Optimal Transfer Rules and Heterogeneity

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Abstract

This paper introduces and estimates a tractable, two-agent New Keynesian model with endogenous switching between household types. The goal is to assess the optimal timing, size, and targeting of fiscal transfers to low-income households using simple, automatic rules. Two key findings emerge: First, incorporating endogenous dynamics into the household distribution improves the model's fit to the data. Second, a transfer rule that responds to consumption inequality emerges as the most efficient for reducing consumption dispersion and redistributing income. Furthermore, a counterfactual analysis of the COVID-19 recession reveals that while fiscal stimulus payments helped mitigate output losses, their overall impact was limited due to their excessive size and irregular distribution, with a significant portion being saved; smaller and more sustained transfer payments could have led to more favorable economic outcomes.

*E-mail address: dcardamo@nd.edu (D. Cardamone). I am grateful to my advisor, Eric Sims, for his invaluable guidance and support. I also thank Rudi Bachmann, Christiane Baumeister, Davide Debortoli, Thomas Lubik, Christopher Monjaras, Ben Pugsley, Zach Stangebye, Kenneth West, and Cynthia Wu for their constructive feedback. I received helpful comments from seminar participants at the Southern Economic Association 94th Annual Meeting and the Economics workshop at Notre Dame.

1 Introduction

Throughout the early 2000s recession, the global financial crisis, and the COVID-19 pandemic, the U.S. Congress increasingly prioritized direct financial assistance to low-income households as part of its economic response. These payments, distributed as stimulus checks of up to \$1,400 per eligible individual, represented between 3% and 19% of the government's current transfer payments, totaling a record \$814 billion in 2020 (see the left panel in Figure 1). While designed to alleviate economic hardship and stimulate spending during downturns, these discretionary measures face significant challenges. Fiscal policy lags, including delays in decision-making and implementation, often undermine their timeliness. Moreover, determining the appropriate size of transfers further complicates the issue. Overly large payments may encourage saving, while insufficient payments may fail to stabilize demand or support vulnerable households.

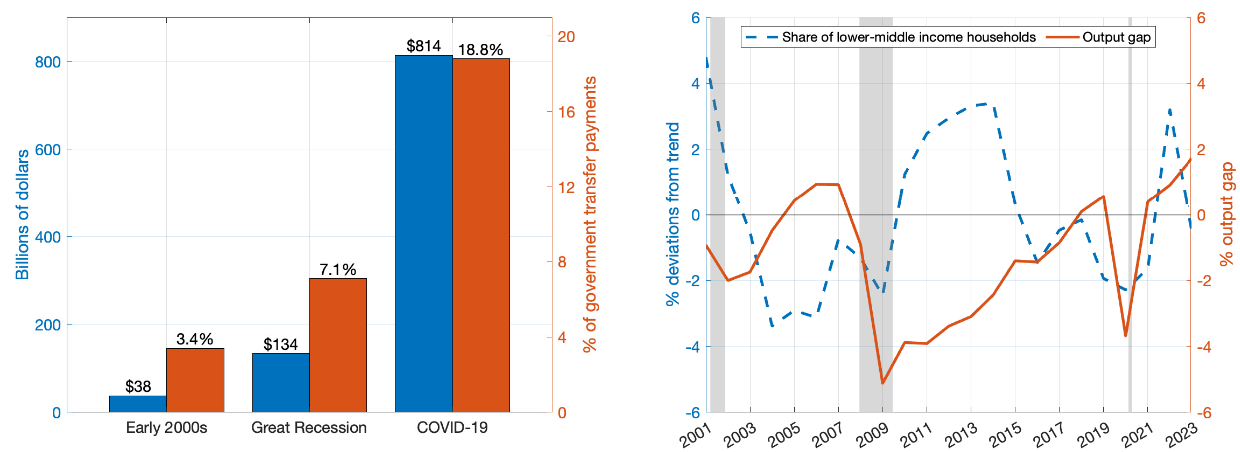


Figure 1: Stimulus checks and household income during economic downturns

(Left panel) Tax rebates and economic payments were provided in response to major economic downturns: the 2001 crisis (Economic Growth and Tax Relief Reconciliation Act), the Great Recession (Economic Stimulus Act of 2008 and American Recovery and Investment Act of 2009), and the COVID-19 pandemic (CARES Act, Tax Relief Act of 2020, and American Rescue Plan Act of 2021). Stimulus checks are shown as a share of government transfer payments during these periods. Sources: *congress.gov.* (Right panel) Quadratically detrended share of households below 400% of the Federal Poverty Level (U.S. Census Bureau), based on pretax family income over the past 12 months as reported in the Consumer Expenditure Survey. The output gap is defined as the log difference between observed and potential real GDP (CBO estimates). See Subsection D.1 in the Appendix for more details.

Against this backdrop, this paper examines how simple, automatic rules can optimize the timing, size, and targeting of fiscal transfers to ensure a more effective response to prevailing economic conditions. The analysis employs an otherwise-standard two-agent New Keynesian model extended to allow for endogenous switching between household types. This extension is important for jointly studying the role of optimal transfers in reducing cyclical income risk, an important mechanism absent in conventional two-agent models, and for directly stimulating consumption. Specifically, the model introduces time-varying probabilities into the tractable HANK (THANK) model (Bilbiie, 2024), determining when households face a binding borrowing constraint. These probabilities evolve in response to changes in disposable income, leading to time-varying shares of household types.

The proposed *dynamic* THANK (D-THANK) model combines the simplicity of the two-agent framework with elements from models featuring richer heterogeneity (e.g., HANK). It introduces a novel composition channel where aggregate economic dynamics are shaped not only by the distinct consumption and saving behaviors of household types but also changes in their relative proportions. This mechanism aligns with the extensive empirical evidence on the countercyclical nature of income risk (Storesletten et al., 2004; Guvenen et al., 2014), as further illustrated in the right panel of Figure 1. The figure shows how the share of households classified as lower-middle income fluctuates with economic conditions,[1] increasing during downturns and decreasing during expansions.

The D-THANK model extends the welfare function of the Ramsey planner in the two-agent framework by incorporating elements from more complex heterogeneous-agent models (e.g., McKay and Wolf, 2023), where cross-sectional consumption depends on not only variations in relative consumption but also shifts in the proportions of households across income groups. The D-THANK model thereby effectively captures welfare risks associated with cyclical fluctuations in consumption shares, expanding the planner's objective from stabilizing relative consumption to also mitigating welfare losses stemming from cyclical income

[1] I classify households with annual income below 400% of the Federal Poverty Level as lower-middle income. This threshold, approximately equivalent to $43,000 in 2009 dollars, aligns with the income characteristics of hand-to-mouth households as described in Aguiar et al. (2024). The results are even more pronounced when using thresholds at 200% to 300% of the FPL.

risk – an aspect absent in models that assume a fixed household distribution.

Two key findings emerge from the analysis. First, by incorporating endogenous changes in the distribution of households, the D-THANK model provides a better empirical fit than the THANK model, as evidenced by several key metrics of out-of-sample forecast performance. Second, under the optimal transfer regime, a policy that responds to deviations in consumption inequality proves to be more effective than rules based on relative or aggregate consumption. This is because consumption inequality offers a systematic measure of changes in household consumption shares, capturing both differences in relative consumption and shifts in the distribution of households across income groups.

These findings are further examined through a counterfactual simulation of the COVID-19 recession, assuming that the U.S. government had adhered to an inequality-targeting transfer rule. The analysis shows that while fiscal stimulus payments helped mitigate output losses, their overall impact was limited due to their excessive size and irregular distribution, with a significant portion being saved.[2] Furthermore, the model suggests that smaller, more sustained transfer payments could have led to more favorable economic outcomes, reducing the output decline by up to 3.7%.

Related literature. This paper adds to the growing literature that integrates micro-heterogeneity channels from quantitative HANK models into analytically tractable frameworks, as seen in Bilbiie (2024), Debortoli and Gali (2024), and Ravn and Sterk (2021). Building on the two-agent framework of Bilbiie (2024), the D-THANK incorporates a novel mechanism allowing households to switch types endogenously, with their distribution adjusting dynamically to aggregate shocks. In a related study, Bilbiie et al. (2023) model time-varying probabilities for (only) unconstrained agents to switch types, emphasizing cyclical precautionary saving as a driver of economic amplification while maintaining a fixed household distribution. The D-THANK model extends these dynamics by relaxing this assumption, allowing *both* constrained and unconstrained agents to switch types endogenously. This

[2]This result aligns with empirical findings from Coibion et al. (2020) based on survey data.

approach reflects the endogenous shifts in household composition found in traditional HANK models (e.g., Kaplan et al., 2018; McKay and Wolf, 2023; Bayer et al., 2023; LeGrand et al., 2024) while avoiding the computational complexity of modeling time-varying income distributions with idiosyncratic shocks and high-dimensional state spaces.

This paper also contributes to the literature on optimal fiscal policy in heterogeneous-agent models. In this regard, Bilbiie et al. (2024) examine the conduct of monetary and fiscal policy within a standard two-agent New Keynesian (TANK) framework, while Wu and Xie (2024) expand this analysis to incorporate unconventional monetary policy. Both studies use welfare loss functions where cross-sectional consumption dispersion is driven solely by differences in consumption across household types (i.e., the consumption gap), assuming a fixed household distribution. In contrast, the D-THANK model relaxes this assumption and broadens the Ramsey planner's problem to account for changes in the proportions of households across income groups. This new framework introduces cyclical income risk as an additional source of welfare volatility, rendering strict consumption-gap targeting suboptimal.[3]

Furthermore, this paper differs in its primary objective: evaluating the unconditional properties of a simple, implementable fiscal rule that adjusts transfers in response to key macroeconomic indicators. In this regard, it also differs from McKay and Wolf (2023), who analyze optimal fiscal policy in a HANK model but do not propose a practical or implementable rule for adjusting transfers to economic conditions. Instead, their proposed rules are based on the dynamic causal effects (i.e., impulse responses) of policy instruments on the targets established by policymakers. Related works proposing systematic fiscal rules include Kliem and Kriwoluzky (2014), who suggest rules for capital and labor income tax rates, and Evers (2012), who examine rules for federal fiscal transfers in monetary unions.

Finally, this paper contributes to the literature on the impact of fiscal stimulus payments

[3] A related strand of literature investigates the distributional effects of monetary policy, proposing augmented Taylor rules to explicitly account for these factors (e.g., Yang, 2023). In contrast, this paper proposes fiscal rules that are *conditional* on the central bank's mandate, as defined by a standard Taylor rule.

during the COVID-19 recession. While prior studies, such as Bayer et al. (2023) and Faria-e-Castro (2021), quantify the impact of fiscal stimuli, they do not analyze the optimal fiscal policy response to the pandemic. In contrast, this paper uses the COVID-19 crisis as a case study to systematically compare potential economic losses under different policy scenarios, offering quantitative evidence on the economic benefits of an optimal transfer policy rule.

The remainder of this paper is organized as follows: Section 2 introduces the D-THANK model; Section 3 outlines the empirical strategy and presents the estimation results; Section 4 introduces the welfare loss function and characterizes the optimal transfer rules; Section 5 discusses the COVID-19 counterfactual analysis; and the final section concludes the paper.

2 The dynamic THANK model

The dynamic THANK (D-THANK) model builds on the tractable two-agent framework of Bilbiie (2024), incorporating endogenous switching between household types and allowing their proportions to evolve dynamically over time.

The economy consists of two distinct types of agents: hand-to-mouth (H) agents and savers (S). Hand-to-mouth agents are financially constrained and must consume their entire disposable income each period, while savers are able to smooth consumption over time by investing in risk-free bonds. In each period, a fraction of households transitions between types according to a *time-varying* Markov process, which adjusts dynamically in response to fluctuations in real disposable labor income. Agents anticipate these fluctuations and self-insure based on the probability of such events occurring. As a result, consumption–saving decisions and optimal labor supply choices are made after aggregate shocks occur but before household types are determined.

In line with Schmitt-Grohe and Uribe (2005), households supply homogeneous labor to labor unions, which then transform it into differentiated labor inputs and sell these to intermediate firms. Labor unions and intermediate firms face nominal rigidities in their wage-setting and price-setting decisions, respectively. Additionally, the central bank sets the nominal interest rate based on a standard Taylor rule, while the government provides tax rebates to financially constrained households in the form of exogenous redistribution. This condition implies that fiscal policy is fully financed through taxation of savers.

2.1 Households

Each household type $i \in \{H, S\}$ chooses the optimal sequence of consumption, labor supply, and risk-free bonds, denoted by $\{C_t^i, N_t^i, Z_{t+1}^i\}_{t=0}^{\infty}$, respectively, to maximize the discounted sum of utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\log \left(C_t^i \right) - \frac{\left(N_t^i \right)^{1+\varphi}}{1+\varphi} \right) \tag{2.1}$$

where $C_t^i \equiv \left(\int_0^1 C_t^i (j)^{\frac{\varepsilon_p - 1}{\varepsilon_p}} dj \right)^{\frac{\varepsilon_p}{\varepsilon_p - 1}}$ is an index of intermediate consumption goods $C_t^i (j)$, $\varepsilon_p > 1$ represents the price elasticity of substitution, and φ is the inverse Frisch elasticity.

