications of this monetary policy reform. One may argue that a monetary policy rule augmenting the Gini coefficient is not practical because it is extremely difficult to measure the Gini coefficient precisely in real-time or frequently. Hence, we also consider more implementable monetary policy rules—more accommodating monetary policy rules with an additional target regarding employment—and derive their welfare implications.

Our findings can be summarized as follows. First, the systematic reaction of monetary policy to inequality can be welfare-improving. In particular, the impatient wealth-poorest households with lower productivity earn the biggest welfare gains. This result implies that explicit inequality-targeting can improve the welfare of the poorest the most. Second, a more inclusive monetary policy increases the cyclical variation in income inequality over the business cycle, which we refer to as *the paradox of inequality targeting*. Third, there is a trade-off between output and inequality variations. An economy should sacrifice more volatile output to have smaller cyclical variations in income inequality. Lastly, a more accommodative monetary policy fails to achieve higher welfare, while a subgroup-targeting monetary policy can improve economic welfare. That is, a subgroup targeting monetary policy can be a tool for an *implementable* inclusive monetary policy.

Related Literature

This paper is primarily related to the literature looking at the welfare implication of a more inclusive monetary policy. Hansen, Lin and Mano (2020) find that a more inclusive monetary policy can improve social welfare by becoming more accommodative when the consumption gap between Ricardian and rule-of-thumb households widens within a two-agent New Keynesian model with no savings or investment. Baek (2021) constructs a New Keynesian model with regular and irregular labor types that reflect the cyclical nature of labor composition. The main finding of the paper is that if the central bank targets the deviations of cut-offs that determine the behavior of labor market participation, it can reduce the variation of the size of irregular employees, and in turn economic welfare can be improved. While previous literature only considered employment and labor income as relevant channels to determine the degree of inequality, the rich heterogeneity among households introduced in our model allows more complicated interactions between income and idiosyncratic states, such as labor efficiency, preferences, and asset holdings.

This study is also complementary to a chain of quantitative papers that incorporate heterogeneity across individual households to study the transmission mechanism of monetary policy. Seminal work by Kaplan, Moll and Violante (2018) develops a HANK model that incorporates two types of assets with different degrees of liquidity and returns. Their main finding is that indirect channels from the general equilibrium effects, such as an increase in labor demand, are larger than the direct effects from intertemporal substitution channels. Auclert (2019) shows that redistribution channels, including the Fisher and earnings heterogeneity channels, amplify the real effect of monetary policy on aggregate consumption.[3] Bayer, Born and Luetticke (2020) estimate a HANK economy that enlarges the medium scale New Keynesian model studied in Smets and Wouters (2007), and argue that the estimated shocks, including monetary and fiscal policy shocks, significantly contributed to wealth and income inequality dynamics in the U.S. In addition, they also show that the systematic components of monetary and fiscal policy rules are important in shaping inequality. Ma (2020) studies a labor-supply-side story for the monetary transmission mechanism by developing a HANK model where a nonlinear mapping from hours worked into labor services generates an operative adjustment along the intensive and extensive margins of labor supply.[4] Among the normative studies,

[3] Doepke and Schneider (2006) also study the effects of inflation through changes in the value of nominal assets (i.e., the Fisher effect) and find that the effects are large and heterogeneous across households.

[4] Other studies featuring adjustments along both the intensive and extensive margins are Rogerson and Wallenius (2009) and Chang et al. (2019).

Acharya, Challe and Dogra (2020) explore an optimal monetary policy in a HANK economy and show that policy preventing the fall in output during recessions can mitigate the increase in inequality when income risk is countercyclical. On the other hand, Le Grand, Martin-Baillon and Ragot (2020) find that an optimal monetary policy is still required to focus on inflation stability, and that redistribution is a matter of fiscal policy, by analyzing Ramsey monetary and fiscal policies within a HANK framework. Bhandari et al. (2021) show that the optimal monetary policy in HANK differs qualitatively as well as quantitatively from that in a representative agent model as monetary policy can provide insurance against aggregate shocks to heterogeneous agents. The work that is probably closest to this paper is Gornemann, Kuester and Nakajima (2016), who develop a HANK economy where matching frictions generate countercyclical labor-market risk. They find that stabilization of unemployment is preferred by a majority of households, even if prices are more unstable. This paper differs from the previous literature as we focus on the importance of the *systematic* response of the monetary policy authority to inequality and evaluate whether there is policy room for reacting to inequality and introducing more inclusive policy goals into the monetary policy framework in the context of HANK economies.

There has been research that empirically evaluates the role of monetary policy in inequality. The conclusions from this literature are divided. For instance, Coibion et al. (2017), Furceri, Loungani and Zdzienicka (2018), Casiraghi et al. (2018), and Lenza and Slacalek (2018) show that an expansionary monetary policy can ease income inequality. On the other hand, Andersen et al. (2021) and Cloyne, Ferreira and Surico (2015) find that a softer monetary policy aggravates income inequality. Since empirical analyses generally study specific channels of monetary policy propagation, this difference can arise as documented in Colciago, Samarina and de Haan (2019). Moreover, it is difficult to examine the role of systematic parts of monetary policy on inequality from those previous studies. This paper calls for a line of research that focuses more on the inequality implication of systematic monetary policy.[5]

The remainder of the paper is organized as follows. In Section 2, the model that will be used in the subsequent analyses is introduced. Section 3 specifies the benchmark model economy with the standard Taylor Rule. Sections 4 and 5 conduct the welfare analyses for various monetary policy rules. Finally, Section 6 concludes.

[5] Bartscher et al. (2021) empirically document the relationship between monetary policy and racial inequality and find that an accommodating monetary policy affects the employment of black people in the U.S., but that these employment effects are substantially smaller than the portfolio effects through changes in asset prices.

2 The Model

In this section, we introduce the economic environment of a quantitative New Keynesian model economy with heterogeneous households. The model economy has three main building blocks: a continuum (measure one) of households, firms, and a central bank. In the economy, households are subject to two types of idiosyncratic shocks: the time discounting preference (as in Krusell and Smith, 1998) and labor efficiency (as in Aiyagari, 1994). Asset markets are incomplete: households cannot fully insure against idiosyncratic shocks. The asset market incompleteness together with borrowing constraints will generate *ex-post* substantial heterogeneity in a household's wealth, income, and consumption. In turn, heterogeneous households will respond differently to aggregate shocks. The extensive margin of labor supply is known to be a crucial factor of inequality across the business cycles (Castañeda, Díaz-Giménez and Ríos-Rull, 1998; Kwark and Ma, 2021). Hence, as in Rogerson and Wallenius (2009), we embed a nonlinear mapping from time devoted to work to labor services, which generates operative intensive and extensive margins of labor supply. Standard assumptions in the New Keynesian literature are employed—sticky nominal prices, monopolistic competitive markets, and a conventional Taylor rule.

2.1 Heterogeneity

We build our model to reproduce substantial heterogeneity across characteristics of individual households, including wealth, income, employment, and consumption, as observed in U.S. data. To this end, we introduce two types of idiosyncratic shocks in the model economy: households are exposed to idiosyncratic risks of variations in time discount factor and labor efficiency. In particular, as documented in Krusell and Smith (1998) and Gornemann, Kuester and Nakajima (2016), heterogeneity in the time discounting preference is known to be a crucial factor to match the empirically realistic wealth distribution. We assume that both shocks do not depend on the business cycles.

First, households are subject to idiosyncratic labor efficiency shocks, denoted by z. Labor efficiency, z, follows an AR(1) process in logs:

$$\ln z' = \rho_z \ln z + \varepsilon_z, \quad \varepsilon_z \sim N(0, {\sigma_z}^2).$$

We discretize the continuous AR(1) process as a Markov chain, $\mathbb{T}^{\mathbf{z}}$, by using the algorithm developed in Tauchen (1986). We assume that labor efficiency z takes on N_z values, i.e., $z \in$

$\mathbb{Z} = \{z_1, z_2, ..., z_{N_z}\}$, and hence z follows an N_z-state first-order Markov process. The transition probability from i to j is given: $\mathbb{T}^{\mathbf{z}}(i, j) \geq 0$, where $\sum_j \mathbb{T}^{\mathbf{z}}(i, j) = 1$ for each $i = 1, 2, ..., N_z$.

Second, individual households face idiosyncratic shocks to discount factors, β. The time discount factor, β, can take on two values, i.e., $\beta \in \mathbb{B} = \{\beta_L, \beta_H\}$, where $0 < \beta_L < \beta_H < 1$. Stochastic evolution of β is described by the transition matrix, $\mathbb{T}^{\beta}$. The probability of a transition from l to m is given $\mathbb{T}^{\beta}(l, m) \geq 0$, where $\sum_m \mathbb{T}^{\beta}(l, m) = 1$ for each $l = L$ and H. Households cannot issue any assets contingent on their future idiosyncratic risks, β and z, which implies that asset markets are incomplete as in Huggett (1993) and Aiyagari (1994).

2.2 Households

The model economy is populated by a continuum of infinitely-lived households. Each household maximizes its expected lifetime utility by choosing consumption, c_t, and hours worked, h_t :

$$\max \mathbb{E}_0 \left[\sum_{t=0}^{\infty} B_t \left(\frac{c_t^{1-\sigma} - 1}{1 - \sigma} - \chi \frac{h_t^{1+1/\nu}}{1 + 1/\nu} \right) \right]$$

subject to

$$c_t + a_{t+1} = w_t z_t \varphi(h_t) + (1 + r_t) a_t + \xi_t, \tag{1}$$

and

$$a_{t+1} \geq \underline{a},$$

where σ is the inverse intertemporal elasticity of substitution, $\chi > 0$ denotes a parameter for disutility from working, and ν is a parameter for a curvature in preferences over hours of work. B_t denotes the cumulative discounting between period 0 and t, i.e., $B_t = \prod_{s=0}^{t} \beta_s$. In each period, an individual household is endowed with a unit of time, which is allocated between hours worked and leisure. We consider factors that generate nonconvex budget sets to operate adjustment along both the intensive and extensive margins of labor supply. A household with labor efficiency of z providing h units of time will generate $\varphi(h)z$ efficiency units of labor, where $\varphi(h)$ is the mapping from time devoted to work into units of labor services. As in Rogerson and Wallenius (2009) and Chang et al. (2019), we consider a nonconvexity that takes the form with time costs:

$$\varphi(h) = \max\left\{h - \Delta_h, 0\right\}, h \in [0,1], \tag{2}$$

where $0 < \Delta_h < 1$ is time costs. The above functional form implies that i) time costs arise at any time in which hours devoted to market work are positive, and ii) hours of market work have a convex relationship with labor earnings. Accordingly, when a household supplies h units of labor, it earns $w_t z_t \varphi(h_t)$ as labor income, where w_t is the wage rate per effective unit of labor. Households can trade a claim for financial assets, a_t, which yields the real rate of return, r_t. Each household earns profit income, ξ_t, from firms. A household faces a borrowing constraint that limits the fixed amount of debt: the assets holding, a_{t+1}, should not be less than $\underline{a}$ for all t.

We define ω and Ω as the vectors of individual and aggregate state variables, respectively: $\omega \equiv (\beta, a, z)$ and $\Omega \equiv (\mu, A)$, where $\mu(\omega)$ is the type distribution of households, and A denotes aggregate productivity.[6] The value function for a household, denoted by $V(\omega, \Omega)$, is defined as:

$$V(\omega,\Omega) = \max_{c,a',h}\left\{\tfrac{c^{1-\sigma}-1}{1-\sigma} - \chi\tfrac{h^{1+1/\nu}}{1+1/\nu} + \beta\mathbb{E}\left[V(\omega',\Omega')\right]\right\}$$

subject to

$$c + a' = wz\varphi(h) + (1+r)a + \xi,$$

$$\varphi(h) = \max\{h - \Delta_h, 0\},$$

$$a' \geq \underline{a},$$

and

$$\mu' = \Gamma(\Omega),$$

where Γ denotes a transition operator for μ.

[6] The measure $\mu(\beta, a, z)$ is defined over a σ-algebra of $\mathcal{B} \times \mathcal{A} \times \mathcal{Z}$, where $\mathcal{B}$, $\mathcal{A}$ and $\mathcal{Z}$ denote sets of all possible realizations of β, a, and z, respectively.

2.3 The Representative Final Goods Producing Firm

It is assumed that the representative final goods producing firm operates in a competitive sector. The final goods firm uses $y_t(j)$ units of each intermediate good $j \in [0,1]$ to produce a homogeneous output, Y_t, according to the constant-return-to-scale technology given by:

$$Y_t = \left(\int_0^1 y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}, \tag{3}$$

where $\epsilon > 1$ is the elasticity of substitution for intermediate goods. The firm in this sector takes the final goods price, P_t, as given and purchases each of its inputs at the nominal price $p_t(j)$, where $p_t(j)$ is the price of the jth intermediate input. The profit maximization problem of the representative final goods producing firm is given by:

$$\max_{y_t(j)} \left\{ P_t Y_t - \int_0^1 p_t(j) y_t(j) dj \right\}$$

subject to Equation 3. The first order condition for the final goods firm's problem and the zero profit condition yield the demand for intermediate good j:

$$y_t(j) = \left(\frac{p_t(j)}{P_t}\right)^{-\epsilon} Y_t \quad \text{where } P_t = \left(\int_0^1 p_t(j)^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}}.$$

2.4 Intermediate Goods Producing Firm

There is a continuum of monopolistically competitive firms indexed by $j \in [0,1]$, each of which produces a different type of intermediate good, $y_t(j)$. Intermediate goods producing firms employ $k_t(j)$ units of capital and $n_t(j)$ units of effective labor in order to produce $y_t(j)$ units of intermediate good j. Their production technology is represented by the Cobb-Douglas function:

$$y_t(j) = A_t k_t(j)^{\alpha} n_t(j)^{1-\alpha} - \Delta_f,$$

where A_t is aggregate productivity, α is capital income share, and $\Delta_f \geq 0$ is the fixed cost of production.[7] Aggregate productivity, A, follows a stationary AR(1) process in logs:

[7] The fixed cost is introduced to rule out entry in the steady state and will be set to ensure that steady-state profits are zero, as in Christiano, Motto and Rostagno (2014). However, introducing such a fixed cost does not alter the dynamics of the model economy.

$$\ln A' = \rho_A \ln A + \varepsilon_A, \quad \varepsilon_A \sim N(0, \sigma_A^2).$$[8]

The cost minimization problem implies that intermediate goods producing firms must all have the same real marginal cost, mc_t, and capital-labor ratio, and i.e.,

$$mc_t = \Theta \tfrac{1}{A_t} \left(r_t^d\right)^{\alpha} w_t{}^{1-\alpha},$$

$$\tfrac{k_t(j)}{n_t(j)} = \tfrac{\alpha}{1-\alpha} \tfrac{w_t}{r_t^d},$$

where $\Theta = (1-\alpha)^{\alpha-1}\alpha^{-\alpha}$, and $r_t^d = r_t + \delta$. Price adjustment costs are introduced to generate sticky prices. Following the price setting mechanism as in Rotemberg (1982), we assume that when intermediate goods firms adjust their prices, they pay quadratic costs. Accordingly, an intermediate goods producing firm, j, maximizes its expected discounted profit by choosing its price $p_t(j)$:

$$\max_{p_{t+\tau}(j)} \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \left\{ \left(\tfrac{p_{t+\tau}(j)}{P_{t+\tau}} - mc_{t+\tau} \right) y_{t+\tau}(j) - \tfrac{\theta}{2} \left(\tfrac{p_{t+\tau}(j)}{p_{t+\tau-1}(j)} - \overline{\Pi} \right)^2 Y_{t+\tau} \right\} \right],$$

where, $\Lambda_{t,t+\tau}$ is the stochastic discount factor,[9] $\theta > 0$ represents the extent of nominal stickiness, and $\overline{\Pi}$ is the steady-state gross inflation. In the symmetric equilibrium conditions, i.e., $p_t(j) = P_t$ and $y_t(j) = Y_t$,[10] the first order condition associated with the optimal price implies:

$$\epsilon(1 - mc_t) - 1 + \theta \left(\tfrac{P_t}{P_{t-1}} - \overline{\Pi} \right) \tfrac{P_t}{P_{t-1}} = \theta \mathbb{E}_t \left[\Lambda_{t,t+1} \left\{ \tfrac{P_{t+1}}{P_t} - \overline{\Pi} \right\} \tfrac{P_{t+1}}{P_t} \tfrac{Y_{t+1}}{Y_t} \right].$$

2.5 Mutual Fund and Central Bank

We follow Gornemann, Kuester and Nakajima (2016) and assume that a representative mutual fund trades assets owned by all the households in the economy. This implies that there is no portfolio decision by individual households in the model economy. The mutual fund determines the price of claims based on the its shareholders' period-to-period valuation, so it is important how to define the stochastic discount factor. We need to first discuss how monopoly profits from intermediate goods producing firms are distributed, since this issue is closely related to the definition of the stochastic discount factor. Similar in spirit to Kaplan, Moll and Violante (2018), we assume that dividend,

[8] Like the process of the individual efficiency, z, we discretize the continuous AR(1) process of the aggregate productivity shock as a Markov chain, using the algorithm developed in Tauchen (1986).

[9] The stochastic discount factor will be defined in the next subsection.

[10] All intermediate goods producing firms face the identical profit maximization problem, so they choose the same price and produce the same quantity.

D, is proportionally distributed according to both asset holdings of households and labor efficiency of employed households:

$$\xi(\beta, a, z) = \left\{\gamma\psi^a + (1-\gamma)\psi^z \mathbf{1}_{h(\beta,a,z)>0}\right\} D, \tag{4}$$

where $\psi^a = \frac{a}{\int a d\mu}$, $\psi^z = \frac{z}{\int z d\mu^E}$, γ is the fraction of profits for assets, $\mathbf{1}_{h(\beta,a,z)>0}$ is an indicator function for working households, and μ^E is the type distribution conditional on working. Accordingly, we can define the stochastic discount factor between t and $t+1$, denoted by $\Lambda_{t,t+1}$:

$$\Lambda_{t,t+1} = \gamma \int \beta \tfrac{u_c(c_{t+1})}{u_c(c_t)} \psi_t^a d\mu_t + (1-\gamma) \int \beta \tfrac{u_c(c_{t+1})}{u_c(c_t)} \psi_t^z d\mu_t^E,$$

where $u_c(\cdot)$ is the marginal utility of consumption.[11] Note that the stochastic discount factor here is consistent with the distribution of profits described in Equation 4. We follow Woodford (1998) and assume that the gross nominal interest on risk-free bonds, R_t^f, is controlled by the central bank. Accordingly, the optimal bond investment decision of the mutual fund leads to a standard Euler equation:

$$\mathbb{E}_t \left[\Lambda_{t,t+1} \frac{R_t^f}{\Pi_{t+1}}\right] = 1, \tag{5}$$

where Π_{t+1} is the gross inflation rate, $\frac{P_{t+1}}{P_t}$. The gross nominal interest rate on risk-free bonds, R_t^f, is assumed to follow a conventional Taylor rule by stabilizing the inflation and output gaps:

$$\ln R_t^f = \ln \overline{R^f} + \phi_\Pi \left(\ln \Pi_t - \ln \overline{\Pi}\right) + \phi_Y \left(\ln Y_t - \ln \overline{Y}\right), \tag{6}$$

where $\phi_\Pi > 1$, $\phi_Y \geq 0$, and $\overline{R^f}$ and $\overline{Y}$ are the deterministic steady-state values of the corresponding variables.

2.6 Definition of Equilibrium

A recursive competitive equilibrium is a value function $V(\omega, \Omega)$, a transition operator $\Gamma(\Omega)$, a set of policy functions $\{c(\omega,\Omega), a'(\omega,\Omega), h(\omega,\Omega), k_j(\Omega), n_j(\Omega), p_j(\Omega), y_j(\Omega)\}$, and a set of prices $\left\{w(\Omega), r(\Omega), R^f(\Omega), \mathit{\Pi}(\Omega)\right\}$ such that:

[11] Similarly, Gornemann, Kuester and Nakajima (2016) assume that the mutual fund's claims are priced based on the asset weighted average of its shareholders' period-to-period valuation.

1. Individual households' optimization: given $w(\Omega)$ and $r(\Omega)$, optimal decision rules $c(\omega, \Omega)$, $a'(\omega, \Omega)$, and $h(\omega, \Omega)$ solve the Bellman equation, $V(\omega, \Omega)$.

2. Intermediate goods firms' optimization: given $w(\Omega)$, $r(\Omega)$, $\Lambda(\Omega, \Omega')$, and $P(\Omega)$, the associated optimal decision rules are $k_j(\Omega)$, $n_j(\Omega)$, and $p_j(\Omega)$.

3. Final good firm's optimization: given a set of prices $P(\Omega)$ and $p_j(\Omega)$, the associated optimal decision rules are $y_j(\Omega)$ and $Y(\Omega)$.

4. The stochastic discount factor, $\Lambda(\Omega, \Omega')$, satisfies $\mathbb{E}\left[\Lambda(\Omega, \Omega')\frac{R^f(\Omega)}{\Pi(\Omega')}\right] = 1$.

5. The gross nominal interest rate, $R^f(\Omega)$, satisfies the Taylor rule (Equation 6).

6. Market clearing: for all Ω,

   - labor market clearing: $N(\Omega) = \int z\varphi(h(\omega, \Omega))d\mu$, where $N(\Omega) = \int n_j(\Omega)dj$
   - capital market clearing: $K(\Omega) = \int a d\mu$, where $K(\Omega) = \int k_j(\Omega)dj$
   - goods market clearing: $Y(\Omega) = C(\Omega) + I(\Omega) + \Xi(\Omega)$ where $Y(\Omega) = AK(\Omega)^\alpha N(\Omega)^{1-\alpha} - \Delta_f$, $C(\Omega) = \int c(\omega, \Omega)d\mu$, $I(\Omega) = K'(\Omega) - (1-\delta)K(\Omega)$, and $\Xi(\Omega) = \frac{\theta}{2}(\Pi(\Omega) - \overline{\Pi})^2 Y(\Omega)$.

7. Consistency of individual and aggregate behaviors: for all $B^0 \subset \mathcal{B}$, $A^0 \subset \mathcal{A}$, and $Z^0 \subset \mathcal{Z}$,

$$\mu'(B^0, A^0, Z^0) = \int_{B^0, A^0, Z^0} \left\{ \int_{\mathcal{B}, \mathcal{A}, \mathcal{Z}} \mathbf{1}_{a'=a'(\omega,\Omega)} \mathbb{T}^\beta(\beta, \beta')\mathbb{T}^{\mathbf{z}}(z, z')d\mu \right\} da' d\beta' dz'.$$

2.7 Calibration

In this subsection, we describe how we calibrate the model economy. Table 1 summarizes the parameter values used for the benchmark model. A simulation period in the economy is a quarter.

We set the inverse intertemporal elasticity of substitution (IES), σ, to 1. Following Chang et al. (2019) and Ma (2020), we choose the curvature parameter, ν, to be 1.[12] Given the value of ν, the disutility parameter of working, χ, and the nonconvexity parameter, Δ_h, are chosen so that the employment rate is 70 percent, and the average hours conditional on working are 0.26. The latter moment comes from the fact that prime-age men spend around 41 hours per week (out of 160 hours) working. Similar in spirit to Kaplan, Moll and Violante (2018), the borrowing limit, $\underline{a}$, is set to -0.2, which implies that the maximum debt is around the quarterly average earnings of a household.

[12] Chang et al. (2019) use a wide range of values for ν, but use the case that $\nu = 1$ as a benchmark when they report the various model results.