At the individual level, agents transition between state H and state S according to an endogenous transition matrix:

$$P = \begin{bmatrix} s_t & 1 - s_t \\ 1 - h_t & h_t \end{bmatrix} \tag{2.2}$$

where s_t and h_t represent the probabilities that savers and hand-to-mouth agents, respectively, remain in their current states. A more detailed explanation of the process governing the dynamics of s_t and h_t is provided below.

For each individual of type i, the period budget constraints are:

$$(H): \qquad C_t^H + Z_{t+1}^H = \frac{W_t}{P_t} N_t^H + T_t^H + \frac{\tau_t^D}{\lambda_t} D_t + \frac{1 + i_{t-1}}{1 + \pi_t} \frac{\mathcal{B}_t^H}{\lambda_t} \tag{2.3}$$

$$(S): \qquad C_t^S + Z_{t+1}^S = \frac{W_t}{P_t} N_t^S + T_t^S + \frac{1 - \tau_t^D}{1 - \lambda_t} D_t + \frac{1 + i_{t-1}}{1 + \pi_t} \frac{\mathcal{B}_t^S}{1 - \lambda_t} \tag{2.4}$$

These constraints are based on real labor earnings $\frac{W_t}{P_t} N_t^i$, lump-sum taxes/transfers T_t^i, and dividends D_t from firms owned by savers. The dividends are redistributed at rates $\frac{\tau_t^D}{\lambda_t}$ and $\frac{1-\tau_t^D}{1-\lambda_t}$. For simplicity, the endogenous redistribution rate τ_t^D is assumed to track the proportion of households that are hand-to-mouth at all times, i.e., $\tau_t^D = \lambda_t$, and to be zero in the steady state, meaning that dividends accrue to savers only.[4] Additionally, they include accumulated financial wealth $\mathcal{B}_{t+1}^i$, which results from the aggregation of savings Z_{t+1}^i by agents transitioning to the same state:

$$\mathcal{B}_{t+1}^H = \lambda_t h_{t+1} Z_{t+1}^H + (1-\lambda_t)(1-s_{t+1}) Z_{t+1}^S \tag{2.5}$$

$$\mathcal{B}_{t+1}^S = \lambda_t (1-h_{t+1}) Z_{t+1}^H + (1-\lambda_t) s_{t+1} Z_{t+1}^S \tag{2.6}$$

These are remunerated at the gross ex post real interest rate $\frac{1+i_{t-1}}{1+\pi_t}$. To maintain tractability, the original model by Bilbiie (2024) imposes a series of assumptions regarding agents' ability to save and borrow, which are discussed in further detail below.

Optimality conditions

Let there be a family head who optimally allocates resources on behalf of savers and hand-to-mouth agents according to the value function:

$$V\left(\mathcal{B}_t^S, \mathcal{B}_t^H\right) = \max_{\substack{C_t^S, Z_{t+1}^S,\\ C_t^H, Z_{t+1}^H}} \left\{(1-\lambda_t)\log C_t^S + \lambda_t \log C_t^H + \beta E_t\left[V\left(\mathcal{B}_{t+1}^S, \mathcal{B}_{t+1}^H\right)\right]\right\} \tag{2.7}$$

subject to Equations (2.3)-(2.6) and the borrowing constraints $Z_{t+1}^S \geq 0, Z_{t+1}^H \geq 0$.

Optimal consumption/saving decisions are described by the following Euler equations:

$$\left(C_t^S\right)^{-1} = \beta E_t\left[\frac{1+i_t}{1+\pi_{t+1}}\left(s_{t+1}\left(C_{t+1}^S\right)^{-1} + (1-s_{t+1})\left(C_{t+1}^H\right)^{-1}\right)\right] + \Xi_t^S \tag{2.8}$$

[4]This assumption simplifies the computation of the steady state for the model estimation while retaining the core implications.

$$\left(C_t^H\right)^{-1} = \beta E_t\left[\frac{1+i_t}{1+\pi_{t+1}}\left(h_{t+1}\left(C_{t+1}^H\right)^{-1} + (1-h_{t+1})\left(C_{t+1}^S\right)^{-1}\right)\right] + \Xi_t^H \tag{2.9}$$

where Ξ_t^i for $i \in \{H, S\}$ represent the Kuhn-Tucker multipliers on the borrowing constraints. To maintain tractability, three simplifying assumptions are introduced in Bilbiie (2024). First, it is assumed that savers will never reach the borrowing limit, i.e., $\Xi_t^S = 0$ and $Z_{t+1}^S \neq 0$ for all t. Second, hand-to-mouth agents are assumed to be financially constrained in every period, i.e., $\Xi_t^H \neq 0$ and $Z_{t+1}^H = 0$ for all t, and they must consume their entire period's disposable income. Third, a zero-liquidity limit is imposed on savers' budget constraint, meaning that bonds are in zero net supply in equilibrium. As a result, the optimal consumption decisions for savers and hand-to-mouth agents reduce to:

$$\left(C_t^S\right)^{-1} = \beta E_t\left[\tfrac{1+i_t}{1+\pi_{t+1}}\left(s_{t+1}\left(C_{t+1}^S\right)^{-1} + (1-s_{t+1})\left(C_{t+1}^H\right)^{-1}\right)\right] \tag{2.10}$$

$$C_t^H = \frac{W_t}{P_t}N_t^H + T_t^H + D_t \equiv Y_t^D \tag{2.11}$$

Here, savers account for the possibility of transitioning to the hand-to-mouth state by "self-insuring" in the present. Conversely, a hand-to-mouth household is constrained to consume its disposable labor income, denoted by Y_t^D.

Time-varying probabilities. Probabilities are assumed to deviate from their steady-state values, denoted by the scalars s and h, in a way that is proportional to changes in agents' disposable labor income:[5]

$$h_t = h\left[\frac{Y_t^D}{Y_{t-1}^D}\cdot\right]^{-\gamma_h} \tag{2.12}$$

$$s_t = s\left[\frac{Y_t^D}{Y_{t-1}^D}\right]^{\gamma_s} \tag{2.13}$$

where $\frac{Y_t^D}{Y_{t-1}^D}$ represents the gross changes in disposable labor income, with the elasticities γ_h and γ_s determining the magnitude of the response. The rationale for this choice is based on

[5] Bilbiie et al. (2023) assume that the only time-varying factor in the transition matrix (2.2) is the probability of savers remaining in their current state, s_t, which is modeled as a function of the GDP gap.

two main facts. First, disposable labor income constitutes a substantial share of low- and middle-income households' total disposable income, as emphasized by Aguiar et al. (2024). As a result, within the model, changes in labor earnings are treated as uninsurable income shocks, leading to short-term fluctuations in the share of hand-to-mouth individuals.[6] This mechanism is also consistent with the empirical analysis of Heathcote et al. (2020), who find that the countercyclicality of income inequality is primarily driven by dynamics at the lower end of the earnings distribution. Second, fiscal stimulus payments create a wealth effect through households' budget constraints, effectively functioning as an income shock. This mechanism aligns with empirical observations from the COVID-19 recession, where fiscal transfers helped limit the rise in the poverty rate by approximately 3.6% (Burns et al., 2021). Additionally, quantitative analyses by Bayer et al. (2023) indicate that fiscal transfers effectively contained the increase in the income Gini coefficient by approximately 3%.

At the aggregate level, the shares of savers $(1-\lambda_t)$ and hand-to-mouth agents (λ_t) also evolve over time, following a Markov process:

$$\begin{bmatrix} (1-\lambda_t) & \lambda_t \end{bmatrix} = \begin{bmatrix} (1-\lambda_{t-1}) & \lambda_{t-1} \end{bmatrix} \begin{bmatrix} s_t & 1-s_t \\ 1-h_t & h_t \end{bmatrix} \tag{2.14}$$

In log-linear form, the process is expressed as:

$$\hat{\lambda}_t = (s+h-1)\,\hat{\lambda}_{t-1} + \lambda \hat{h}_t - (1-\lambda)\,\hat{s}_t. \tag{2.15}$$

When combined with the log-linearized Equations (2.12) and (2.13), this yields:

$$\hat{\lambda}_t = (s+h-1)\,\hat{\lambda}_{t-1} - (\tilde{\gamma}_s + \tilde{\gamma}_h)\,\Delta\hat{y}_t^D \tag{2.16}$$

Here, $\tilde{\gamma}_s \equiv (1-\lambda)\cdot s\cdot\gamma_s$ and $\tilde{\gamma}_h \equiv \lambda\cdot h\cdot\gamma_h$, where λ represents the steady-state share of hand-

[6]In models featuring rich heterogeneity, these fluctuations resemble the direct income effects on households near the borrowing constraint.

to-mouth individuals. Therefore, conditional on $\tilde{\gamma}_s > 0$ and $\tilde{\gamma}_h > 0$, an increase in disposable labor income results in a proportional decrease in the aggregate share of hand-to-mouth agents and an increase in the number of savers in the economy.

Importantly, the D-THANK model expands on the household blocks of the THANK models developed in Bilbiie (2024) and Bilbiie et al. (2023). When both $\tilde{\gamma}_s$ and $\tilde{\gamma}_h$ are set to zero, the model simplifies to that of Bilbiie (2024), where the Markov process in (2.14) is in equilibrium, and there is no time variation in the probabilities of transitioning between household types or in their distribution. Similarly, by fixing the transition probability h_t and the distribution of household types at their steady-state values, the household block of the model reduces to that of Bilbiie et al. (2023).

Labor supply. As in Schmitt-Grohe and Uribe (2005), households supply different types of labor, indexed by $z \in [0, 1]$. Type-specific unions aggregate labor inputs and exchange them with firms for a nominal wage $W_t(z)$. Given $W_t(z)$, a worker of type z is willing to supply labor, $N_t(z)$, as demanded by firms:

$$N_t(z) = \left(\frac{W_t(z)}{W_t}\right)^{-\varepsilon_w} N_t^D \tag{2.17}$$

where $\varepsilon_w > 1$ represents the labor elasticity of substitution, W_t is the nominal wage index, and N_t^D denotes the aggregate labor demand.

Households are uniformly distributed across unions, leading to a uniform aggregate demand for labor of type z. As a result, the individual labor supply, $N_t(z)$, is equal across households, such that $N_t^S = N_t^H = N_t$.

2.2 Labor markets

Nominal wages are sticky and can be adjusted with a probability of $1 - \theta_w$ in each period. As described in Colciago (2011), wages are set by labor unions, which seek to maximize a social welfare function. This function averages the utility of hand-to-mouth households and savers, subject to the labor demand for type z by intermediate firms:

$$\max_{W_t(z)} E_t \sum_{k=0}^{\infty} (\beta\theta_w)^k \left[\left(\frac{\lambda_{t+k}}{C^H_{t+k}} + \frac{1-\lambda_{t+k}}{C^S_{t+k}} \right) \frac{W_t(z)}{P_{t+k}} N_{t+k} - \frac{N_{t+k}^{1+\varphi}}{1+\varphi} \right]$$
$$s.t. \tag{2.18}$$
$$N_{t+k} = \left(\frac{W_t(z)}{W_{t+k}} \right)^{-\varepsilon_w} N^D_t$$

Importantly, the weights in the social welfare function correspond to the *time-varying* shares of households, λ_{t+k} and $1-\lambda_{t+k}$, linking changes in the household distribution to wage inflation. In the absence of wage rigidities, the optimal wage would simplify to the condition derived in Gali et al. (2007):

$$\frac{W_t(z)}{P_t} = \mathcal{M}_w \left[\frac{\lambda_t}{MRS^H_t} + \frac{1-\lambda_t}{MRS^S_t} \right]^{-1} \tag{2.19}$$

where $MRS^i_t \equiv (N^i_t)^{\varphi} C^i_t$ denotes the marginal rate of substitution for agent i and $\mathcal{M}_w \equiv \frac{\varepsilon_w}{\varepsilon_w - 1} > 1$ represents the wage markup. Under the condition that $\frac{W_t}{P_t} > MRS^S_t > MRS^H_t$, both households are always willing to supply the amount of labor, N_t, demanded by the labor unions.

As a result, holding everything else constant, an increase in λ_t, reflecting a higher share of constrained households, alters the average marginal rate of substitution, leading to a decline in the nominal wage. Furthermore, since in Equation (2.19), no term other than the nominal wage $W_t(z)$ depends on the worker type z, it follows that $W_t(z) = W_t$ and $N^D_t = N_t$.

2.3 Production

There exists a continuum of monopolistically competitive firms that produce differentiated intermediate goods. These goods are then utilized as inputs by a perfectly competitive firm to manufacture a single final good.

Final good producer. The representative final good producer uses a constant elasticity of substitution (CES) technology to produce the final good, Y_t:

$$Y_t = \left(\int_0^{F_t} Y_t\left(j\right)^{\frac{\varepsilon_p - 1}{\varepsilon_p}} dj \right)^{\frac{\varepsilon_p}{\varepsilon_p - 1}} \tag{2.20}$$

where $Y_t\left(j\right)$ denotes the quantity of intermediate good j used as an input while F_t represents an exogenous AR(1) cost-push shock arising from the entry and exit of intermediate goods producers, as modeled in Bilbiie and Melitz (2023):

$$\log F_t = \rho_f \log F_{t-1} + u_t^f$$

where u_t^f is an i.i.d. innovation.