Table 1: Parameters of the Benchmark Model

Parameter	Value	Description	Source/Target Moments
		Households	
β_H	0.98145	High time discount factor	See text
β_L	0.94219	Low time discount factor	See text
$\mathbb{T}^{\beta}(L, L)$	0.9969	L to L transition Prob.	Gornemann, Kuester and Nakajima (2016)
σ	1	Inverse IES	Standard
ν	1	Curvature parameter	See text
Δ_h	0.112	Time fixed costs	Average hours worked
ρ_z	0.95	Persistence of z shocks	Standard
σ_z	0.225	Standard deviation of z shocks	Earnings Gini
$\underline{a}$	-0.2	Borrowing limit	See text
		Firms and Mutual Fund	
α	0.33	Capital income share	Standard
δ	0.025	Capital depreciation rate	Standard
Δ_f	0.051	Production fixed costs	Zero profit
ϵ	10	Elasticity of substitution	11% markup
θ	100	Price adjustment cost	See text
ρ_A	0.95	Persistence of A shocks	Kydland and Prescott (1982)
σ_A	0.01	Standard deviation of A shocks	Standard
γ	0.33	Fraction of profits for asset	Kaplan, Moll and Violante (2018)
		Monetary Authority	
ϕ_Π	1.5	Weight on inflation	Standard
ϕ_Y	0.125	Weight on output	Standard
$\overline{\Pi}$	1	Steady-state gross inflation	Standard

We then calibrate the parameters related to the heterogeneity in the time preference and labor efficiency. These parameters are set to match the key moments related to the wealth and earnings distributions, respectively. We calibrate parameters associated with labor efficiency as follows. We obtain the transition matrix $\mathbb{T}^{\mathbf{z}}$, by discretizing the log-normal process using the algorithm developed in Tauchen (1986) with 11 values of labor efficiency ($N_z = 11$). We set ρ_z to 0.95, based on the empirical fact that individual labor efficiency shocks have a high persistence (Floden and Linde, 2001; Chang, Kim and Schorfheide, 2013). We parameterize σ_z to target the earnings Gini index of 0.63 in the steady state. For the time preference parameter, we follow Gornemann, Kuester and Nakajima (2016) and assume that each household has the same probability of drawing each of the two states. This means that the transition matrix for β is symmetric, i.e., $\mathbb{T}^{\beta}(L, L) = \mathbb{T}^{\beta}(H, H)$. Given $\mathbb{T}^{\beta}(L, L)$, $\mathbb{T}^{\beta}(L, H)$ can be obtained by the condition that $\mathbb{T}^{\beta}(L, L) + \mathbb{T}^{\beta}(L, H) = 1$. Accordingly, there are three parameters related to the stochastic time preference to parameterize: β_L, β_H, and $\mathbb{T}^{\beta}(L, L)$. We calibrate $\mathbb{T}^{\beta}(L, L)$ to capture changes in the saving behavior between generations (Krusell and Smith, 1998). To be specific, we choose $\mathbb{T}^{\beta}(L, L)$ to target the average duration of discount factors of 40 years, following Gornemann, Kuester and Nakajima (2016). Regarding the remaining parameters, β_L and β_H, we choose them so that the model economy generates the quarterly return to capital of one percent (4 percent annualized) and the wealth Gini coefficient of 0.78 in the steady state.

The parameter values for production are standard. Regarding the parameters for aggregate productivity shocks, we choose $\rho_A = 0.95$ and $\sigma_A = 0.01$. The capital income share, α, and the quarterly depreciation rate, δ, are calibrated to be 0.33 and 2.5 percent, respectively. The production fixed cost, Δ_f, is set for intermediate goods firm to have zero profit in the steady state. The elasticity of substitution across intermediate goods ϵ is equal to 10, which implies that a steady-state markup is 11 percent. The parameter for the Rotemberg price adjustment, θ, is set to 100, implying that firms, on average, update their prices every four quarters, given the choice of the elasticity of substitution.[13] As in Kaplan, Moll and Violante (2018), we assume that the fraction of profits for asset holdings, γ, is the same as α, i.e., $\gamma = \alpha = 0.33$.

The Taylor rule coefficients of inflation and output, ϕ_{Π} and ϕ_Y, are chosen to be 1.5 and 0.125, respectively, which are conventional values in the New Keynesian literature. The steady-state gross inflation, $\overline{\Pi}$, is set to 1.

The main results of the paper will be discussed in the following order. First, we examine if the benchmark model economy i) generates empirical features of the heterogeneity in wealth, income, consumption, and earnings, and ii) produces empirically realistic aggregate dynamics—business cycle moments and the impulse response to the productivity shock. Then we include an additional monetary policy objective that aims to reduce any inequality variation in the economy. As a natural starting point, we augment the income Gini coefficient in the benchmark Taylor rule. We study aggregate and disaggregate welfare implications of this more "inclusive" monetary policy. Then, we consider several other monetary policy rules as alternatives, since Gini coefficients are hard to obtain in real-time and are not suitable in practice.

[13] Denote ϕ for a Calvo price stickiness parameter. Then the Rotemberg price adjustment cost parameter, θ, can be obtained such that: $\theta = \frac{\phi(\epsilon-1)}{(1-\phi)(1-\bar{\beta}\phi)}$, where $\bar{\beta}$ is the average time discount factor.

Table 2: Cross-sectional Distributions

	Gini Index for			
	Wealth	Earnings	Income	Consumption
U.S. Data	0.78	0.63	0.57	0.33
Benchmark Model	0.77	0.63	0.58	0.38

Note: The Gini coefficients for income, earnings, and wealth in the data are from the Survey of Consumer Finances (SCF) 1992 in Diaz-Gimenez, Quadrini and Rios-Rull (1997), while the consumption Gini is from the Consumer Expenditures Survey (CEX) 1992. In the SCF, income is the sum of labor, capital, business income, both government and private transfers, and others; earnings are wages and salaries of all kinds, plus a fraction of business income; and wealth is the net worth of the households. In the model, income is defined as the sum of labor, capital and profit incomes; earnings are defined as labor income; and wealth is the net worth of the household. In both data and model, consumption is non-durable goods.

3 Benchmark Findings

3.1 Cross-Sectional Distributions

The main objective of this paper is to investigate welfare implications of an inequality-targeting monetary policy. To this end, it is important for our model economy to produce empirically realistic heterogeneity across households. In Table 2, we compare the Gini coefficients for income, earnings, net asset holdings, and consumption in the model to U.S. data.[14] The benchmark model successfully targets the wealth and earnings distributions in the U.S. data. The earnings and wealth Gini coefficients in the benchmark model are 0.63 and 0.77, respectively, which are almost comparable to what we observe in the U.S. data. Untargeted distributions are also reasonably reproduced by the benchmark model. The model economy fits the income distribution in the data. The income Gini index (0.58) in the model economy is very similar to that in the data (0.57). Consumption inequality is also well replicated by the model. The Gini index for consumption is 0.38 in the model, which is comparable to what is observed in the U.S. data (0.33). From the results, we argue that our benchmark model is successful in generating reasonable cross-sectional distributions as found in the U.S. data.

[14]The Gini coefficients for income, earnings, and wealth in the data are from the Survey of Consumer Finances (SCF) 1992 in Diaz-Gimenez, Quadrini and Rios-Rull (1997), while the consumption Gini is from the Consumer Expenditures Survey (CEX) 1992. We use the 1992 survey year because this survey year falls in the midpoint of the sample period used for the business cycle analysis in the next subsection. In the SCF, income is the sum of labor, capital, business income, both government and private transfers, and others; earnings are wages and salaries of all kinds, plus a fraction of business income; and wealth is the net worth of the households. In the model, income is defined as the sum of labor, capital and profit incomes; earnings are defined as labor income; and wealth is the net worth of the household. In both data and model, consumption is non-durable goods.

3.2 Aggregate Dynamics

3.2.1 Business Cycle Statistics

We next examine the aggregate business cycle properties of the benchmark model economy in the presence of exogenous shifts in total factor productivity (TFP), A. The conventional set of business cycle statistics of the model economy along with the cyclical behavior of the U.S. aggregate data for the great moderation period from 1985 to 2007 is reported in Table 3. We focus on the (relative) volatilities and cross correlations with output of the key aggregate variables. The model targets well the volatility of output in the data. The cyclical variation of output in the model is 1.29, which is comparable to what is observed in the U.S. data (1.26). Although the relative volatility of hours in the model is small compared to that in the data,[15] the business cycle statistics of other variables are similar to those found in the standard DSGE models as well as in the data. For example, consumption is about half as volatile as output, and investment is about three times as volatile as output.

It is important for the model to replicate the business cycle behavior of the U.S. income distribution. In the data, the income distribution measured by the Gini coefficient is countercyclical over the business cycle. As reported in Table 3, the income Gini is negatively correlated with output. The correlation between the income Gini index and output, $\rho(G, Y)$, is -0.58.[16] Our model is successful in reproducing the countercyclicality of the income Gini coefficient. It has a negative cross correlation with output, -0.89.[17] The countercyclical income Gini in the benchmark model is mainly due to changes in the extensive margin of labor supply of income-poor households over the business cycles, as documented in Castañeda, Díaz-Giménez and Ríos-Rull (1998) and Kwark and Ma (2021).

3.2.2 Transmission of Technology Shock

Next we discuss how an expansionary total factor productivity (TFP) shock affects the economy. The responses of the key aggregate variables to an expansionary one-percent TFP shock for 100

[15] The little variation in hours worked is the well-known finding in the standard DSGE models. This is also found in the models with rich household heterogeneity. For example, Chang et al. (2019) find that their heterogeneous agent general equilibrium models featuring intensive and extensive margins of labor supply generate the relative volatilities of hours that are up to two-thirds of the observed one.

[16] The two-year lagged Gini coefficient is used to compute the correlation with output due to the lagging behavior of the income distribution as in Kwark and Ma (2021).

[17] In this table, the model's Gini coefficient is annualized to be consistent with the data.

Table 3: Volatilities and Comovements of Aggregate Variables

	σ_Y	σ_C/σ_Y	σ_I/σ_Y	σ_H/σ_Y	$\sigma_{Y/H}/\sigma_Y$	σ_G/σ_Y
U.S. Data	1.23	0.52	2.57	0.76	0.63	0.55
Benchmark Model	1.29	0.50	3.18	0.26	0.76	0.28

	$\rho(Y,Y)$	$\rho(C,Y)$	$\rho(I,Y)$	$\rho(H,Y)$	$\rho(\frac{Y}{H},Y)$	$\rho(G,Y)$
U.S. Data	1.00	0.79	0.93	0.77	0.64	-0.58
Benchmark Model	1.00	0.96	0.96	0.95	0.99	-0.89

Note: σ_x and $\rho(x, Y)$ are the standard deviation of variable x, and the cross correlation of x with output (Y), respectively. C, I, H, and G denote consumption, investment, total hours, and the income Gini coefficient, respectively. The Gini coefficients in the model are annualized to be consistent with the data. The two-year lagged correlation of the Gini coefficient with output is used in the data while the contemporaneous correlation is used in the model. All variables are logged and detrended by the HP filter.

quarters of horizon are shown in Figure 1.[18] The transmission mechanism of the technology shock in the benchmark model is in play through a rise in overall productivity at all firms. An expansionary TFP shock makes intermediate goods firms more productive, which leads to an increase in the demand for both labor and capital inputs and, in turn, their prices. This causes households to provide more hours devoted to work by adjusting both margins of labor supply. Consumption and savings at the same time rise due the increase in household incomes. Accordingly, output, consumption, and investment rise by 1.4 percent, 0.7 percent, and 4.5 percent, respectively. As expected, profits or dividends positively respond to a favorable aggregate productivity shock. The expansion makes an aggregate supply shift to the right, so annualized inflation falls by around 1.1 percent points. In response to the significant decline in inflation, the Fed decreases nominal interest rates on risk-free bonds (or the federal funds rate, FFR) following the Taylor Rule. As discussed above, an expansionary technology shock decreases income inequality, mainly due to a rise in employment from the bottom of the income distribution (Castañeda, Díaz-Giménez and Ríos-Rull, 1998; Kwark and Ma, 2021).[19] The responses to technology shocks are comparable to the other HANK literature (i.e., Bayer, Born and Luetticke, 2020) both quantitatively and qualitatively.

4 Gini Coefficient in the Taylor Rule

[18]The impulse response functions show the deviation from the steady state. For inflation and FFR, the figure shows changes in annualized percentage points, while for the remaining variables other than dividends, it shows percent change. Dividends are not logged.

[19]As we will discuss later in Figure 5, employment significantly increases for income-poor households in response to a favorable aggregate productivity shock.

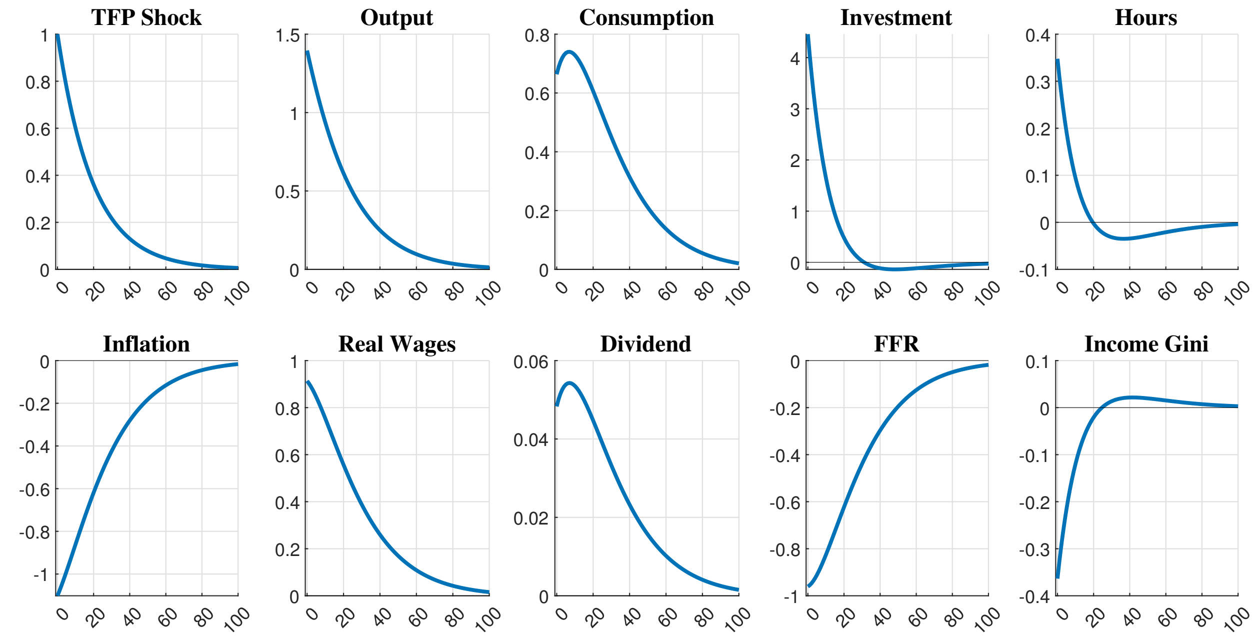

Figure 1: Impulse responses to TFP Shock

Note: Impulse response to a one-percent TFP shock. For inflation and the FFR, the y axis shows changes in annualized percentage points, while for the remaining variables other than dividends, the y axis shows percent changes. Dividends are not logged. The x-axis shows quarters after the shock.

4.1 Augmented Taylor Rule

Our primary interest is in studying how monetary policy with an explicit targeting of inequality affects aggregate and disaggregate outcomes, as well as economic welfare. In this subsection, we assume a hypothetical situation where the central bank switches its policy rule to a more inclusive one to reduce inequality fluctuations over the business cycles in the economy. Then, we compare the aggregate and distributional outcomes and economy-wide welfare obtained under this alternative policy rule to those derived under the benchmark policy rule. To this end, we first consider a simple policy experiment: the central bank includes an inequality measure into the Taylor rule. The income Gini coefficient is the most widely-used single-summary number for judging the level of inequality in a particular country or region. Also, relative to earnings and wealth, income is a more general dimension of inequality since this variable includes both labor earnings and income generated by wealth. Accordingly, we assume that, among various measures and dimensions of inequalities, the Fed considers the income Gini index as a targeting variable. That is, we impose that the central bank tries to achieve equity by reducing the variability of the income Gini coefficient. We consider the following Taylor rule, which augments the income Gini coefficient as the third objective:

$$\ln R_t^f = \ln \overline{R^f} + \phi_\Pi \left(\ln \Pi_t - \ln \overline{\Pi}\right) + \phi_Y \left(\ln Y_t - \ln \overline{Y}\right) + \phi_G \left(\ln G_t - \ln \overline{G}\right), \tag{7}$$

where ϕ_G is a weight on the income Gini index, and $\overline{G}$ is the deterministic steady-state value of the Gini coefficient of income. While the augmented rule is quite straightforward to understand, there are two practical issues to be settled before bringing it into the model. First, we need to determine the right sign of the coefficient ϕ_G. As discussed above (in Table 3 and Figure 1), the income Gini coefficient is countercyclical over the business cycles. In this respect, a natural candidate for ϕ_G is a negative sign as the Taylor rule coefficient for output, ϕ_Y, is positive. In other words, the central bank sets a lower nominal interest rate when the income Gini exceeds its steady state level. As an accommodating monetary policy boosts real activity and employment, we could expect that it can reduce inequality because it is believed that employment is a major source of economic inequality (Baek, 2021; Ma, 2021). Assigning a negative reaction coefficient for a measure of inequality is also implemented in previous studies, such as Hansen, Lin and Mano (2020). However, this is still an open question, since the general equilibrium effect may affect inequality in a very different manner than we expect (Colciago, Samarina and de Haan, 2019). Therefore, we consider both signs for ϕ_G in this experiment.

The other issue is the range of the weight for the income Gini index, ϕ_G. It is unclear to what extent a central bank needs to respond to inequality measures. There is no consensus regarding the value of ϕ_G, while there are some ranges of empirical estimates for ϕ_Π and ϕ_Y. Put differently, in terms of the Taylor rule considered above, we do not have prior knowledge regarding the suitable magnitude of ϕ_G. For this reason, we consider a reasonable range of values for ϕ_G in order to illustrate how this affects outcomes from both a quantitative and qualitative perspective. Specifically, we normalize the changes in the Gini coefficient with its standard deviation, and then vary the coefficient for a reasonable range. We assume that the central bank changes the *annualized* interest rate on risk-free bonds by *up to* 1 percent point in response to a change in one standard deviation of the logged income Gini index. This assumption leads to a range that runs from -0.35 to 0.35.

4.2 Should the Fed Care About Inequality?

4.2.1 Aggregate Welfare Effect of Inequality Targeting

Should a central bank consider inequality when setting a systematic monetary policy? This subsection discusses this question, which is the main focus of this paper. We explore the welfare implication of the systematic response of monetary policy to inequality. The systematic reform of monetary policy may affect the shape of the business cycle. Moreover, any new monetary policy rules could affect welfare-related economic variables differently. They could stabilize or destabilize employment (or output) and inflation. Accordingly, it is natural to ask whether a systematic reaction of monetary policy to the income Gini index could improve economic welfare. Toward this end, we change the Taylor rule coefficient for the inequality gap, ϕ_G, while keeping the response to the inflation and output fixed at the benchmark levels ($\phi_\Pi = 1.5$ and $\phi_Y = 0.125$). Our main finding is that there is a possibility that conducting a more inclusive monetary policy by negatively responding to a deviation in income Gini from its steady state could improve the average welfare of households, although employment and the income Gini index become more volatile.

We compute the welfare effect of the policy reform for an individual household by comparing value functions between different policy regimes. Let $\mathbb{E}[V(a, \beta, z; A, \mu, \tau)]$ be unconditional expectation of the value function for an individual household under a policy regime, τ. The unconditional expectation is taken over aggregate states A and μ, which is nothing but the long-run average welfare (or the value function) for each household type. Let τ' be a new policy regime. Then the welfare effect of a regime change from τ to τ' can be expressed as the consumption-equivalent measure, λ, which satisfies:

$$\mathbb{E}[V(a, \beta, z; A, \mu; \tau')] = \mathbb{E}[V(a, \beta, z; A, \mu; \tau, \lambda)], \tag{8}$$

where

$$\mathbb{E}[V(a, \beta, z; A, \mu; \tau, \lambda)] = \max \mathbb{E}_0 \left[\sum_{t=0}^{\infty} B_t \left(\log(1-\lambda)c_t - \chi \frac{h_t^{1+1/\nu}}{1+1/\nu} \right) \right]$$

subject to the budget constraint (1) under a policy regime τ. It should also be noted that λ depends on individual state variables, i.e., $\lambda = \lambda(a, \beta, z)$. Positive (Negative) λ means that the household is better off (worse off), relative to the benchmark policy regime.

Figure 2 shows the welfare consequences of switching to an inequality-targeting monetary policy with different values of the weight on the income Gini index, ϕ_G. Specifically, the welfare effects in the figure are measured as the average consumption-equivalent welfare gains, $\overline{\lambda}(= \int \lambda(a, \beta, z) d\mu)$. As found in Figure 2, the systematic change in monetary policy generates different welfare consequences

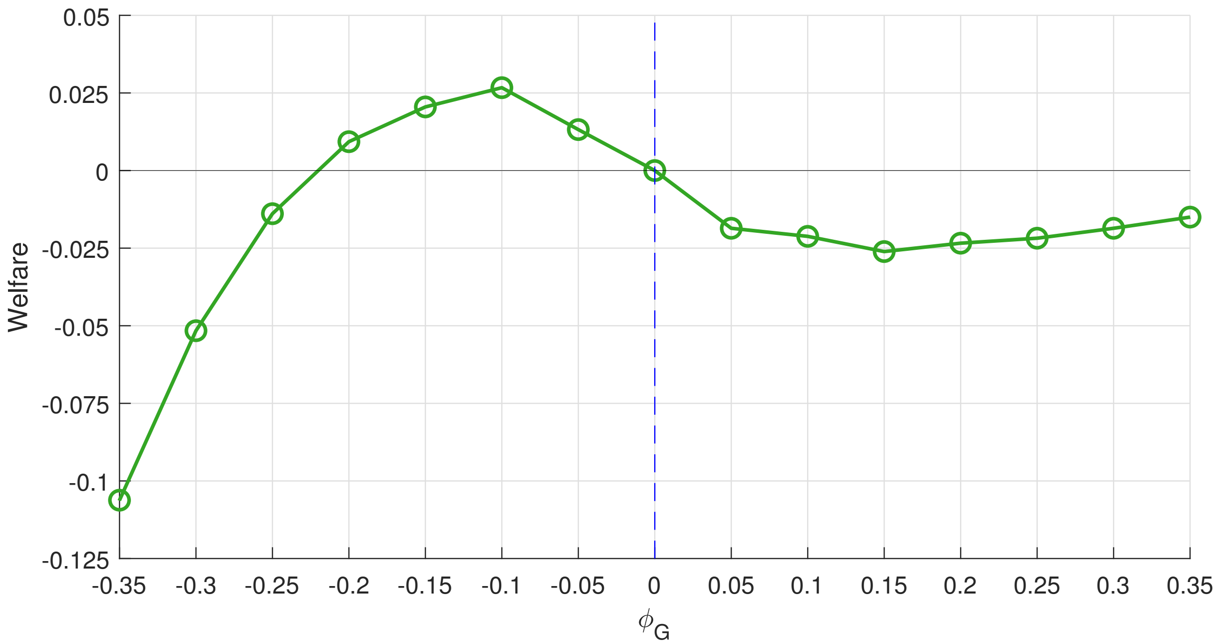

Figure 2: Welfare Effect of Inequality Targeting

Note: This figure shows the average consumption-equivalent welfare gains from a switch from the benchmark Taylor rule to one with a different weight on the income Gini index, ϕ_G.

from both the qualitative and quantitative perspective, depending on the size of the Taylor rule coefficient for the inequality gap, ϕ_G. The key quantitative finding is that the systematic reaction of monetary policy to inequality could be welfare-improving. The figure suggests that there is a region of ϕ_G that generates welfare gains. Specifically, households are better off on average when ϕ_G has a value between -0.2 and 0. Notably, the welfare gain peaks when $\phi_G = -0.1$: the average consumption-equivalent welfare increases by 0.0267 percent compared to the benchmark model.