Profit maximization yields the demand schedule for intermediate good j:

$$Y_t\left(j\right) = \left(\frac{P_t\left(j\right)}{P_t} \right)^{-\varepsilon_p} Y_t \tag{2.21}$$

where $P_t\left(j\right)$ and P_t denote the prices of intermediate and final goods, respectively, and are taken as given. Furthermore, the zero-profit condition implies:

$$P_t = \left(\int_0^{F_t} P_t\left(j\right)^{1-\varepsilon_p} dj \right)^{\frac{1}{1-\varepsilon_p}}. \tag{2.22}$$

Intermediate goods producers. Labor is the only input used in the production of intermediate goods. The production function is given by:

$$Y_t\left(j\right) = A_t N_t\left(j\right)^{1-\alpha} \tag{2.23}$$

where α represents the share of capital;[7] A_t, which represents aggregate productivity, evolves exogenously according to:

$$\log A_t = \rho_a \log A_{t-1} + u_t^a \tag{2.24}$$

where u_t^a is an i.i.d. productivity shock.

Nominal prices are sticky and can be adjusted with probability $1 - \theta_p$ in each period. Firms that are able to adjust their prices in a given period set $P_t^* (j)$ to maximize their expected profits, subject to the demand schedule for good j:

$$\begin{gathered} \max_{P_t^*(j)} E_t \textstyle\sum_{k=0}^{\infty} \theta_p^k \Lambda_{t,t+k}^S \left\{ P_t^* (j) \, Y_{t+k|t} (j) - \Psi \left(Y_{t+k|t} (j) \right) \right\} \\ s.t. \\ Y_{t+k|t} (j) = \left(\frac{P_t^*(j)}{P_{t+k}} \right)^{-\varepsilon_p} Y_{t+k} \end{gathered} \tag{2.25}$$

where $\Psi (\cdot)$ represents the total costs associated with producing $Y_{t+k|t} (j)$ units of the good and $\Lambda_{t,t+k}^S \equiv \beta^k \frac{U_{c,t+k}^S}{U_{c,t}^S}$ is the saver's stochastic discount factor. The optimal reset price, $P_t^* (j)$, satisfies the following condition:

$$\sum_{k=0}^{\infty} \theta_p^k \Lambda_{t,t+k}^S Y_{t+k|t} (j) \left\{ P_t^* (j) - \mathcal{M}_p \psi_{t+k|t} \right\} = 0$$

where $\mathcal{M}_p \equiv \frac{\varepsilon_p}{\varepsilon_p - 1} > 1$ is the desired price markup and $\psi_{t+k|t}$ denotes the expected marginal cost in period $t + k$ for a firm that last adjusted its price in period t.

2.4 Monetary policy

A central bank sets the nominal interest rate in each period following a simple Taylor rule:

$$i_t = \rho_i i_{t-1} + (1 - \rho_i) \left(\phi_\pi \pi_t + \phi_y \hat{y}_t \right) + u_t^v \tag{2.26}$$

[7] Alternatively, aggregate productivity can be expressed as $A_t \equiv \tilde{A}_t K (j)^\alpha$, where $K (j)$ denotes a fixed capital input in the production function.

where ρ_i is the persistence of the nominal interest rate, $\phi_\pi > 0$ and $\phi_y > 0$ are the policy coefficients for inflation and the output gap, respectively, and u_t^v represents an i.i.d. shock to the interest rate.

2.5 Fiscal policy

The government imposes taxes on savers, $\mathcal{T}_t^S \equiv (1-\lambda_t)\, T_t^S$, and redistributes these taxes in lump-sum payments to hand-to-mouth agents, represented as $\mathcal{T}_t^H \equiv \lambda_t T_t^H$. This ensures that transfers are always in zero net supply, as given by the condition:

$$-T_t^H \lambda_t = (1-\lambda_t)\, T_t^S \tag{2.27}$$

To reflect their historically sporadic use, lump-sum transfers are assumed to remain at the (zero) steady state in the estimation of the D-THANK model. More detailed rules for discretionary transfers are provided in Section 4, where optimal fiscal policy is discussed.

2.6 Aggregation and market clearing

This subsection concludes the description of the D-THANK model by presenting the aggregate resource constraints and market clearing conditions. A complete set of nonlinear and log-linear equilibrium conditions is provided in Appendices A and C.

Consumption. Aggregate consumption is calculated as the weighted average of consumption from both households:

$$C_t^A = \lambda_t C_t^H + (1-\lambda_t)\, C_t^S \tag{2.28}$$

Labor market. Labor supply must satisfy the resource constraint:

$$N_t = \int_0^1 N_t\,(z)\, dz \tag{2.29}$$

which, when combined with the labor demand in Equation (2.17), gives:

$$N_t = N_t^D \int_0^1 \left(\frac{W_t(z)}{W_t} \right)^{-\varepsilon_w} dz \tag{2.30}$$

where $\int_0^1 \left(\frac{W_t(z)}{W_t} \right)^{-\varepsilon_w} dz$ represents the degree of wage dispersion. Ultimately, the total labor income is expressed as:

$$W_t N_t^D = \int_0^1 W_t(z) N_t(z) dz = N_t^D \int_0^1 W_t(z) \left(\frac{W_t(z)}{W_t} \right)^{-\varepsilon_w} dz \tag{2.31}$$

Goods market. The goods market clearing condition requires:

$$Y_t(j) = C_t(j) \qquad \forall j \tag{2.32}$$

and

$$Y_t = C_t^A \tag{2.33}$$

3 Model estimation and analysis

This section presents empirical estimates of the parameters in both the D-THANK model and the THANK model of Bilbiie (2024). Given the relatively small scale of these DSGE models, the estimation primarily focuses on informing key structural parameters related to nominal rigidities, monetary policy conduct, and the persistence and variance of structural shocks, using a limited set of key observables.[8] These estimates are required to empirically inform the analysis of optimal policy and counterfactual exercises in Sections 4 and 5. Additionally, this section examines the impact of introducing an endogenous household distribution on the models' empirical fit.

[8]Furthermore, the model effectively generates smoothed estimates of variables that are inherently difficult to measure (e.g., the historical share of hand-to-mouth households), as detailed in Appendix D.2.

Data and estimation. The models are estimated using Bayesian methods with U.S. quarterly time series data on the log difference of real GDP per capita, log hours worked per capita, the log difference of the GDP deflator, and the Federal funds rate. A full description of the data is provided in Appendix D.1. The corresponding measurement equation is:

$$X_t = \begin{bmatrix} y_t^{obs} \\ h_t^{obs} \\ \pi_t^{obs} \\ i_t^{obs} \end{bmatrix} = \begin{bmatrix} y_t - y_{t-1} \\ h_t \\ \pi_t \\ i_t \end{bmatrix} \tag{3.1}$$

where the variables have been previously demeaned and are assumed to be stationary.

Following the approach in Ratto et al. (2009), the estimation process begins by identifying the mode of the posterior distribution that maximizes the log-posterior function. This function integrates information from both the priors on the parameters and the likelihood of the observed data. Next, a chain of 500,000 iterations of the Metropolis–Hastings algorithm is employed to obtain the full posterior distribution. This number of iterations is considered sufficient to guarantee the algorithm's convergence, as outlined in Appendix D.2.

Prior distributions of the parameters. The prior distributions of the parameters are selected based on the existing literature on estimated dynamic stochastic general equilibrium (DSGE) models, such as Smets and Wouters (2007). Specifically, parameters governing the AR(1) processes are assumed to follow inverse gamma distributions for the standard deviations and beta distributions for the AR(1) coefficients.[9] Additionally, the elasticities of inflation and the output gap in the systematic component of monetary policy, the share of capital, the inverse of the Frisch elasticity, and the elasticities of substitution for prices and wages are assumed to follow normal distributions. The parameters governing price and wage stickiness are assumed to follow beta distributions, while the discount factor, defined as

[9] As noted in Subsection 2.5, during the estimation of the D-THANK and THANK models, lump-sum transfers are assumed to remain at their steady-state value of zero, reflecting their historically sporadic use.

$100 \cdot (1/\beta - 1) \equiv \tilde{\beta}$, is based on the approach of Bilbiie et al. (2023) and is assumed to follow a gamma distribution. Finally, the two newly introduced parameters, the income elasticities s and h, are assumed to follow gamma distributions to ensure that they remain nonnegative. In the estimation process, two parameters are fixed: the steady-state probabilities in matrix (2.2), set at $s = 0.9800$ and $h = 0.9459$. These values lead to a steady-state share of hand-to-mouth agents of 0.27 and are consistent with the average marginal propensity to consume out of transitory income shocks reported by Parker et al. (2013).

Table 1 summarizes the priors and posterior estimates for the parameters of the D-THANK model. For comparison, the corresponding estimates for the THANK model are presented in Appendix D.2. Overall, the data provide substantial information, resulting in noticeable changes in the posterior distributions. The posterior modes of the nondistributional parameters demonstrate strong similarities across the THANK and D-THANK models. Furthermore, the estimated income elasticities, $\tilde{\gamma}_h$ and $\tilde{\gamma}_s$, indicate that hand-to-mouth households require substantially larger income gains to transition to the saver state. In contrast, savers are more likely to become hand-to-mouth after a comparatively smaller income decline. These findings are consistent with Aguiar et al. (2024), who show that hand-to-mouth households are more than ten times as likely to remain in their current state compared to non-hand-to-mouth households.

Empirical fit. The empirical performance of the models is evaluated using the Laplace approximation (LA) and the modified harmonic mean (MHM) of the marginal likelihood, in addition to the Bayesian information criterion (BIC). These metrics assess how well the model explains the observed data. The marginal likelihood quantifies the probability of the data given the model, with higher values indicating a better fit. The BIC balances model fit and complexity, where lower values favor models that achieve a strong fit while remaining parsimonious. These metrics serve as informative summary statistics of out-of-

	Parameters	Prior Distribution			Posterior Distribution	
		Distr.	Mean	St. Dev.	Mode	90% C. I.
σ^f	Std - Cost Push Shock	IG	0.1	2.0	0.09	$[0.05, 0.17]$
σ^v	Std - Mon. Policy Shock	IG	0.1	2.0	0.13	$[0.11, 0.14]$
σ^a	Std - Tech. Shock	IG	0.1	2.0	0.47	$[0.43, 0.53]$
σ^w	Std - Wage Shock	IG	0.1	2.0	0.04	$[0.03, 0.06]$
ρ^f	AR(1) Coeff. - Cost Push Shock	B	0.5	0.2	0.98	$[0.97, 0.99]$
ρ^a	AR(1) Coeff. - Productivity Shock	B	0.5	0.2	0.97	$[0.95, 0.99]$
ρ^i	AR(1) Coeff. - Monetary Policy	B	0.5	0.2	0.87	$[0.85, 0.89]$
ρ^w	AR(1) Coeff. - Wage Shock	B	0.5	0.2	0.98	$[0.95, 0.99]$
ϕ_y	Taylor Rule: Output	N	0.125	0.05	0.09	$[0.06, 0.13]$
ϕ_π	Taylor Rule: Inflation	N	1.5	0.25	1.97	$[1.70, 2.25]$
$\tilde{\beta}$	Discount Factor $100 \cdot (1/\beta - 1) \equiv \tilde{\beta}$	G	0.25	0.1	0.21	$[0.09, 0.40]$
α	Share of Capital	N	0.25	0.05	0.29	$[0.22, 0.37]$
ϕ	Inverse Frisch Elasticity	N	2.0	0.75	3.73	$[2.93, 4.79]$
θ_w	Calvo Parameter: Wages	B	0.66	0.1	0.68	$[0.50, 0.83]$
θ_p	Calvo Parameter: Prices	B	0.66	0.1	0.35	$[0.26, 0.49]$
ε_w	Elas. of Substitution: Wages	N	7.5	1.0	7.50	$[5.87, 9.16]$
ε_p	Elas. of Substitution: Prices	N	7.5	1.0	6.65	$[5.01, 8.41]$
$\tilde{\gamma}_s$	Income Elasticity on s	G	0.5	0.25	0.96	$[0.54, 1.34]$
$\tilde{\gamma}_h$	Income Elasticity on h	G	0.5	0.25	0.13	$[0.04, 0.35]$

Table 1: Structural parameters of the D-THANK model

Note: B, G, IG, and N denote beta, gamma, inverse gamma, and normal distributions, respectively.

sample forecast performance.[10]

Table 2 presents a comparison of these three statistics between the THANK and D-THANK models. The D-THANK model shows higher LA and MHM values than the THANK model, indicating a better fit to the data. Furthermore, the D-THANK model has a lower BIC value than the THANK model, suggesting that it provides a more accurate fit, even with the inclusion of two additional estimated parameters. Based on these statistics, the D-THANK model appears to be the preferred model, offering a better fit to the data than the THANK model. The improvement in empirical performance can be attributed to the endogenous household distribution, as demonstrated by the gains in the three key statistics when the assumption of fixed household shares (λ) is relaxed.