4.2.2 Why is Inequality Targeting Welfare-improving?

To discuss why households are better off when ϕ_G is small and negative, we compare the responses of the key aggregate variables in Figure 3 for model economies with different values of ϕ_G: the benchmark case ($\phi_G = 0$), and the models when $\phi_G = -0.1$ and $\phi_G = 0.1$.

We first discuss this issue through the lens of inflation vs. output-gap variations. The systematic reaction of monetary policy to inequality can be welfare-improving since this policy stabilizes output or consumption over the business cycles. As discussed in the optimal monetary policy literature (Khan, King and Wolman, 2003; Schmitt-Grohe and Uribe, 2007; Woodford, 2010), the combination of variations in output (or consumption) and inflation is at the root of welfare analysis over the business cycles in New Keynesian economies. As is well-known, the less volatile the output

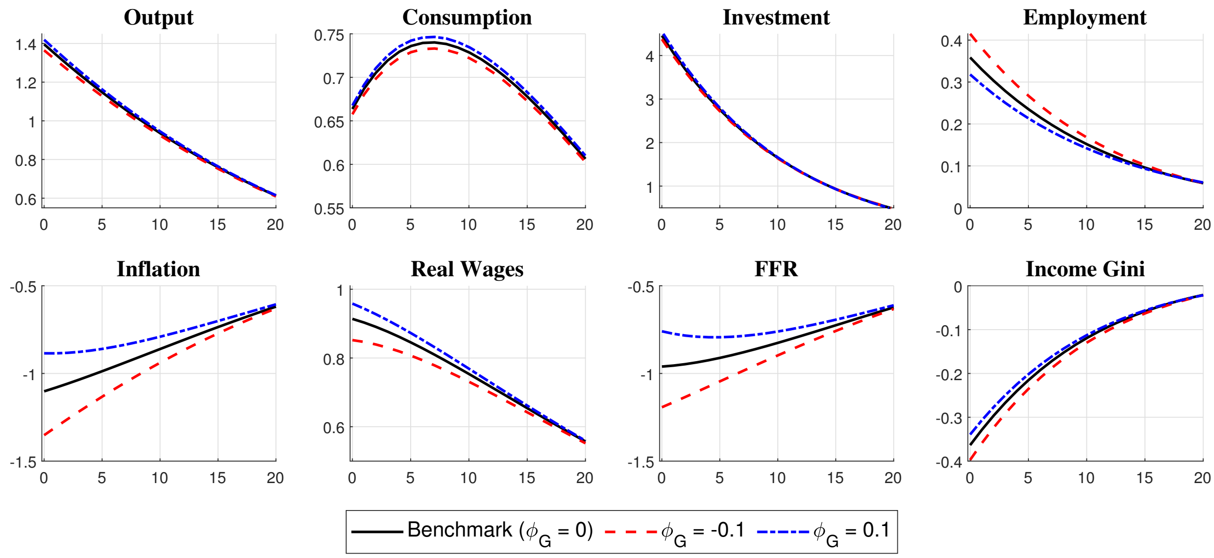

Figure 3: Impulse Responses to TFP Shock: Different Values of ϕ_G.
Note: Impulse response to a one-standard-deviation TFP shock. For inflation, the y axis shows changes in annualized percentage points, while for the remaining variables, the y axis shows percent changes. The x-axis shows quarters after the shock.

and inflation, the larger the welfare households will enjoy, and vice versa. Since the income Gini coefficient is negatively correlated with output over the business cycles (as discussed in Table 3 and Figure 1), the negative response of monetary policy to the Gini index implies a more accommodative policy. As shown in Figure 3, the response of output in the model with $\phi_G = -0.1$ is smaller than that in the benchmark economy. As a consequence, variations in consumption and investment also decline. On the other hand, the reform of monetary policy with a negative ϕ_G results in deviations from price stability, just as a more accommodating policy does. This is obvious as monetary policy is now more accommodating and inflation stability is relatively less valued compared to the benchmark case. This more volatile inflation leads to welfare loss as price adjustment becomes costlier. Hence, the intuition from standard New Keynesian models leads to inconclusive welfare implications as inflation volatility increases while that of output declines.

However, there is an additional channel that works through the market incompleteness in this model. In particular, if the alternative policy we consider can relax "consumption risk," the possibility of low consumption caused by the binding borrowing constraint, it can help improve the welfare of households.[20] As a matter of fact, our quantitative evaluation suggests that reducing con-

[20] Consumption risk is an additional feature that affects the aggregate welfare in a heterogeneous agent model (Gornemann, Kuester and Nakajima 2016; Acharya, Challe and Dogra 2020; Hansen, Lin and Mano 2020). As the consumption risk declines, the overall welfare improves in this model. The central bank can reduce the pass-through from income to consumption risks by adjusting the nominal interest rate on risk-free bonds over the business cycle fluctuations. In other words, monetary policy can provide aggregate consumption insurance, as is discussed in Gornemann, Kuester and Nakajima (2016) and Acharya, Challe and Dogra (2020).

sumption risk caused by the market incompleteness and output variability outweighs an increase in inflation variation. To be precise, when $\phi_G = -0.1$, overall welfare in the economy increases, as households benefit from the smaller variation in output along with the reduced consumption risk, even if it generates more volatile inflation. This means that the positive effect from the smaller fluctuation in output or consumption and from the reduced probability of substantially lower consumption due to the market incompleteness dominates the negative effect from the output loss due to destabilized inflation when ϕ_G is small and negative. However, the latter effect increases as ϕ_G decreases, so households are worse off when ϕ_G is less than -0.25, as shown in Figure 2, as output loss increases exponentially when inflation deviates more away from its steady state. This implies that the welfare effects are nonlinear in ϕ_G.

Besides, the welfare consequences of switching to an inequality-targeting monetary policy are asymmetric. As found in Figure 2, the reform of monetary policy with positive ϕ_G results in welfare losses to households, on average, and there is no range of ϕ_G in which households are better off. In this case, the large fluctuation in output or the increased consumption risk over the business cycle outweighs the effects from less volatile inflation, and hence households are worse off for any value of positive ϕ_G.

In this economy, an ability to smooth consumption against income fluctuations would be different across households depending on their individual state variables (labor efficiency, net worth, and time preference). In this regard, the systematic reaction of monetary policy to inequality can be welfare-improving by shaping more efficient insurance distribution—an insurance distribution channel. Under the reform of monetary policy with a negative ϕ_G, the Fed systematically decreases the nominal interest rate in response to a rise in the income Gini index. This implies that the Fed provides more consumption insurance to poor households, who tend to have lower abilities to hedge against the business cycle. This is closely related to the distributional effects on welfare. We will discuss this issue in detail in the next subsection.

4.3 Who Benefits the Most?

As discussed above, monetary policy reform shapes the business cycles, and this will, in turn, affects household decisions. To restate it, switching to an inequality-targeting monetary policy with a small negative ϕ_G allows households to benefit from the reduced fluctuation in output or consumption, but this policy hurts households due to there now being more volatile inflation. In this unequal

Table 4: Welfare Effects of More Inclusive Monetary Policy ($\phi_G = -0.1$)

Labor Efficiency (z)				Discount Factor (β)				Average
$Z1$	$Z2$	$Z3$	$Z4$		β_L	β_H		
0.0273	0.0270	0.0263	0.0245		0.0312	0.0222		
Wealth (a) Decile								0.0267
1st-3rd	4th	5th	6th	7th	8th	9th	10th	
0.0319	0.0291	0.0264	0.0240	0.0224	0.0213	0.0219	0.0259	

Note: Consumption-equivalent welfare gains of a switch from the benchmark Taylor rule to one with a $\phi_G = -0.1$, by the type of households: time discount factor (β), net wealth (a), and efficiency (z).

society, the extent to which households are exposed to the changes in the business cycles may be significantly different, depending on how they are well-insured. There are mainly two channels in our model economy through which households can insure against business cycle fluctuations: savings (or wealth) and labor supply. On the one hand, households that hold enough wealth are reasonably well insured, as found in standard incomplete market models. On the other hand, households also can adjust their labor supply to insure against business fluctuations (Cho, Cooley and Kim, 2015).[21]

Table 4 shows the welfare effects of a switch from the benchmark monetary policy rule to one with $\phi_G = -0.1$ by household type. Specifically, the table reports the consumption-equivalent welfare gains by labor efficiency (z), time discount factor (β), and net wealth (a), i.e., $\lambda(a, \beta, z)$.[22] As far as time discount factor heterogeneity is concerned, as expected, impatient households tend to have higher welfare gains than patient households. Households with the smaller time discount factor are willing to pay as much as 0.0312 percentage of their lifetime consumption for monetary policy reform, while the consumption-equivalent welfare gain for patient households is 0.0222 percent, which is smaller than the average (0.0267). Households with a lower preference for future consumption tend to be less affected by the destabilized inflation, which makes future consumption more uncertain. This is a well-known finding in the literature studying welfare analysis, in the presence of incomplete markets with time discount factor heterogeneity (Krusell et al., 2009; Gornemann, Kuester and Nakajima, 2016).

An important finding is that, on average, less productive households are more positively affected by an inequality-targeting monetary policy than productive households.[23] As shown in Table 4,

[21] Naturally, the discounting behavior of households directly affects their welfare, since it determines how they value their future consumption.

[22] In the steady state, the borrowing constraint is binding for around 25 percent of the population in the economy. Hence, in the table, we report the first three wealth deciles as a single group.

[23] To save space, we classify households into four productivity groups, based on 11 grid points of labor efficiency.

the welfare gain of households in the first efficiency group ($Z1$) is 0.273 percent in consumption equivalents, which is larger than that of households in the highest productivity group ($Z4$). The decreasing pattern of the welfare gain can be attributed to the labor supply channel. In the model economy, households can insure against the business cycles by adjusting both margins of labor supply: being employed or providing more time devoted to work. The effects from this channel will be substantially different across households, since nonlinear mapping generates huge heterogeneity in labor supply elasticity across households. As discussed in Ma (2021), the non-linear budget constraint endogenously creates a decreasing pattern of labor supply elasticity over the level of labor efficiency, and the substantial heterogeneity in labor supply elasticity is mainly due to the extensive margin.[24] In other words, households at the bottom of the labor efficiency distribution can adjust both margins of labor supply to insure against aggregate fluctuations.[25] However, most of the very productive households are already employed, so they only have an intensive margin adjustment as an insurance tool. Therefore, households with lower productivity tend to have a more elastic labor supply, and hence have relatively large welfare gains.

Lastly, regarding the asset dimension, consumption-equivalent welfare gains are U-shaped across wealth levels. The U-shaped welfare effects may be attributed to the relative size of the determinants of a household's welfare. On the one hand, the wealth-poor are likely to be more impatient or less productive. Thus, they benefit from the low time discount factor and/or larger labor supply elasticity. That is why the welfare gains are largest for the wealth-poorest (households at the bottom 30 percent). On the other hand, as found in standard incomplete market models, wealth is an important tool of a household's ability to smooth its consumption path. Wealthy households can use their savings to insure against the business cycle. This savings channel also works in this model economy: the welfare of the wealthiest is larger than that of households in the 60th to 90th percentile groups.

Who benefits the most from a systematic response by monetary policy to inequality? To answer this question, it is more instructive to take a closer look at the labor supply and savings channels. To this end, we report the welfare gains in greater detail in Figure 4.[26] The upper and bottom panels

The first three grid points (z_1, z_2, and z_3) belong to the first group ($Z1$). The next two groups of three grid points belong to the second and third groups ($Z2$ and $Z3$), respectively, and the last two grid points (z_{10} and z_{11}) belong to the last group ($Z4$).

[24] That is, more marginal workers belong to the lower productivity groups.

[25] Less productive households' active adjustment along the extensive margin of labor supply is consistent with the countercyclical income Gini coefficient over the business cycles, as discussed above.