Model	LA	MHM	BIC
THANK	-256.99	-256.74	518.00
D-THANK	-245.64	-245.39	500.47

Table 2: Empirical performance of the THANK and D-THANK models

Note: LA, MHM, and BIC refer to the Laplace approximation, the modified harmonic mean, and the Bayesian information criterion, respectively.

3.1 Impulse response analysis

This subsection begins by analyzing the effects of an exogenous shock to the share of constrained households in the economy, referred to as a "hand-to-mouth shock," which can be interpreted as an uninsurable income shock. It then discusses the endogenous dynamics of the household distribution when the economy is impacted by an external shock, such as a productivity shock.

Consistent with the empirical observation that low-income households have lower consumption expenditures, an exogenous increase in the share of hand-to-mouth households reduces aggregate demand, thereby decreasing prices, as illustrated in Figure 2. In addition

[10] For a detailed discussion on forecast evaluation, see Section III and footnote 11 in Smets and Wouters (2007).

to the price decline, a higher share of hand-to-mouth workers lowers the average marginal rate of substitution, leading labor unions to set lower nominal wages. The central bank responds to the decline in prices and depressed economic activity with a nominal interest rate cut. However, this policy adjustment has a limited stabilizing effect on the income distribution. Therefore, a distributional shock to household types can have notable economic implications, with approximately one-quarter of the shock's magnitude being reflected in changes to both nominal and real macroeconomic indicators.

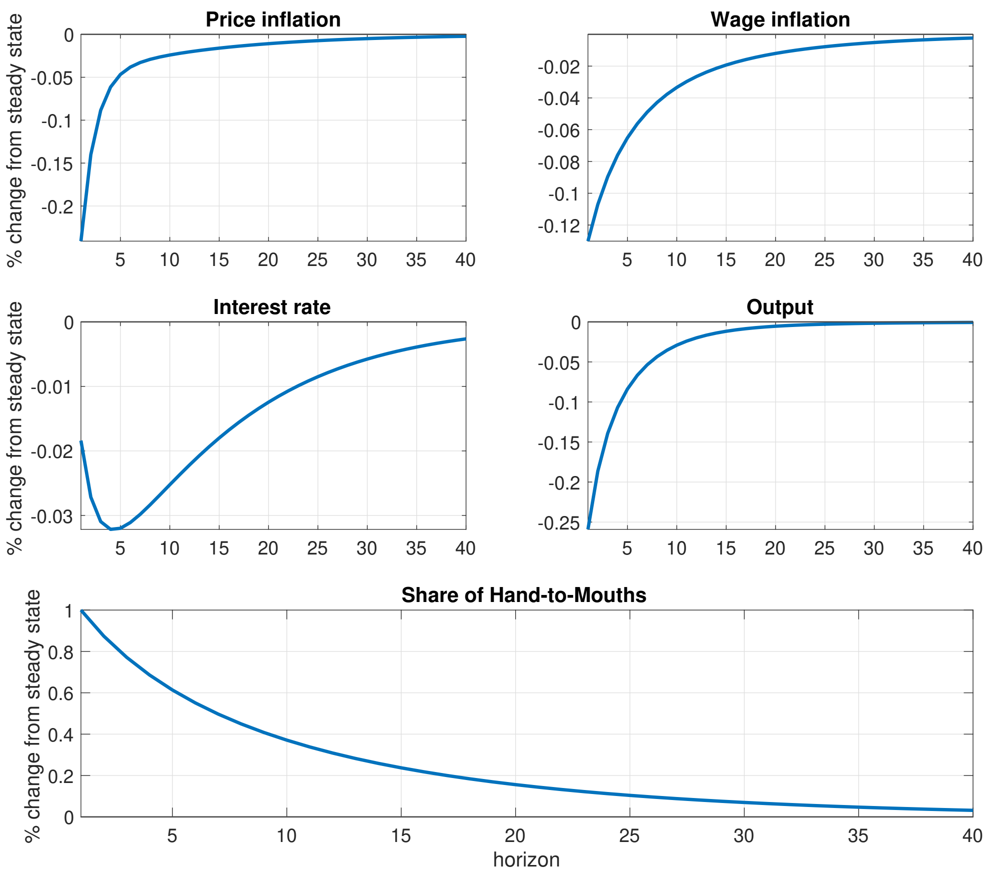


Figure 2: Impulse response functions to a hand-to-mouth shock

Note: Impulse responses are constructed using the posterior mode of the structural parameters and are modeled to induce a 1% increase in the share of hand-to-mouth agents. The exogenous hand-to-mouth shock is calibrated with a standard deviation of 0.25.

In contrast, Figure 3 illustrates the economic and distributional impact of an unforeseen external shock, such as a productivity shock.[11] This shock causes a temporary decline

[11] For other exogenous shocks, see Figures 9 to 11 in Appendix F.1.

in firms' total factor productivity, reducing output and increasing prices and wages. In response to inflationary pressures, the central bank adjusts the interest rate according to the Taylor rule. Additionally, aggregate demand falls as hand-to-mouth households reduce their spending due to their lower disposable income, while savers decrease consumption for precautionary reasons.

Figure 3: Impulse response functions to a productivity shock

Note: Impulse responses are constructed using the posterior mode of the structural parameters and are modeled to induce a 1% decline in aggregate output.

A key distinction between the THANK and D-THANK models lies in how savers respond to an increased likelihood of facing financial constraints in the future. In the THANK model, savers assume that this probability remains constant, leading them to hold their saving behavior constant. Moreover, the THANK model does not account for the potential distributional effects on macroeconomic aggregates, thus limiting the amplification of the shock arising from shifts in household composition. In contrast, savers in the D-THANK model recognize the increased likelihood of transitioning to a financially constrained state due to lower disposable income. This awareness raises the opportunity cost of saving for the future, prompting a reduction in current consumption, a mechanism also identified in Bilbiie et al. (2023). However, in addition, the model predicts higher transition rates to the hand-to-mouth state, which further intensify the decline in consumption. These distinctions are critical for understanding the role of optimal transfers in achieving both economic stabilization and cross-sectional redistribution.

4 Optimal transfer rules

This section derives a second-order approximation of the Ramsey planner's social welfare function and evaluates the effectiveness of simple and optimal transfer rules.

In the presence of household heterogeneity, the standard production subsidy to intermediate goods producers is insufficient to restore the efficient steady state, as fluctuations in consumption shares also affect social welfare. The welfare loss function is derived accordingly, following the literature on inverse optimal taxation (e.g., McKay and Wolf, 2023, Heathcote and Tsujiyama, 2021). Specifically, given a specified fiscal rule, the Ramsey planner residually assigns Pareto weights to household utility to achieve an efficient steady state, as shown in Appendix B.2.[12]

The remainder of this section is structured as follows. Subsection 4.1 derives the welfare function and introduces a new measure of consumption inequality. Subsection 4.2 analyzes optimal transfer policies and compares impulse responses under the first-best and no-transfer regimes.

4.1 Welfare function and inequality

Social welfare function. The welfare function of the Ramsey planner aggregates the utilities of all households in the economy as follows:

$$\mathcal{W} = \sum_{t=0}^{\infty} \beta^t \sum_{i=\{H,S\}} \varphi_i \left(\frac{\left(\omega_t^i C_t^A\right)^{1-\sigma}}{1-\sigma} - \frac{\left(N_t\right)^{1+\varphi}}{1+\varphi} \right) \tag{4.1}$$

[12]Since this paper primarily focuses on the short-term benefits of fiscal transfers, this approach is preferred over the alternative of implementing a combination of taxes and transfers to restore long-term efficiency (e.g., equalizing consumption across households), given fixed Pareto weights.

where φ_i represents the Pareto weight assigned to household i and $\omega_t^i \equiv \lambda_t^i \frac{C_t^i}{C_t^A}$ denotes its consumption share. To the second order, social welfare in Equation (4.1) can be approximated by the loss function $-\mathcal{L}$, given by:

$$\mathcal{L} = \frac{1}{2} \sum_{t=0}^{\infty} \beta^t \left[\chi_w \left(\pi_t^w\right)^2 + \chi_p \left(\pi_t^p\right)^2 + \chi_y \left(\hat{y}_t\right)^2 + \chi_s \left(\hat{\omega}_t^S\right)^2 + \chi_h \left(\hat{\omega}_t^H\right)^2 \right] \tag{4.2}$$

where $\chi_{r \in \{w,p,y,s,h\}} > 0$ represents the relative weights assigned to inflation, output, and consumption shares (for full derivations, see Appendix E). In models with a representative household and nominal rigidities (RANK), welfare losses arise solely from inflation and output volatility. However, when household heterogeneity is introduced, the welfare loss function expands to include additional terms that account for the cross-sectional dispersion in consumption across households: $\hat{\omega}_t^S = \omega^S \left(-\frac{1}{1-\lambda}\hat{\lambda}_t + \hat{c}_t^S - \hat{c}_t^A\right)$ and $\hat{\omega}_t^H = \omega^H \left(\frac{1}{\lambda}\hat{\lambda}_t + \hat{c}_t^H - \hat{c}_t^A\right)$.

A key distinction of the D-THANK framework, relative to standard two-agent models, is that consumption shares are now influenced by shifts in the distribution of household types (e.g., $\hat{\lambda}_t$). This implies that volatility in cross-sectional consumption can arise not only from changes in the relative consumption levels of the two household types but also from fluctuations in their population proportions. As a result, the planner's objective expands from stabilizing relative consumption to also addressing welfare losses stemming from income risk.

Consumption inequality. Consumption inequality is defined as $I_t^C = \omega_t^H / \omega_t^S$, representing the ratio of consumption shares between hand-to-mouth households and savers. In log-linear terms, consumption inequality is approximated by $\hat{\iota}_t^C$, given by:

$$\hat{\iota}_t^C = \hat{\omega}_t^H - \hat{\omega}_t^S = \frac{1}{(1-\lambda)\,\lambda}\hat{\lambda}_t + \hat{c}_t^G \tag{4.3}$$

where $\hat{c}_t^G \equiv \hat{c}_t^H - \hat{c}_t^S$ represents the consumption gap between hand-to-mouth households and savers. In contrast to standard two-agent models, consumption inequality in the D-THANK framework accounts for both variations in the household distribution ($\hat{\lambda}_t$) and changes in the relative consumption gap. This allows the model to capture a more nuanced measure of inequality, reflecting both shifts in household composition and disparities in consumption across household types.

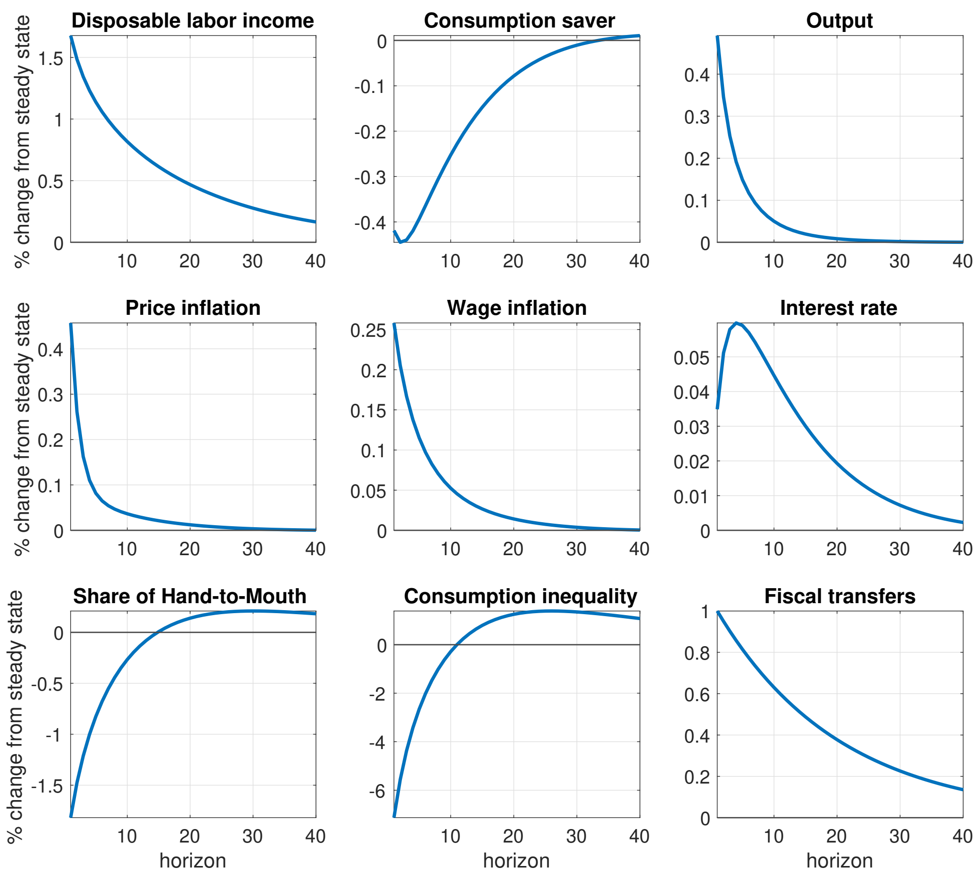


Figure 4: Impulse response functions to a transfer shock

Note: Impulse responses are constructed using the posterior mode of the structural parameters and are modeled to induce a 1% increase in transfers to hand-to-mouth households. The exogenous transfer shock is calibrated with a unitary standard deviation and persistence parameter of 0.95.

4.2 Optimal transfer rules

The effects of a transfer shock. Before analyzing the optimality of a transfer rule, it is helpful to first examine the effects of an exogenous transfer shock within the D-THANK framework in isolation. Fiscal transfers play a critical role in stabilizing the income distribution and reducing consumption inequality. As shown in Figure 4, a positive transfer shock redistributes income from savers to hand-to-mouth households. This reallocation leads to an immediate reduction in the proportion of financially constrained households, as fewer agents in the economy face a binding borrowing constraint. Additionally, the increase in disposable income and consumption for hand-to-mouth agents drives up aggregate demand, with this demand effect outweighing the decline in consumption among savers. These dynamics, further amplified by shifts in the household distribution, reduce consumption inequality. As aggregate demand increases and inflation rises, the transfers reduce the opportunity cost of working, resulting in higher wages. Finally, in line with the Taylor rule, the central bank raises the interest rate to control inflation and prevent the economy from overheating.

Transfer rules. Assume that the government allocates transfers to hand-to-mouth households according to a fiscal rule that adjusts in response to key macroeconomic indicators. Given a generic target variable, expressed as deviations from the efficient steady state, $\widehat{target}_t$, the transfer rule can be written as:

$$\hat{t}_t^H = \eta \cdot \widehat{target}_t \tag{4.4}$$

For any given target, the objective is to determine the optimal coefficient η that minimizes the weighted sum of the elements in Equation (4.2). Plausible transfer rules may include targets such as hand-to-mouth consumption $\hat{c}_t^H$, the consumption gap $\hat{c}_t^G$, aggregate consumption $\hat{c}_t^A$, aggregate disposable income $\hat{y}_t^A$,[13] and consumption inequality $\hat{\imath}_t^C$.

Welfare analysis. Table 3 presents welfare losses in the D-THANK model under various policy rules, comparing them to a baseline scenario with no transfers.

The D-THANK model predicts countercyclical optimal transfers under all proposed rules,

[13] Aggregate disposable income is defined as $Y_t^A = \lambda_t Y_t^H + (1-\lambda_t) Y_t^S$, where $Y_t^H = C^H$ denotes the income of hand-to-mouth households and $Y_t^S = C_t^S + Z_{t+1}^S$ represents the income of savers. The term Z_{t+1}^S is inferred from the savers' budget constraint in (2.4).

providing financial support to low-income households during economic downturns and reducing this support during periods of expansion. Endogenous transfers respond to increases in the consumption gap or consumption inequality, as well as declines in hand-to-mouth consumption, aggregate consumption, or aggregate disposable income. While all proposed rules improve welfare, the rule targeting consumption inequality proves to be the most effective, reducing welfare losses by 14.18% relative to the baseline case, or equivalently, resulting in a permanent 5.04% increase in consumption. This rule specifies a 0.40% increase in transfers to hand-to-mouth households for every 1% increase in consumption inequality. In contrast to rules that target aggregate variables such as consumption or income, or those that focus solely on household consumption, either in absolute or relative terms, a rule responsive to consumption inequality best serves a dual purpose: mitigating income risk for households approaching their borrowing constraints and stimulating economic activity through higher consumption. This contrasts with the implications of the THANK model, where fiscal transfers influence consumption levels without affecting its distribution due to the assumption of time-invariant household type shares, resulting in suboptimal welfare outcomes.

	HtM Cons. ($\hat{c}_t^H$)	Aggr. Cons. ($\hat{c}_t^A$)	Cons. Gap ($\hat{c}_t^G$)	Aggr. Inc. ($\hat{y}_t^A$)	Cons. Ineq. ($\hat{\imath}_t^C$)
Optimal η	-27.46	-0.82	0.65	-1.87	0.40
C.E.V.	4.44%	4.43%	4.45%	4.80%	5.04%
% $\mathcal{L}$ gain	12.53%	12.51%	12.56%	13.53%	14.18%

Table 3: Optimal transfer rules in the D-THANK

Optimal simple rules are evaluated numerically by minimizing the expected welfare loss, as outlined in Equation (4.2), following the methodology of Evers (2012) and Schmitt-Grohé and Uribe (2007). Each column compares welfare losses for various target variables against a benchmark case with no transfers in the D-THANK model. Welfare losses are reported both as consumption equivalent variation (% CEV) and a percentage gain relative to the benchmark. Details on the derivation of % CEV are provided in Appendix E.

Volatility gains. An ideal transfer rule should be designed to stabilize consumption shares and output, while minimizing the increase in the volatility of price and wage inflation. These tradeoffs are illustrated in Figure 5, which shows the percentage change in the standard deviation of these variables relative to the baseline scenario with no transfers, for each rule analyzed in Table 3. The rule targeting consumption inequality provides the most effective balance, reducing the volatility of consumption shares by approximately 43% and output by approximately 5%, while also mitigating the welfare costs associated with higher inflation. Specifically, this optimal rule minimizes the increases in price and wage inflation to approximately 14% and 15%, respectively. In contrast, alternative rules, such as aggregate consumption targeting, effectively reduce cross-sectional volatility but result in excessive inflation.

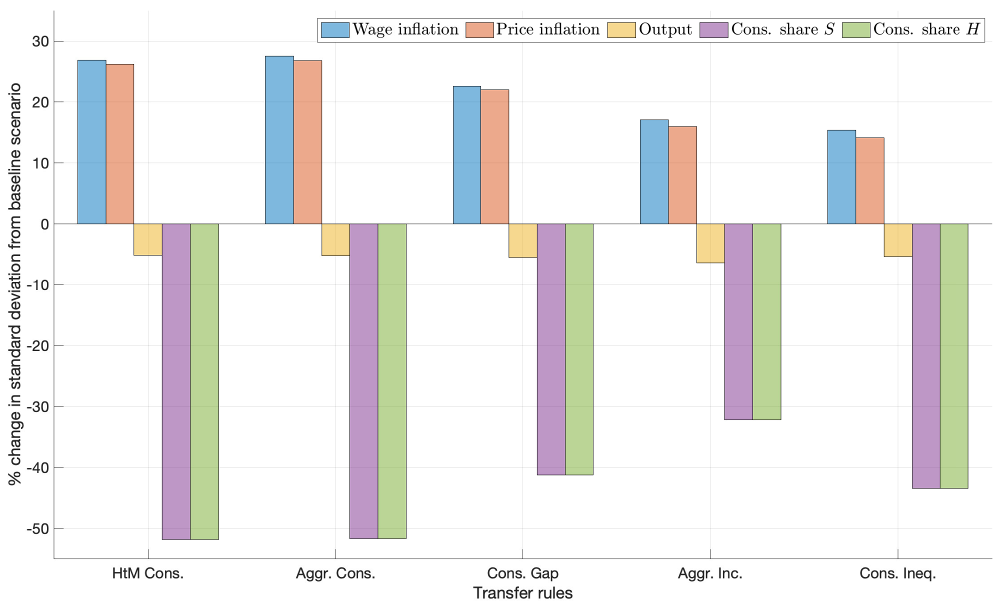


Figure 5: Volatility gains in the D-THANK model under various rules

Note: Volatility gains are measured as the percentage change in the standard deviation of output, inflation, and consumption shares under various transfer rules, compared to the benchmark scenario with no transfers.

Impulse response analysis. The analysis is further complemented by comparing the impulse responses to a productivity shock in a model with an inequality-targeting transfer rule and a model without fiscal intervention. As shown in Figure 6, a negative productivity shock decreases output and firm profits, thereby reducing agents' disposable labor income and consumption. This negative impact increases the proportion of hand-to-mouth agents in the economy, shifting consumption shares toward this group and widening consumption inequality. In response to the shock, the fiscal authority implements an endogenous redistribution of wealth: Resources are gathered from savers and distributed lump-sum to hand-to-mouth individuals, with the objective of stabilizing cyclical income risk and stimulating economic growth through increased consumption. This action reduces the likelihood of households transitioning to or remaining in the hand-to-mouth state, ultimately decreasing the concentration of financially constrained households and resulting in a less severe decline in output. Furthermore, the optimal inequality-targeting rule effectively minimizes the inflationary impact of the transfers, achieving the best balance between reducing consumption inequality and limiting the rise in prices. Similar dynamics are observed in the impulse responses to cost-push, monetary policy, and wage shocks, as shown in Figures 12 through 14 in Appendix F.2.

Figure 6: Impulse response functions to a productivity shock

Note: Impulse responses are constructed using the posterior mode of the structural parameters and are modeled to induce a 1% decline in aggregate productivity.

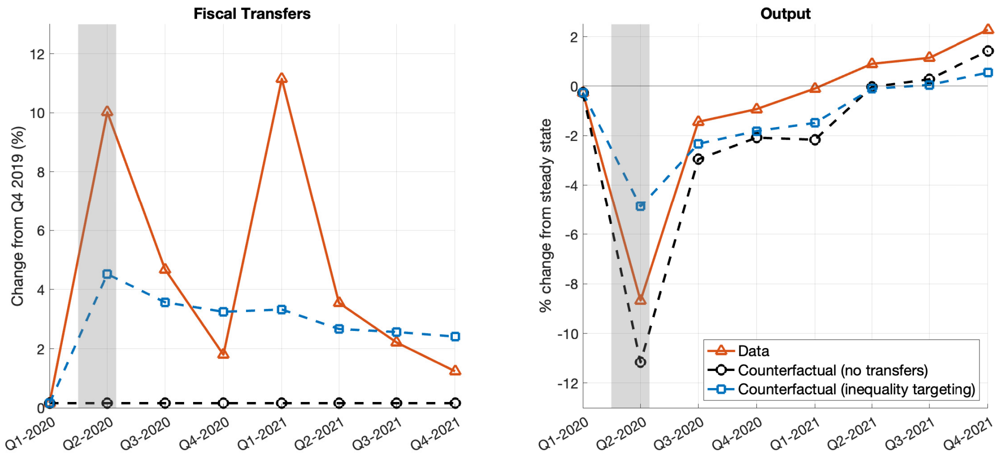
5 COVID-19 counterfactuals

The key contributions discussed in Sections 3 and 4 are ultimately evaluated through two counterfactual simulations of the COVID-19 recession. In the first simulation, the model is used to generate a counterfactual scenario in which the U.S. government implements an inequality-targeting transfer rule, as outlined in Table 3. The objective is to assess the extent to which fiscal stimulus payments alleviated output losses and whether the timing and scale of their implementation were optimal. The second counterfactual scenario assumes that fiscal transfers were never implemented. In this context, the D-THANK model is used to decompose the contributions of agents' self-insurance behavior and the effects of endogenous transitions between household types in shaping the dynamics of output and consumption inequality.

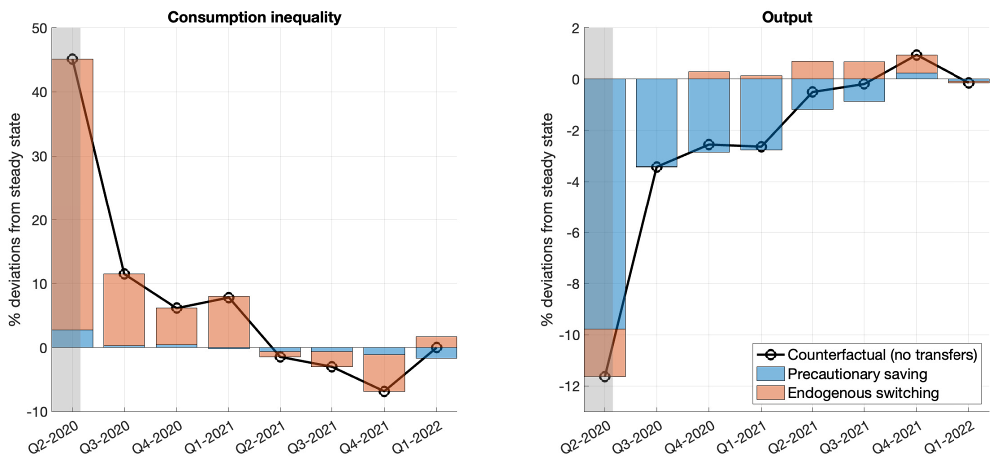
Optimal fiscal transfers. Were the timing and size of the COVID-19 transfer payments optimal? To what extent did these fiscal stimulus payments help mitigate output losses?