[26] As in Table 4, the first three wealth deciles are reported as a group in the figure since the borrowing constraint

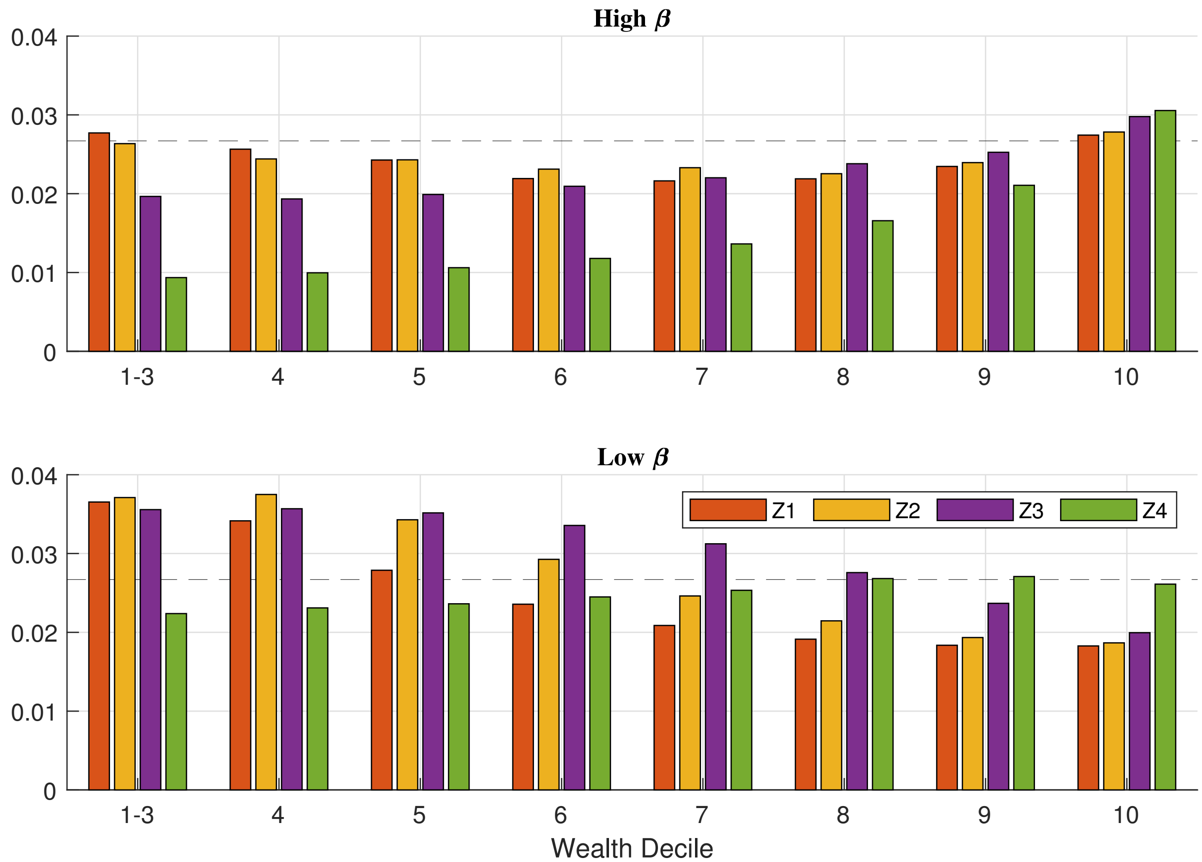

Figure 4: WELFARE GAINS OF SWITCHING TO $\phi_G = -0.1$

Note: This figure shows the consumption-equivalent welfare gains of a switch from the benchmark Taylor rule to one with $\phi_G = -0.1$, by the type of household: time discount factor (β), net wealth (a), and productivity (z). The dashed horizontal lines show the average welfare gain.

in Figure 4 show the welfare effects for patient and impatient households, respectively (households with high and low time discount factors, β_H and β_L, respectively). In each panel, the horizontal axis shows the asset holdings of households by decile of the wealth distribution. For each decile, four household groups by labor efficiency (from lowest to highest) are reported using bars with different colors (red, yellow, purple, and green). We first discuss the asset channel. As shown in the upper panel of Figure 4, the welfare gains of households with the higher time discount factor tend to show an increasing pattern over asset holdings since they can use their savings to insure against the business cycle. The savings channel is clearer for productive and patient households. For these households, the labor supply channel is relatively small since most of them are already employed, and provide enough time devoted to work. For example, the consumption-equivalent welfare gain for the most productive households in the lowest wealth group is around 0.01 percent while it is

is binding for around 25 percent of the population in the steady state .

three times as much for the corresponding households in the highest decile.

As far as the labor supply channel is concerned, this channel considerably affects households with lower labor efficiency. As seen in Figure 4, the welfare gain for less productive households tends to be relatively large, especially among wealth-poor households. For example, conditioning households with a higher time discount factor (the upper panel of Figure 4), the consumption-equivalent welfare gain for the least efficient households ($Z1$) in the lowest wealth group is around 0.03 percent while it is less than 0.01 percent for the most productive households ($Z4$) in the same wealth group. The effect of the labor supply channel seems decreasing with the level of asset holding due to the conventional wealth effect. This finding implies that the savings channel is more dominant for households with a higher time discount factor while impatient households benefit more from the labor supply channel.[27]

Importantly, it is impatient wealth-poor households with lower labor efficiency that have the biggest welfare gains from the monetary policy reform. The wealth-poorest households in the first or second productivity group gain around 0.04 percent if they are impatient, which is around 40 percent larger than the average welfare gain. This result implies that explicit inequality-targeting can improve the welfare of the poorest the most. It should be noted that for these households, the labor supply channel is more dominant than the savings channel. Who benefits the least? Patient and productive households at the bottom 30 percent of the wealth distribution gain the least welfare, since the effects from the two channels are very limited for them—lower labor supply elasticity and limited asset holdings.

In short, a monetary policy that explicitly considers the income Gini index as a targeting variable can improve economic welfare. The welfare gains are heterogeneous across households, but the poor can benefit more from this policy. This result is comparable to that in the previous literature that studies the welfare implication of a more inclusive monetary policy. In particular, Hansen, Lin and Mano (2020) find that when the consumption gap between Ricardian and rule-of-thumb households widens within a two-agent New Keynesian model with no savings or investment, a more inclusive monetary policy can improve social welfare by becoming more accommodative. Similarly, Baek (2021) develops a New Keynesian model with regular and irregular labor types and finds that

[27] Among patient households, the labor supply channel is still in play. The welfare gain for less productive households in the lower wealth groups tends to be relatively large, compared to more efficient households in the corresponding wealth groups. On the other hand, for impatient households, wealth still plays a role in hedging against the business cycle fluctuations. The welfare gain for households in the highest productivity group tends to increase with asset holdings.

reducing the variation of the size of irregular employees can improve welfare on average.

4.4 Discussions

4.4.1 Paradox of Inequality Targeting

The systematic response of monetary policy to inequality has a critical limitation, even if it can be welfare-improving. According to Figure 3, the cyclical variation in income inequality over the business cycle is larger in a monetary policy with $\phi_G = -0.1$ than that in the benchmark model, even if this policy makes households in the economy better off. The income Gini index decreases by 0.36 percent in the benchmark model while it falls by 0.40 percent when $\phi_G = -0.1$. This is mainly because households with low productivity take advantage of the labor supply channel to hedge against the economic fluctuations. In particular, most of these households utilize the extensive margin of labor supply rather than the intensive margin.[28] As discussed above, this can be interpreted through the lens of labor supply elasticity. Less productive households tend to be newly employed since their labor supply is relatively more elastic (Ma, 2021). Figure 4 provides suggestive evidence for this argument. The employment response in the model with $\phi_G = -0.1$ is larger than that in the benchmark model. In response to a technology shock, employment increases by 0.36 percent in the benchmark model while it rises by 0.42 percent when the central bank conducts an inequality-targeting monetary policy with $\phi_G = -0.1$.

It is more instructive to directly compare the employment response for households at the bottom and the top of the income distribution across the model economies. Figure 5 shows the relative employment responses computed by log difference of impulse responses between income-poor and income-rich households in the benchmark economy ($\phi_G = 0$) and the model with $\phi_G = -0.1$. The income-poor are defined as households in the first income quartile while the income-rich are households in the last income group (the fourth quartile). In the benchmark model, the relative employment response is larger than five percent: the immediate response of employment for the income-poor is more than five percent larger than that for the income-rich. This clearly suggests that during expansions, households at the bottom of the income distribution can benefit relatively more because many of them are newly employed (Castañeda, Díaz-Giménez and Ríos-Rull, 1998; Kwark and Ma, 2021). Notably, in the model with $\phi_G = -0.1$, the relative employment response becomes

[28] Note that the nonconvexity is most severe at low times devoted to work, and this may lead households at the bottom of the productivity distribution to be non-employed in the steady state.

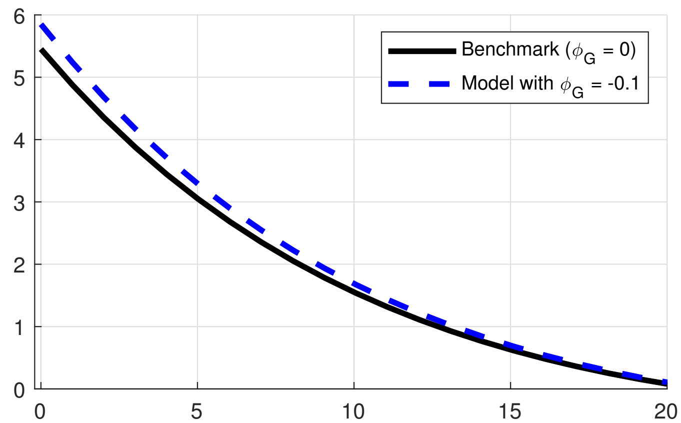

Figure 5: RELATIVE EMPLOYMENT RESPONSE BETWEEN INCOME POOR AND RICH HOUSEHOLDS
Note: The relative employment response between the income-poor and the income-rich in the benchmark economy ($\phi_G = 0$) and the model with $\phi_G = -0.1$. The income-poor are defined as households in the first income quartile, while the income rich are households in the last income group (the fourth quartile). The y axis shows percent change, and the x-axis shows quarters after the shock.

much larger: the difference reaches almost six percents. This implies that under an inequality-targeting monetary policy regime, households in the lower income group considerably increase their extensive margin of labor supply to hedge against aggregate shocks, compared to in the benchmark economy.

Accordingly, income inequality becomes more volatile under the inequality-targeting monetary policy due to the larger fluctuation of employment, as shown in Figure 2. This finding is a bit puzzling because the central bank intended to reduce the inequality variation by including the inequality gap in the monetary policy rule, but it ends up increasing the volatility of inequality. Hence, we refer to this anomaly as *the paradox of inequality targeting*. This paradox has an important policy implication. Social welfare is not directly observed in reality. Accordingly, in spite of its welfare improvement, an explicit targeting of inequality can be considered a failed policy due to the more volatile income Gini index.