Fiscal transfers accounted for 2.5 percentage points of the reduction in output decline,[14] as indicated by the difference between the observed output (orange solid lines) and the counterfactual scenario with no fiscal intervention (black circled lines) in Figure 7a. Output losses were primarily mitigated through a reduction in the probability of transitioning away from the saver state, coupled with a direct stimulus to consumption for low- and middle-income households (see Figure 15 in Appendix G). However, the model also suggests that the impact of fiscal stimulus payments was constrained by their excessive size and irregular distribution, with a substantial portion being saved. In contrast, had the U.S. government adhered to the optimal inequality-targeting rule, the economy would have benefited from smaller, more sustained transfer payments (blue dashed lines with squares), potentially limiting the output decline by up to 3.7%.

[14] This magnitude aligns with findings from Bayer et al. (2023), who report that fiscal stimulus during the COVID-19 pandemic reduced the output decline by approximately two percentage points at the trough.



(a) Actual versus optimal fiscal transfers



(b) Decomposition of consumption inequality and output

Figure 7: COVID-19 recession counterfactuals

Note: These counterfactual scenarios are constructed by applying smoothed shocks to the calibrated D-THANK model, with calibration based on the mode posteriors of the estimated parameters, to match the observed dynamics in real GDP growth per capita $\left(y_t^{obs}\right)$, government social benefits to individuals $\left(t_t^{obs}\right)$, the nominal interest rate $\left(i_t^{obs}\right)$, and inflation $\left(\pi_t^{obs}\right)$, as detailed in Subsection D.1 in the Appendix. The model is utilized to predict output, inequality, and fiscal transfers if the U.S. government had followed an optimal transfer rule targeting consumption inequality from 2020Q2 onward. In Panel (b), the contributions of households' self-insurance behavior and endogenous switching are separately identified by muting the latter mechanism in a counterfactual scenario with no transfers.

Endogenous switching versus precautionary saving. As a generalization of the model in Bilbiie et al. (2023), the D-THANK model allows for the isolation of the contributions of agents' self-insurance behavior and the effects of endogenous transitions between income groups in shaping aggregate economic dynamics. The first mechanism captures how households adjust their savings in anticipation of future income changes, while the second mechanism isolates the role of endogenous transitions between financially constrained and unconstrained states in response to external shocks.

These contributions are depicted in Figure 7b, which shows the counterfactual dynamics of consumption inequality and output, assuming that fiscal transfers were never implemented. The analysis reveals that in the absence of fiscal intervention, consumption inequality would have increased by up to 45% during the recession, primarily driven by endogenous transitions between income groups. The model also suggests that inequality would have reverted to its steady state within approximately one year, highlighting the importance of implementing stimulus payments in a more gradual and proportionate manner. Furthermore, shifts in the household distribution would have accounted for roughly one-sixth of the output decline in the second quarter of 2020, with the remaining impact attributed to changes in self-insurance behavior.

6 Conclusions

This paper examines the effectiveness of simple and optimal transfer rules targeting low-income households within an extended two-agent New Keynesian model that allows for endogenous transitions between household types.

Two key findings emerge from the analysis. First, incorporating endogenous variation in the household distribution improves the model's empirical fit, as shown by out-of-sample forecast metrics. Second, among the proposed transfer rules, a policy targeting consumption inequality proves to be the most effective, yielding a 14.18% welfare gain relative to a baseline with no transfers, or a permanent 5.04% increase in consumption. By focusing on consumption inequality, the government reduces the likelihood of households nearing their borrowing constraints from transitioning into a financially constrained state, while also boosting economic activity through higher aggregate consumption. These benefits are evident in the reduced volatility of consumption shares and output, while also minimizing inflationary pressures compared to a model without transfers.

These findings are further examined through two counterfactual simulations of the COVID-

19 recession. The first simulation shows that while fiscal stimulus payments helped mitigate output losses, their overall impact was limited due to their excessive size and uneven distribution, with a large portion of transfers being saved. The counterfactual analysis suggests that smaller, more sustained transfers could have resulted in better economic outcomes, potentially limiting the output decline by approximately 3.7 percentage points. The second exercise demonstrates that in the absence of fiscal transfers, consumption inequality would have risen by as much as 45% during the recession, with endogenous switching being the primary driver. This factor would have accounted for approximately one-sixth of the output decline in the second quarter of 2020.

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Appendix

A Nonlinear equilibrium conditions

A.1 Households

Hand-to-mouth agents always consume their current income. Conversely, savers optimally smooth consumption through a conditional Euler equation. The optimal consumption decisions are:

$$\left(C_t^S\right)^{-1} = \beta E_t\left[\frac{1+i_t}{1+\pi_{t+1}}\left(s_{t+1}\left(C_{t+1}^S\right)^{-1} + \left(1-s_{t+1}\right)\left(C_{t+1}^H\right)^{-1}\right)\right] \tag{A.1}$$

$$C_t^H = \frac{W_t}{P_t}N_t + T_t^H + D_t \tag{A.2}$$

A.2 Labor markets

The optimal reset wage at time t by the labor union is:

$$W_t\left(z\right) = \mathcal{M}_w \frac{E_t\sum_{k=0}^{\infty}\left(\beta\theta_w\right)^k\left[N_{t+k|t}\left(z\right)\right]^{1+\varphi}}{E_t\sum_{k=0}^{\infty}\left(\beta\theta_w\right)^k\frac{N_{t+k|t}(z)}{P_{t+k}}\left(\frac{\lambda_{t+k|t}}{C_{t+k}^H(z)} + \frac{\left(1-\lambda_{t+k|t}\right)}{C_{t+k}^S(z)}\right)} \tag{A.3}$$

Finally, the equation describing the dynamics for the aggregate wage level is:

$$W_t = \left[\theta_w W_{t-1}^{1-\varepsilon_w} + \left(1-\theta_w\right)\left(W_t^*\right)^{1-\varepsilon_w}\right]^{\frac{1}{1-\varepsilon_w}} \tag{A.4}$$

A.3 Final good producer

Profit maximization yields the set of demand schedules:

$$Y_t\left(j\right) = \left(\frac{P_t\left(j\right)}{P_t}\right)^{-\varepsilon_p} Y_t, \qquad \forall j \tag{A.5}$$

A no-profit condition yields the following aggregate price equation:

$$P_t = \left(\int_0^1 P_t\left(j\right)^{1-\varepsilon_p} dj\right)^{\frac{1}{1-\varepsilon_p}} \tag{A.6}$$

A.4 Intermediate goods producers

The real marginal cost is the same across all firms:

$$\frac{W_t}{P_t A_t \left(1-\alpha\right) N_t^{-\alpha}} = MC_t \tag{A.7}$$

The optimal reset price at time t by intermediate goods producers is:

$$P_t\left(j\right) = \mathcal{M}_p \frac{E_t \sum_{k=0}^{\infty} \left(\beta\theta_p\right)^k \left[C_{t+k}^{1-\sigma} P_{t+k}^{\varepsilon_p} MC_{t+k|t}\right]}{E_t \sum_{k=0}^{\infty} \left(\beta\theta_p\right)^k \left[C_{t+k}^{1-\sigma} P_{t+k}^{\varepsilon_p - 1}\right]} \tag{A.8}$$

B Steady states

B.1 Model estimation

The model is estimated around an inefficient steady state, as in Bilbiie et al. (2023). To log-linearize the model, the elements $W/P, N, Y, C^S, C^H$ are required. First, combine the production function, $Y = N^{1-\alpha}$, with the aggregate resource constraint, $Y = C^A$, and the equation for aggregate consumption, $C^A = \lambda C^H + \left(1-\lambda\right) C^S$:

$$Y = C^A = N^{1-\alpha} = \lambda C^H + \left(1-\lambda\right) C^S \tag{B.1}$$

Substitute the definition of consumption for the hand-to-mouth household, $C^H = \frac{W}{P} N$, into the above equation:

$$\Rightarrow N^{1-\alpha} = \lambda \left(\frac{W}{P} N\right) + \left(1-\lambda\right) C^S \tag{B.2}$$

Next, incorporate $C^H = \frac{W}{P} N$ into the wage setting equation $\frac{W}{P} = \mathcal{M}_w N^{\varphi} \left(\frac{\lambda}{C^H} + \frac{(1-\lambda)}{C^S}\right)^{-1}$:

$$\Rightarrow \frac{W}{P} = \mathcal{M}_w N^{\varphi} \left(\frac{\lambda}{\frac{W}{P} N} + \frac{(1-\lambda)}{C^S} \right)^{-1} \tag{B.3}$$

Finally, combine Equations $(B.2)$ and $(B.3)$ with the labor market condition $\frac{W}{P} = \frac{1}{\mathcal{M}_p} (1-\alpha) N^{-\alpha}$ to obtain:

$$N = \left[\frac{\lambda \mathcal{M}_p + (1-2\lambda)(1-\alpha)}{\mathcal{M}_w (\mathcal{M}_p - \lambda (1-\alpha))} \right]^{\frac{1}{1+\varphi}} \tag{B.4}$$

Use the result above to recover $\frac{W}{P} = \frac{(1-\alpha)N^{-\alpha}}{\mathcal{M}_p}$, $C^S = \left(\frac{\mathcal{M}_p - \lambda(1-\alpha)}{\mathcal{M}_p (1-\lambda)} \right) N^{1-\alpha}$, $C^H = \frac{W}{P} N$, $C^A = \lambda C^H + (1-\lambda) C^S$, and $Y = C^A$.

B.2 Optimal policy analysis

To conduct optimal policy analysis and derive a welfare loss function without relying on a full second-order approximation of the equilibrium conditions, the economy is assumed to be at an efficient steady state. This is achieved through a production subsidy, τ, which subsidizes firms' labor demand and is financed through lump-sum taxation of firms' dividends, resulting in zero dividends in steady state.

First, assume that steady-state dividends are given by:

$$D = Y - (1-\tau) \frac{W}{P} N - T$$

where $T = \tau \frac{W}{P} N$. From the profit maximization problem, we obtain:

$$\frac{W}{P} (1-\tau) = \frac{1}{\mathcal{M}^p} (1-\alpha) N^{-\alpha} \tag{B.5}$$

Similarly, steady-state labor demand is given by:

$$\frac{W}{P} = \mathcal{M}^w N^{\phi} \left(\frac{\lambda}{C^H} + \frac{1-\lambda}{C^S} \right)^{-1} \tag{B.6}$$

Combining these equations yields:

$$\tau = 1 - \frac{1}{\mathcal{M}^p \mathcal{M}^w}$$

where the planner's Pareto weights are residually selected such that the average marginal utility of consumption employed by the labor union equals the marginal utility of aggregate consumption employed by the planner.

C Log-linear model

C.1 Log-linear equilibrium conditions in the D-THANK model

No.	Name	Equation
1:	Wage markup	$\hat{\mu}_t^w = \hat{\omega}_t - \eta_H \hat{c}_t^H - \eta_S \hat{c}_t^S - \phi \hat{n}_t$
2:	Wage Phillips curve	$\pi_t^w = \beta E_t \left[\pi_{t+1}^w\right] - \psi_w \hat{\mu}_t^w - \psi_{w\lambda} \hat{\lambda}_t + \varepsilon_t^w$
3:	Change in real wage	$\Delta\hat{\omega}_t = \pi_t^w - \pi_t^p$
4:	Euler bonds, S	$c_t^S = \gamma_S E_t c_{t+1}^S + \gamma_H E_t c_{t+1}^H - \left(\frac{1}{1+i^*} \hat{i}_t - E_t \left[\pi_{t+1}\right]\right) - \left(\frac{\gamma_S}{s} - \frac{\gamma_H}{1-s}\right) \hat{s}_{t+1}$
5:	Budget constraint, H	$\hat{c}_t^H C^H = \frac{W}{P} N \left(\hat{\omega}_t + \hat{n}_t\right) + Y \hat{t}_t^H + Y \hat{d}_t$
6:	Labor demand	$\hat{\mu}_t^p = -\hat{\omega}_t + \hat{y}_t - \hat{n}_t$
7:	Price Phillips curve	$\pi_t^p = \beta E_t \left[\pi_{t+1}^p\right] - \psi_p \hat{\mu}_t^p + g\left(\hat{f}_t\right)$
8:	Production function	$y_t = \hat{a}_t + h\left(\hat{f}_t\right) + (1-\alpha)\hat{n}_t$
9:	Aggregate cons.	$\hat{c}_t^A = -\psi_\lambda \hat{\lambda}_t + \psi_H \hat{c}_t^H + \psi_S \hat{c}_t^S$
10:	Dividends	$\hat{d}_t = \hat{y}_t - \left(\hat{\omega}_t + \hat{n}_t\right)$
11:	Resource constraint	$\hat{y}_t = \hat{c}_t^A$
12:	Taylor rule	$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[\phi_\pi \pi_t + \phi_y \hat{y}_t\right] + u_t^v$
13:	Household composition	$\hat{\lambda}_{t+1} = (h+s-1)\hat{\lambda}_t - \hat{s}_t + \hat{h}_t + u_t^\lambda$
14:	Process for s	$\hat{s}_t = \gamma_s \Delta y_t^D$
15:	Process for h	$\hat{h}_t = -\gamma_h \Delta y_t^D$
16:	Supply shock	$\hat{f}_t = \rho_f \hat{f}_{t-1} + u_t^f$
17:	Productivity shock	$\hat{a}_t = \rho_a \hat{a}_{t-1} + u_t^a$
18:	Wage shock	$\varepsilon_t^w = \rho_w \varepsilon_{t-1}^w + u_t^w$

Table 4: Log-linear equilibrium conditions: D-THANK model

D Data and estimation results

D.1 Data

Figure 1. The sample period covers 2001 to 2023. Household data are sourced from the Consumer Expenditure Survey (https://www.bls.gov/cex/pumd.htm). The series is based on weighted pretax family income for households with positive income and consumption expenditures, focusing on respondents aged 25 to 64. To determine the proportion of households categorized as lower-middle income, I compare household income to a multiple of the federal poverty threshold, as outlined by the U.S. Census (https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html).

Estimation. The sample period ranges from 1987Q1 to 2019Q4. The endogenous variables include real GDP, the GDP deflator, hours worked, the population level, and the Federal funds rate. During the zero lower bound period, the Federal funds rate is adjusted using the shadow rate of Wu and Xia (2016). The variables are expressed in per capita terms utilizing the Hodrick-Prescott- (HP-)filtered trend of the population level, Pop_t, to eliminate measurement noise associated with census years.

Simulations. COVID-19 counterfactuals are constructed using smoothed shocks to replicate the dynamics of output, inflation, the nominal interest rate, and discretionary transfers from 2018Q1 to 2022Q1. Fiscal transfers are based on data from government accounts under "Federal government current transfer payments: Government social benefits: to persons," which represent the fiscal stimulus payments provided to support households during the COVID-19 pandemic.

Tables 5 and 6 provide detailed descriptions of the series construction used in the model estimation process.

Label	Frequency	Description	Source
GDP	Q	Gross Domestic Product	FRED
GDPC1	Q	Real Gross Domestic Product	FRED
CNP16OV	Q	Population Level	FRED
GDPDEF	Q	Gross Domestic Product Deflator	FRED
FFR	M	Federal Funds Rate	Atlanta FED
HOANBS	Q	Nonfarm Business Sector: Hours Worked for All Workers	FRED
B087RC1Q027SBEA	Q	Federal Government Current Transfer Payments: Government Social Benefits: To Persons	FRED

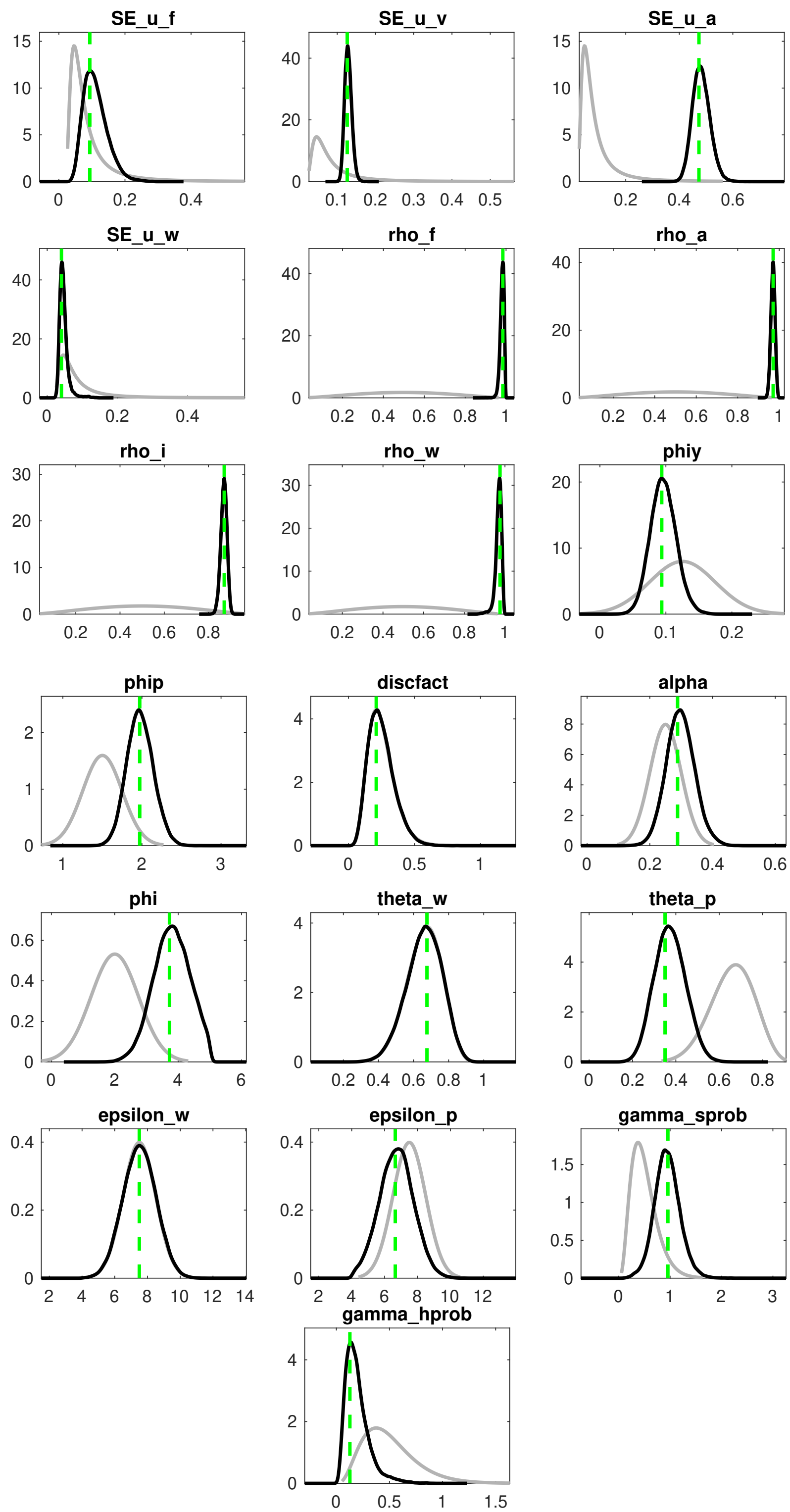
Table 5: Data series description and sources

Label	Construction
Y_t	$\ln(GDPC1_t/Pop_t)$
P_t	$\ln(GDPDEF_t)$
i_t	FFR_t
H_t	$\ln(HOANBS_t/Pop_t)$
T_t^H	$\left[B087RC1Q027SBEA_t/GDP_t^{HP_{trend}}\right]$
y_t^{obs}	$100 \times (Y_t - Y_{t-1}) - mean\,(100 \times (Y_t - Y_{t-1}))$
π_t^{obs}	$100 \times (P_t - P_{t-1}) - mean\,(100 \times (P_t - P_{t-1}))$
i_t^{obs}	$100 \times \ln\left[1 + \frac{i_t}{400}\right] - mean\left(100 \times \ln\left[1 + \frac{i_t}{400}\right]\right)$
h_t^{obs}	$100 \times [H_t] - mean\,(100 \times [H_t])$
t_t^{obs}	$100 \times \left[T_t^H\right] - mean\left(100 \times \left[T_t^H\right]\right)$

Table 6: Data series in the model

D.2 Estimation results

Bayesian estimation



Estimation results: THANK

	Parameters	Prior Distribution			Posterior Distribution	
		Distr.	Mean	St. Dev.	Mode	90% C. I.
σ^f	Std - Cost Push Shock	IG	0.1	2.0	0.11	$[0.07, 0.21]$
σ^v	Std - Mon. Policy Shock	IG	0.1	2.0	0.13	$[0.12, 0.15]$
σ^a	Std - Tech. Shock	IG	0.1	2.0	0.46	$[0.42, 0.52]$
σ^w	Std - Wage Shock	IG	0.1	2.0	0.05	$[0.04, 0.07]$
ρ^f	AR(1) Coeff. - Cost Push Shock	B	0.5	0.2	0.97	$[0.91, 0.99]$
ρ^a	AR(1) Coeff. - Productivity Shock	B	0.5	0.2	0.98	$[0.97, 0.99]$
ρ^i	AR(1) Coeff. - Monetary Policy	B	0.5	0.2	0.85	$[0.83, 0.88]$
ρ^w	AR(1) Coeff. - Wage Shock	B	0.5	0.2	0.98	$[0.98, 0.99]$
ϕ_y	Taylor Rule: Output	N	0.125	0.05	0.02	$[0.00, 0.03]$
ϕ_π	Taylor Rule: Inflation	N	1.5	0.25	1.56	$[1.36, 1.93]$
$\tilde{\beta}$	Discount Factor $100 \cdot (1/\beta - 1) \equiv \tilde{\beta}$	G	0.25	0.1	0.21	$[0.09, 0.41]$
α	Share of Capital	N	0.25	0.05	0.31	$[0.24, 0.37]$
ϕ	Inverse Frisch Elasticity	N	2.0	0.75	2.73	$[2.81, 4.79]$
θ_w	Calvo Parameter: Wages	B	0.66	0.1	0.68	$[0.50, 0.83]$
θ_p	Calvo Parameter: Prices	B	0.66	0.1	0.36	$[0.26, 0.50]$
ε_w	Elas. of Substitution: Wages	N	7.5	1.0	7.50	$[5.83, 9.13]$
ε_p	Elas. of Substitution: Prices	N	7.5	1.0	6.63	$[5.00, 8.33]$

Table 7: Structural parameters of the THANK model

Note: B, G, IG, and N denote the beta, gamma, inverse gamma and normal distributions, respectively.

Historical share of hand-to-mouth households. Several studies have examined hand-to-mouth behavior using cross-sectional survey data on household portfolios (e.g., Aguiar et al., 2024; Kaplan et al., 2014). Nevertheless, constructing a reliable time series of the hand-to-mouth household share remains challenging for several reasons. First, measurements of hand-to-mouth behavior are highly sensitive to how households' net worth is classified (e.g., wealthy vs. non-wealthy hand-to-mouth). Additionally, because income data are typically reported on an annual basis, higher-frequency time series are likely to reflect changes only gradually.[15]

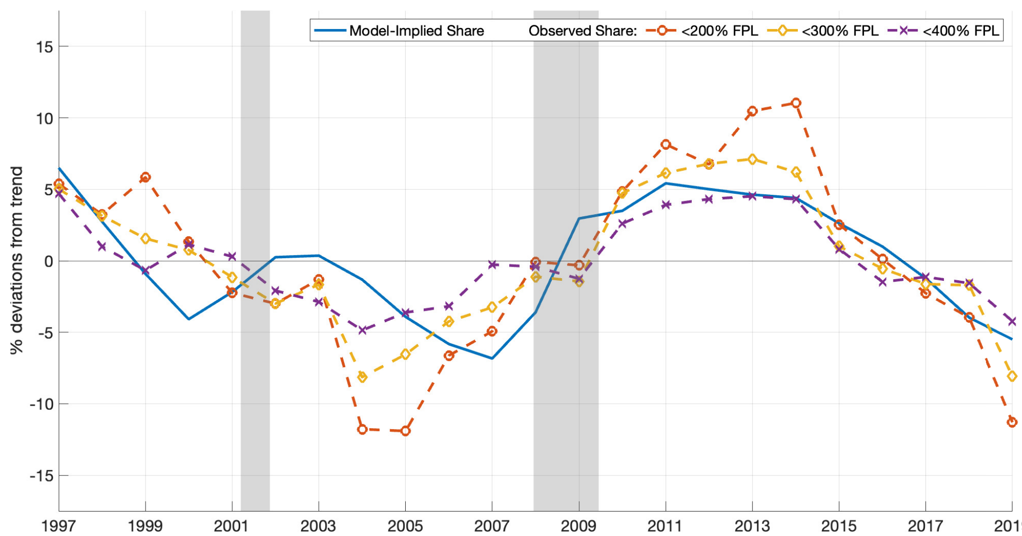


Figure 8: Model-implied vs. observed historical share of hand-to-mouth households

Note: The dashed lines represent the quadratically detrended share of households with pretax family income over the past 12 months below 200% (orange circles), 300% (yellow diamonds), and 400% (purple crosses) of the Federal Poverty Level (U.S. Census Bureau), as reported in the Consumer Expenditure Survey. The blue solid line shows the smoothed estimates of the hand-to-mouth household share implied by the model, expressed in annual terms and quadratically detrended for comparison with observed shares.

In contrast, a model-based approach provides a compelling alternative by generating internally consistent estimates of variables that are inherently difficult to measure (e.g., the hand-to-mouth share). These estimates are derived from the model's underlying assumptions and the sample information used for estimation. Figure 8 presents an example of this approach, comparing the model-implied historical share of hand-to-mouth households

[15]This is due to the retrospective nature of surveys, where households report income over the preceding twelve months during each quarterly interview.

with empirical proxies based on reported pretax income.[16] As illustrated in the figure, the model-implied share of hand-to-mouth households closely aligns with the empirical proxies, displaying similar cyclical dynamics – especially in response to economic downturns such as the early 2000s recession and the Great Recession. Interestingly, the model-implied series responds more rapidly to income fluctuations, whereas survey-based measures reflect these changes with a lag due to retrospective reporting. Overall, these findings further substantiate the income elasticity estimates derived from Equation (2.16), reinforcing their consistency with observed cyclical patterns.