4.4.2 Efficiency-Equity Trade Off

Related to the paradox of an inequality-targeting monetary policy, another interesting finding is that there is a trade-off between output and inequality variations. According to Figure 2, a more inclusive monetary policy with $\phi_G = -0.1$ decreases cyclical variations in output, but increases fluctuations in income inequality over the business cycle. When $\phi_G = 0.1$, on the contrary, the size of the output response increases, but the size of the income inequality response decreases, compared to those in the benchmark economy. This means that it is not possible to reduce the variability of

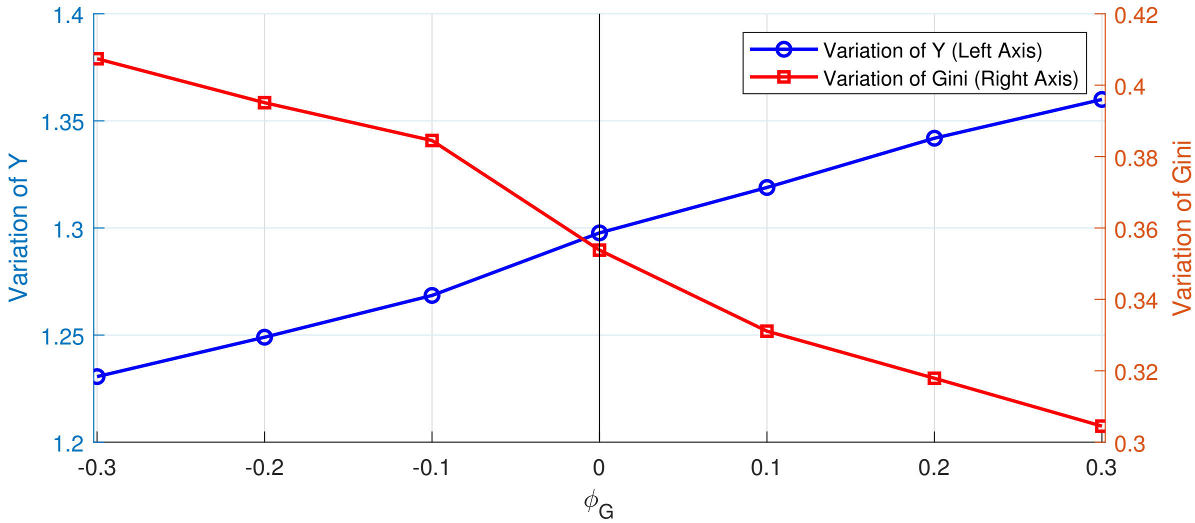

Figure 6: Efficiency-Equity Trade Off

Note: This figure shows the cyclical variations (standard deviation) in output and the income Gini index across different weights on the income Gini index, ϕ_G. Output and the Gini coefficients are quarterly values. Both variables are logged and detrended by the HP filter.

the Gini coefficient by implementing a more accommodative monetary policy. The only way that the economy can achieve less volatile inequality is to have a more hawkish central bank. Hence, there is a trade-off between equity and economic stability.

Specifically, Figure 6 shows the fluctuations (measured by the HP-filtered standard deviation) of output and income inequality with the business cycle frequency across different values of weights on the income Gini index, ϕ_G.[29] The figure clearly shows an efficiency-equity trade-off. There is an inverse relationship between output and income inequality variations. For example, when $\phi_G = -0.3$, the cyclical variations in output and inequality are 1.23 and 0.41 percents, respectively, while the corresponding values are 1.36 and 0.31 percents, respectively, in a case that $\phi_G = 0.3$. This result implies that an economy should sacrifice a more volatile output in order to have smaller cyclical variations in income inequality.

5 Alternative Monetary Policy

The analysis conducted in Section 4.2 implies that it is challenging for a central bank to improve welfare by additionally targeting inequality measured by the income Gini coefficient. That is because the range of ϕ_G that allows for welfare improvements is quite narrow. This suggests that it is not an easy task for a central bank to achieve welfare gain by systematically responding to inequality.

[29] Output and the Gini coefficients are quarterly values. Both variables are logged and detrended by the HP filter.

Table 5: More Accommodative Policy

	σ_Y	σ_Π	σ_E	σ_G	Welfare
Benchmark ($\phi_Y = 0.125$)	1.29	1.03	0.34	0.36	0
$\phi_Y = 0.150$	1.29	1.28	0.34	0.36	-0.0027
$\phi_Y = 0.175$	1.28	1.53	0.34	0.36	-0.0096
$\phi_Y = 0.200$	1.28	1.64	0.35	0.37	-0.0169
$\phi_Y = 0.250$	1.26	2.20	0.38	0.39	-0.0440

Note: σ_x is the standard deviation of variable x. Y, Π , E, and G denote output, gross inflation, employment, and the income Gini coefficients, respectively. All variables are logged and detrended by the HP filter.

Furthermore, while the Gini coefficient is a widely used measure of inequality, it is extremely difficult to measure income Gini coefficients in real-time or even frequently. Gini coefficients are released with considerable lags, resulting in an additional challenge due to the real-time nature of monetary policy. Not only that, estimating the Gini index may involve substantial measurement errors. Hence, it limits the applicability of monetary policy rules augmenting the Gini coefficient. In this regard, we consider more implementable monetary policy rules with inclusive policy natures and their welfare implications.

5.1 More Accommodative Policy

To begin with, we vary the benchmark Taylor rule to gauge the possibility of stabilizing inequality and improving welfare. To be precise, since the income Gini is countercyclical in the model, a more accommodative monetary policy may reduce the volatility of output and inequality at the same time. We postulate a more accommodative policy, while maintaining the dual mandate, by increasing the response of the interest rate to the output gap, ϕ_Y. This seems to be a natural starting point given the countercyclical nature of the income Gini coefficient.

Table 5 reports cyclical variations of the welfare and inequality-related variables and the welfare gains or losses under new monetary policy rules with various values of ϕ_Y. Similar to the previous analyses, more accommodating policies result in a more stable output at the expense of volatile inflation. For example, when $\phi_Y = 0.25$, the cyclical variations in output and inflation are 1.26 and 2.20, respectively, while the corresponding values in the benchmark model are 1.29 and 1.03. These are obvious consequences since these policies have accommodative characteristics compared to the benchmark model. Moreover, employment and the income Gini also become more volatile as in the previous analyses. Under the more accommodative monetary policy with $\phi_Y = 0.25$, the volatilities of employment and the income Gini coefficient are 0.38 and 0.39, respectively, which are larger than those in the benchmark economy. As discussed above, in this case, households in the lower income group rely more on their employment to hedge against aggregate shocks, which increases the inequality variation.

Next, the welfare gains under the new policies are evaluated in the last column of Table 5. When the central bank reacts stronger to the output, households are always worse off with values of ϕ_Y under consideration. This is mainly due to the significant increase in the inflation variation. When $\phi_Y = 0.25$, for instance, the welfare gain is computed as -0.044 percent. Hence, the average household is willing to forgo about 0.04 percent of its consumption every period to stay in the benchmark economy.[30] This is a well-known finding in the optimal monetary policy literature. For example, Schmitt-Grohe and Uribe (2007) show that the welfare costs of a more accommodating monetary policy can be large, thereby underlining the importance of not responding to output. Therefore, attempts to achieve higher welfare through a more accommodative monetary policy have not been successful.

5.2 Employment Targeting

According to the Federal Reserve Act of 1977, which modified the original act establishing the Federal Reserve in 1913, the Fed's goals include *maximum employment*, not maximum GDP. To be more precise, the Act clarified the roles of the Board of Governors and the Federal Open Market Committee (FOMC), by explicitly stating that the Fed's goals include maximum employment, stable prices, and moderate long-term interest rates. Furthermore, many papers based on the incomplete market models show that employment is more closely related to inequality than aggregate output over the business cycles (Castañeda, Díaz-Giménez and Ríos-Rull, 1998; Chang and Kim, 2007; Kwark and Ma, 2021) or in the transmission of monetary policy (Gornemann, Kuester and Nakajima, 2016; Ma, 2021; Baek, 2021). Indeed, in our model, even if there is a strong positive relationship between output and employment, they may not always show the same direction over the business cycles. For example, if already employed households in the top productivity group increase hours of work, output can increase significantly without a rise in employment. Hence, employment may be a more valid proxy for an inequality target. Aggregate employment targeting also benefits

[30] Similar to the previous results, households with a high β, that are wealth-poor with higher labor efficiency dislike the new policy more.

Table 6: EMPLOYMENT TARGETING

	σ_Y	σ_Π	σ_E	σ_G	Welfare
Benchmark ($\phi_E = 0$)	1.29	1.03	0.34	0.36	0
$\phi_E = 0.125$	1.27	1.34	0.38	0.38	-0.0038
$\phi_E = 0.250$	1.25	1.69	0.39	0.39	-0.0212

Note: σ_x is the standard deviation of variable x. Y, Π , E, and G denote output, gross inflation, employment, and the income Gini coefficient, respectively. All variables are logged and detrended by the HP filter.

from the fact that employment can be measured in a timely manner with higher precision, compared to Gini coefficients. In this regard, we modify the benchmark monetary policy rule and consider an additional employment target with a weight on the employment gap, ϕ_E:

$$\ln R_t^f = \ln \overline{R^f} + \phi_\Pi \left(\ln \Pi_t - \ln \overline{\Pi} \right) + \phi_Y \left(\ln Y_t - \ln \overline{Y} \right) + \phi_E \left(\ln E_t - \ln \overline{E} \right), \tag{9}$$

where E_t and $\overline{E}$ are employment at t and its steady state value, respectively.

Table 6 reports the cyclical variations of the key variations and the welfare effects under alternative monetary policy rules with various values of ϕ_E. Similar to the more accommodative monetary policy rule, employment-targeting generates more stable output and more volatile inflation. For example, when $\phi_E = 0.25$, the cyclical variations in output and inflation are 1.25 and 1.69, respectively, while the benchmark model produces the corresponding values of 1.29 and 1.03, respectively. Interestingly, similar to the paradox of inequality targeting, another anomaly is found in the employment-targeting monetary policy. Under this policy, employment becomes more fluctuating, although the central bank explicitly considers the employment gap as an additional target variable. When $\phi_E = 0.25$, the cyclical variation in employment is 0.39, which is greater than the 0.34 in the benchmark economy, as is shown in Table 6. This is due to the general equilibrium effects, as discussed in Colciago, Samarina and de Haan (2019) and in Section 4.4.1 of this paper. Intuitively, poor households tend to adjust the extensive margin of labor supply to hedge against aggregate risks. The larger variation in employment ends up also making the income Gini coefficient more volatile, as in previous analyses. For example, in the model with $\phi_E = 0.25$, the volatility of the income Gini index increases to 0.39, which is 8 percent larger than that in the benchmark model.

As far as the welfare effect is concerned, the last column of Table 6 reports the welfare gains under the employment-targeting rule. When the central bank considers an additional target of employment, it results in very unstable inflation, so households should pay welfare costs for any value of ϕ_E.[31] When $\phi_E = 0.25$, for instance, the welfare losses are 0.0212 percent. On average, households are willing to forgo about 0.02 percent of their life-time consumption to stay in the benchmark economy. Therefore, an employment-targeting monetary policy also fails to achieve higher welfare. This implication is in line with that in Baek (2021), where it is shown that targeting the aggregate unemployment gap is less preferred than targeting statistics related to different subgroups in the labor market.

5.3 Subgroup Employment Targeting

Lastly, we test whether monetary policy rules with an additional target regarding the employment of specific subgroups can improve welfare. In particular, we consider the following subgroup targeting rule: one cares about an employment gap for impatient households (low β). We think that the subgroup can reflect wealth-poor households in practice. This subgroup-targeting monetary policy is quite intuitive, since it is natural to think that the employment of poorer households may have a tighter link with inequality than aggregate-level employment.

This consideration has appeal on both the policy and academic sides. When it comes to calls for an "inclusive monetary policy" in policy circles, a substantial amount of discussion is associated with the economic well-being, including the employment, of disadvantaged groups, such as ethnic or racial minorities or low income families, not those of average households (Powell, 2020; Daly, 2020). In addition, while targeting only subgroups of the economy through a monetary policy has not been widely analyzed in the literature, research on this topic is becoming more common nowadays (Baek, 2021; Bartscher et al., 2021). The analysis in this subsection tries to shed some light on the possibility of an inclusive monetary policy by targeting subgroups in the economy through the lens of a HANK model.

We evaluate the welfare gain for the case that the central bank additionally targets the employment of impatient households as shown below:

[31] We consider smaller values of ϕ_E, such as cases where $\phi_E = 0.025$ or $\phi_E = 0.05$, but the welfare gain is still negative under theses model specifications.

Table 7: Policy with Subgroup Targeting

	σ_Y	σ_Π	σ_E	σ_G	Welfare (Impatient HH)
Benchmark ($\phi_\beta = 0$)	1.29	1.03	0.34	0.36	0 (0)
$\phi_\beta = 0.125$	1.28	1.13	0.35	0.37	0.0039 (0.0042)
$\phi_\beta = 0.250$	1.27	1.36	0.38	0.38	0.0183 (0.0207)

Note: σ_x is the standard deviation of variable x. Y, Π , E and G denote output, gross inflation, employment and the income Gini coefficient, respectively. All variables are logged and detrended by the HP filter. "Impatient HH" is the welfare gain among impatient households.

$$\ln R_t^f = \ln \overline{R^f} + \phi_\Pi \left(\ln \Pi_t - \ln \overline{\Pi}\right) + \phi_Y \left(\ln Y_t - \ln \overline{Y}\right) + \phi_\beta \left(\ln E_t^\beta - \ln \overline{E^\beta}\right), \tag{10}$$

where E_t^β and $\overline{E^\beta}$ are the number of employed among impatient households and its steady state value, respectively. As impatient households tend to retain a relatively smaller amount of assets, this rule can be implicitly interpreted as a policy rule that cares more about the economic conditions of low asset households. Before proceeding, we need to specify the values for ϕ_β. As in the previous analysis, we choose positive values for those parameters so that the central bank decreases its nominal interest rate more when the employment of impatient households goes below its steady state value.

Table 7 reports the cyclical variations of the key variations and the welfare gains under the subgroup-targeting monetary policy rule.[32] A monetary policy with the subgroup employment-targeting results in less volatile output, but more volatile inflation. For example, when $\phi_\beta = 0.250$, the cyclical variations in output and inflation are 1.27 and 1.36, respectively, while the corresponding values in the benchmark model are 1.29 and 1.03. It should be noted that similar to the case where the central bank includes the income Gini into the Taylor rule, employment becomes more fluctuating under the subgroup-targeting monetary policy rule. When $\phi_\beta = 0.250$, the cyclical variation in employment is 0.38, which is greater than the 0.34 in the benchmark economy, as is shown in Table 7.[33] The larger variation in employment leads to an increase in the income Gini coefficient variation, as in previous analyses. For example, in the model with $\phi_\beta = 0.250$, the volatility of the income Gini index increases to 0.38, which is larger than that in the benchmark model. This result implies that the subgroup-targeting policy cannot address the

[32] We consider various values of ϕ_β, but we report here a few cases.

[33] Repeatedly, this is because relatively poor households tend to adjust their employment (the extensive margin of labor supply) to insure against business cycle fluctuations.

paradox of inequality targeting either.

Importantly, when the central bank considers an additional target of subgroup employment, households can be better off. For example, when $\phi_\beta = 0.250$, households are willing to forgo about 0.0183 percent of their life-time consumption to stay in the economy with this alternative monetary policy rule. While the changes in aggregate dynamics, such as lower output variation, can be attributed to higher welfare, it should be noted that the distributional dimension still matters and the targeted households benefit from this policy the most. To be precise, when $\phi_\beta = 0.250$, the average welfare gain of the impatient households is 13 percent higher than those of the average household.

Therefore, the subgroup-targeting monetary policy rule—though more *implementable*—has a similar welfare effect as the monetary policy with an explicit targeting of the income Gini. In other words, welfare improvement can be achieved within a single implementable policy framework. This result calls for further research on the usefulness of a version of the subgroup targeting monetary policy as a tool for a more inclusive monetary policy.

6 Conclusion

This study investigates whether the Federal Reserve should include inequality as an additional objective. We develop a Heterogeneous Agent New Keynesian (HANK) model, which generates empirically realistic inequalities and reasonable business cycle properties as observed in the U.S. data. We include the income Gini coefficient in a monetary policy rule to see how an inequality-targeting monetary policy affects aggregate and disaggregate outcomes, as well as economic welfare.

The main findings can be summarized as follows. First, the systematic reaction of monetary policy to inequality can be welfare-improving. Wealth and labor supply elasticity are important determinants of a household's ability to smooth its consumption path. Hence, individual welfare gains differ considerably across households. We find that impatient households with smaller productivity in the lower wealth groups have the biggest welfare gains. This result implies that explicit inequality-targeting can improve the welfare of the poorest the most. Second, inequality targeting may generate a paradox. A welfare-improving inequality-targeting monetary policy increases the cyclical variation in income inequality across the business cycle. Third, there is a trade-off between output and inequality variations. An economy should sacrifice more volatile output to have smaller cyclical variations in income inequality.

Central banks may face a serious challenge when additionally targeting inequality measured by the income Gini coefficient. Although an inequality-targeting monetary policy can be welfare-improving, uncertainty about the target measure could disrupt the carrying out of such a policy. Accordingly, we consider various alternative monetary policy rules. A more accommodative monetary policy or aggregate employment-targeting fails to achieve higher welfare. Importantly, a subgroup-targeting monetary policy can improve economic welfare, implying that a subgroup targeting monetary policy can be a tool for an *implementable* inclusive monetary policy.

It is worth mentioning that the findings in this paper only suggest that there is a possible way that welfare can be improved when the Fed systematically cares about inequality: the income Gini coefficient or employment of the poor. Although our model is successful in generating reasonable cross-sectional distributions and business cycle statistics found in the U.S. data, the results presented above can be potentially very different from both quantitative and qualitative perspectives, according to various model features and/or calibration methods. Hence, there are possible open areas for the next generation of research into the welfare effects of a more inclusive monetary policy.

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Appendix

A The Computational Algorithm

A.1 Steady-state Economy

The computational algorithm used for the steady-state economy is summarized. In this step, we find the stationary measure, $\overline{\mu}$. The steps are as follows.

Step 1. Endogenous parameters are guessed.

Step 2. Construct grids for asset holdings, a, and logged individual labor efficiency, $\hat{z} = \ln z$, where the number of grids for a and $\widehat{z}$ are denoted by N_a and N_z, respectively. We set $N_a = 151$ and $N_z = 11$. a falls in the rage of $[-0.2, 300]$. More asset grid points are assigned on the lower values of a. $\widehat{z}$ is equally spaced in the range of $[-3\sigma_{\hat{z}}, 3\sigma_{\hat{z}}]$, where $\sigma_{\hat{z}} = \sigma_z/\sqrt{1-\rho_z^2}$.

Step 3. Using the algorithm proposed by Tauchen (1986), compute the transition probability matrices for individual labor efficiency, $\mathbb{T}^z$.

Step 4. Solve the individual Bellman equations. In this step, the optimal decision rules for saving $a'(\beta, a, z)$ and hours worked $h(\beta, a, z)$, the value functions, $V(\beta, a, z)$, are obtained. The detailed steps are as follows:

(a) Compute the steady-state real wage rate based on the firm's first-order condition, where the steady-state capital return, $\overline{r}$, is chosen to be 1 percent.

(b) Make an initial guess for the value function, $V_0(\beta, a, z)$ for each grid point.

(c) Solve the consumption-saving problem for each employment status:

$$V_1^E(\beta, a, z) = \max_{a' \geq \underline{a},\, h \geq \Delta_h} \left\{ \frac{(\overline{w}\varphi(h)z + (1+\overline{r})a + \xi - a')^{1-\sigma} - 1}{1-\sigma} \right.$$

$$\left. -\chi \frac{h_t^{1+1/\nu}}{1+1/\nu} + \beta \sum_{z'} \sum_{\beta'} \mathbb{T}^z(z, z')\mathbb{T}^\beta(\beta, \beta')V_0(\beta', a', z') \right\},$$

and

$$V_1^N(\beta, a, z) = \max_{a' \geq \underline{a}} \left\{ \frac{((1+\overline{r})a+\xi-a')^{1-\sigma}-1}{1-\sigma} + \beta \sum_{z'} \sum_{\beta'} \mathbb{T}^z(z, z') \mathbb{T}^\beta(\beta, \beta') V_0(\beta', a', z') \} \right\}.$$

(d) Compute $V_1(\beta, a, z)$ as $V_1(\beta, a, z) = \max \left\{ V_1^E(\beta, a, z), V_1^N(\beta, a, z) \right\}$.

(e) If V_0 and V_1 are close enough for each grid point, go to the next step. Otherwise, update the value functions ($V_0 = V_1$), and go back to (c).

Step 5. Obtain the time-invariant measure, $\overline{\mu}$, with finer grid points for asset holdings. Using cubic spline interpolation, compute the optimal decision rules for asset holdings with the new grid points. $\overline{\mu}$ can be computed using the new optimal decision rules and $\mathbb{T}^z$.

Step 6. Compute aggregate variables using $\overline{\mu}$. If targeted moments are sufficiently close to the assumed ones, then the steady-state equilibrium of the economy is found, then we find the steady-state equilibrium of the economy. Otherwise, reset the endogenous parameters, and go back to Step 4.

A.2 Economy with Aggregate Shocks

We summarize the computational algorithm used for the economy with aggregate shocks. To solve the dynamic economy, the distribution across households, μ, which will affect prices, should be tracked of. Instead, we follow Krusell and Smith (1998) and use the first moment of the distribution and the forecasting function for it. The steps are as follows.

Step 1. We construct grids for aggregate state variables such as TFP shocks and the mean capital, and individual state variables such as the individual labor efficiency and asset holdings. We construct five grid points for both of them for the aggregate capital, K, and TFP shocks, A. For the logged TFP shock, $\hat{A} = \ln A$, we construct five grid points in the range of $[-3\sigma_{\hat{A}}, 3\sigma_{\hat{A}}]$, where $\sigma_{\hat{A}} = \sigma_A / \sqrt{1-\rho_A^2}$. The grid points for K and $\hat{A}$ are equally spaced. The grids for individual state variables are the same as those in the steady-state economy.

Step 3. We parameterize the forecasting functions for K', Y, Π, w, mc, ψ^a, and ψ^z.

Step 4. Given the forecasting functions, we solve the optimization problems for the individual households.[34] We solve the optimization problems for households and obtain the policy functions

[34] Given the wage rate, w, and the marginal cost, mc, the real interest rate, r, can be obtained from the firm's profit maximization.

Table A.1: Estimates and Accuracy of Forecasting Rules

Dependent Variable	Coefficient Cons.	$\log K$	$\log A$	R^2	Den Haan (2010) Error Mean (%)	Max (%)
$\log K'$	0.09495	0.93513	0.10637	1.0000	0.1763	0.4742
$\log Y$	-1.02609	0.16858	1.38823	0.9997	0.0837	0.4977
$\log \Pi$	0.12331	-0.08398	-0.27690	1.0000	0.0192	0.0695
$\log w$	0.0427	0.34461	0.91403	0.9999	0.0613	0.4694
$\log mc$	-0.00025	-0.07170	0.03320	0.9456	0.0567	0.4564
$\log(1+\psi^a)$	-0.00447	0.00304	0.00354	0.9986	0.0007	0.0030
$\log(1+\psi^z)$	-0.03828	0.02613	0.02910	0.9994	0.0076	0.0251

for asset holdings, $a'(\beta, a, z, K, A)$, and consumption $c(\beta, a, z, K, A)$, and the hours decision rule, $h(\beta, a, z, K, A)$.[35]

Step 5. We generate simulated data for 3,500 periods using the value functions for individuals obtained in Step 4. In this step, K', Y, Π, w, mc, ψ^a, and ψ^z are updated.[36]

Step 6. We obtain the new coefficients for the forecasting functions by the OLS estimation using the simulated time series.[37] If the new coefficients are close enough to the previous ones, the simulation is done. Otherwise, we update the coefficients, and go to Step 4.

The estimates, the goodness of fit, and the accuracy of the forecasting functions in the benchmark model are reported in Table A.1. First, it follows that the goodness of fits based on R^2 for all forecasting rules are large. Second, regarding the accuracy of forecasting rules based on the statistics proposed by Den Haan (2010), it is clear that all forecasting rules generate sufficiently small average errors (not exceeding 0.2 percent) and maximum errors (less than 0.5 percent).

[35] As in the steady-state economy, the transition probabilities for z and A are approximated using Tauchen (1986).
[36] Euler equation (Equation 6) and Taylor rule (Equation 7) are also used for the updates.
[37] We drop the first 500 periods to eliminate the impact of the arbitrary choice of initial aggregate state variables.