E Welfare function

The following welfare function is based on the conventional Ramsey planner problem, as discussed in McKay and Wolf (2023). The social planner chooses the cross-sectional distribution of consumption that maximizes aggregate welfare.

The loss function is formulated based on the generic aggregate utility represented by:

$$U_t = \sum_{i=\{H,S\}} \varphi_i \left(\frac{\left(\omega_{it} C_t^A\right)^{1-\sigma}}{1-\sigma} - \frac{\left(N_t\right)^{1+\varphi}}{1+\varphi} \right) \tag{E.1}$$

where $\omega_{it} \equiv \frac{C_{it}}{C_t^A}$ represents the consumption share of household type i and φ_i denotes a Pareto weight on its utility. The objective is to approximate the function in Equation $E.1$ up to the second order.

First, it is helpful to reframe aggregate utility in terms of deviations from steady state for C_t^A and N_t. The modified utility function becomes:

$$U_t = \sum_{i=\{H,S\}} \varphi_i \left(\frac{\left(\omega_{it} \frac{C_t^A}{C^A} C^A\right)^{1-\sigma}}{1-\sigma} - \frac{\left(\frac{N_t}{N} N\right)^{1+\varphi}}{1+\varphi} \right) \tag{E.2}$$

[16] While income characteristics are not the sole determinant of hand-to-mouth behavior, they serve as an important proxy for consumption patterns, liquidity constraints, and financial vulnerability.

Alternatively, this can be expressed as:

$$U_t = \sum_{i=\{H,S\}} \varphi_i \left(\frac{\left(\omega_{it} e^{\hat{c}_t^A} C^A\right)^{1-\sigma}}{1-\sigma} - \frac{\left(e^{\hat{n}_t} N\right)^{1+\varphi}}{1+\varphi} \right) \tag{E.3}$$

Here, $\frac{C_t^A}{C^A}$ and $\frac{N_t}{N}$ are deviations from their steady states, $e^{\hat{c}_t^A}$ denotes the growth rate of C_t^A, and $e^{\hat{n}_t}$ is the growth rate of N. The goal is to construct a second-order approximation of Equation E.3.

Steady state The optimality of the steady state requires the weighted marginal utility of consumption to be equalized across types, expressed as:

$$\varphi_i \bar{\omega}_i^{-\sigma} \left(C^A\right)^{1-\sigma} = \bar{u}_c C^A \qquad \forall i \tag{E.4}$$

This implies that φ_i is chosen accordingly, where $\bar{u}_c$ is a constant. Solving for the weight yields:

$$\left(\varphi_i\right)^{1/\sigma} = \bar{u}_c^{1/\sigma} \bar{\omega}_i C^A \qquad \forall i \tag{E.5}$$

Additionally, summing both sides of the last expression over i and imposing $\sum_{i=\{H,S\}} \bar{\omega}_i = 1$ gives:

$$\sum_{i=\{H,S\}} \left(\varphi_i\right)^{1/\sigma} = \bar{u}_c^{1/\sigma} \left(C^A\right) \tag{E.6}$$

Therefore, combining Equations E.5 and E.6 makes it possible to solve for the consumption shares $\bar{\omega}_i$ in steady state:

$$\bar{\omega}_i = \frac{\left(\varphi_i\right)^{1/\sigma}}{\sum_{i=\{H,S\}} \left(\varphi_i\right)^{1/\sigma}} \qquad \forall i \tag{E.7}$$

For future reference, define:

$$\Xi \equiv \left(\sum_{i=\{H,S\}} \left(\varphi_i\right)^{1/\sigma} \right)^{\sigma} = \bar{u}_c \left(C^A\right)^{\sigma} = \varphi_i \bar{\omega}_i^{-\sigma} \qquad \forall i \tag{E.8}$$

Second-order approximation The second-order approximation of the planner's utility at time t is:

$$\begin{gathered}U_t \approx \bar{U} + \left(C^A\right)^{1-\sigma} \Xi \hat{c}_t - \hat{n}_t N^{1+\varphi} + \\ +\tfrac{1}{2}\left(1-\sigma\right)\left(C^A\right)^{1-\sigma} \Xi \hat{c}_t^2 - \tfrac{1}{2}\left(1+\varphi\right)\left(N\right)^{1+\varphi} \hat{n}_t^2 - \tfrac{1}{2}\sigma\left(C^A\right)^{1-\sigma} \Xi \textstyle\sum_{i=\{H,S\}} \frac{\hat{\omega}_{i,t}^2}{\bar{\omega}_i} + \\ + \left(C^A\right)^{1-\sigma} \Xi \textstyle\sum_{i=\{H,S\}} \hat{\omega}_{i,t} + \left(1-\sigma\right)\left(C^A\right)^{1-\sigma} \Xi \hat{c}_t \textstyle\sum_{i=\{H,S\}} \hat{\omega}_{i,t}\end{gathered} \tag{E.9}$$

Because $\sum_{i=\{H,S\}} \omega_{i,t} = 1$, which implies $\sum_{i=\{H,S\}} \hat{\omega}_{i,t} = 0$, Equation E.9 simplifies to:

$$\begin{gathered}U_t \approx \bar{U} + \left(C^A\right)^{1-\sigma} \Xi \hat{c}_t - \hat{n}_t N^{1+\varphi} + \\ +\tfrac{1}{2}\left(1-\sigma\right)\left(C^A\right)^{1-\sigma} \Xi \hat{c}_t^2 - \tfrac{1}{2}\left(1+\varphi\right)\left(N\right)^{1+\varphi} \hat{n}_t^2 - \tfrac{1}{2}\sigma\left(C^A\right)^{1-\sigma} \Xi \textstyle\sum_{i=\{H,S\}} \frac{\hat{\omega}_{i,t}^2}{\bar{\omega}_i}\end{gathered} \tag{E.10}$$

The goal is to rewrite Equation E.10 as a function of output, inflation, and consumption shares.

Rewriting the resource constraint First, we need to establish a relationship between aggregate employment and output. Recall that aggregate employment is the sum of labor across skills (denoted as z) and products (denoted as j), expressed as:

$$N_t = \int_0^1 \int_0^{F_t} N_t\left(j,z\right) dzdj$$

Here, F_t represents the cost-push shock. Simplifying the integral, we obtain:

$$N_t = \Delta_{w,t}\Delta_{p,t}\left(\frac{Y_t}{A_t}\right)^{\frac{1}{1-\alpha}} + \int_0^1 \int_1^{F_t} N_t\left(j,z\right) dzdj$$

where $\Delta_{p,t} \equiv \int_0^1 \left(\frac{Y_t(j)}{Y_t}\right)^{\frac{1}{1-\alpha}} dj$ and $\Delta_{w,t} \equiv \int_0^1 \frac{N_t(j,z)}{N_t(j)} dz$. Under the assumption that F_t fluctuates near its steady state, $\int_0^1 \int_1^{F_t} N_t\left(j,z\right) dzdj \approx 0$. Thus, the last expression can be approximated as:

$$N_t \approx \Delta_{w,t}\Delta_{p,t}\left(\frac{Y_t}{A_t}\right)^{\frac{1}{1-\alpha}} \tag{E.11}$$

This leads to the second-order approximation of the relationship between aggregate output and employment:

$$(1-\alpha)\,\hat{n}_t = \hat{y}_t - a_t + d_{w,t} + d_{p,t} \tag{E.12}$$

Here, $d_{w,t} \equiv (1-\alpha)\log\int_0^1 \left(\frac{W_t(z)}{W_t}\right)^{-\varepsilon_w} dz$, and $d_{p,t} \equiv (1-\alpha)\log\int_0^1 \left(\frac{P_t(j)}{P_t}\right)^{-\frac{\varepsilon_p}{1-\alpha}} dj$.

By following a derivation similar to that in Gali (2015), we can show that up to a second-order approximation,

$$d_{p,t} \approx \frac{\varepsilon_p}{2\Theta} var_j\left\{p_t\left(j\right)\right\}, \tag{E.13}$$

$$d_{w,t} \approx \frac{(1-\alpha)\,\varepsilon_w}{2} var_z\left\{w_t\left(z\right)\right\} \tag{E.14}$$

Finally, combining the results from Equations E.13 and E.14 with those from Equation E.12 yields:

$$\hat{n}_t = \frac{\hat{y}_t - a_t}{(1-\alpha)} + \frac{\varepsilon_w}{2} var_z\left\{w_t\left(z\right)\right\} + \frac{\varepsilon_p}{2\Theta\left(1-\alpha\right)} var_j\left\{p_t\left(j\right)\right\} \tag{E.15}$$

Welfare loss function Plugging Equation E.15 into Equation E.10 gives:

$$\begin{gathered} U_t \approx \bar{U} + \left(C^A\right)^{1-\sigma}\Xi\hat{y}_t - \left(\tfrac{\hat{y}_t - a_t}{(1-\alpha)} + \tfrac{\varepsilon_w}{2} var_z\left\{w_t\left(z\right)\right\} + \tfrac{\varepsilon_p}{2\Theta(1-\alpha)} var_j\left\{p_t\left(j\right)\right\}\right) N^{1+\varphi} \\ +\tfrac{1}{2}\left(1-\sigma\right)\left(C^A\right)^{1-\sigma}\Xi\hat{y}_t^2 \\ -\tfrac{1}{2}\left(1+\varphi\right)\left(N\right)^{1+\varphi}\left(\tfrac{\hat{y}_t - a_t}{(1-\alpha)} + \tfrac{\varepsilon_w}{2} var_z\left\{w_t\left(z\right)\right\} + \tfrac{\varepsilon_p}{2\Theta(1-\alpha)} var_j\left\{p_t\left(j\right)\right\}\right)^2 \\ -\tfrac{1}{2}\sigma\left(C^A\right)^{1-\sigma}\Xi\sum_{i=\{H,S\}}\tfrac{\hat{\omega}_{i,t}^2}{\bar{\omega}_i} \end{gathered} \tag{E.16}$$

Ignoring terms higher than second order and those independent of policy reduces the expression in Equation E.16 to:

$$\begin{gathered} U_t \approx \bar{U} + \left(C^A\right)^{1-\sigma}\Xi\hat{y}_t - N^{1+\varphi}\left(\tfrac{\hat{y}_t}{(1-\alpha)} + \tfrac{\varepsilon_w}{2} var_z\left\{w_t\left(z\right)\right\} + \tfrac{\varepsilon_p}{2\Theta(1-\alpha)} var_j\left\{p_t\left(j\right)\right\}\right) \\ +\tfrac{1}{2}\left(1-\sigma\right)\left(C^A\right)^{1-\sigma}\Xi\hat{y}_t^2 - \tfrac{1}{2}\left(1+\varphi\right)\left(N\right)^{1+\varphi}\left(\tfrac{\hat{y}_t}{(1-\alpha)}\right)^2 - \tfrac{1}{2}\sigma\left(C^A\right)^{1-\sigma}\Xi\sum_{i=\{H,S\}}\tfrac{\hat{\omega}_{i,t}^2}{\bar{\omega}_i} \end{gathered} \tag{E.17}$$

Under the assumption that $\sigma = 1$ and recalling that $\Xi \equiv \bar{u}_c \left(C^A\right)^\sigma$, this can be further simplified to:

$$U_t \approx \bar{U} + \tfrac{N}{(1-\alpha)} \left(\bar{u}_c (1-\alpha) N^{-\alpha} - N^\varphi\right) \hat{y}_t - N^{1+\varphi} \tfrac{\varepsilon_w}{2} var_z \{w_t(z)\} - N^{1+\varphi} \tfrac{\varepsilon_p}{2\Theta(1-\alpha)} var_j \{p_t(j)\}$$
$$-\tfrac{1}{2}(1+\varphi)(N)^{1+\varphi} \left(\tfrac{\hat{y}_t}{(1-\alpha)}\right)^2 - \tfrac{1}{2}\Xi \textstyle\sum_{i=\{H,S\}} \tfrac{\hat{\omega}_{i,t}^2}{\bar{\omega}_i} \tag{E.18}$$

where $\bar{u}_c (1-\alpha) N^{-\alpha} - N^\varphi = 0$.

Thus, returning to the planner's problem, it is possible to use the results in Equation E.18 to rewrite the discounted sum of utility as:

$$\textstyle\sum_{t=0}^{\infty} \beta^t \left(U_t - \bar{U}\right) \approx$$
$$\textstyle\sum_{t=0}^{\infty} \beta^t \left[-N^{1+\varphi} \tfrac{\varepsilon_w}{2} var_z \{w_t(z)\} - N^{1+\varphi} \tfrac{\varepsilon_p}{2\Theta(1-\alpha)} var_j \{p_t(j)\} - \tfrac{1}{2}(1+\varphi)(N)^{1+\varphi} \left(\tfrac{\hat{y}_t}{(1-\alpha)}\right)^2 - \tfrac{1}{2}\Xi \sum_{i=\{H,S\}} \tfrac{\hat{\omega}_{i,t}^2}{\bar{\omega}_i}\right] =$$
$$= -\tfrac{1}{2} \textstyle\sum_{t=0}^{\infty} \beta^t \left[N^{1+\varphi} \varepsilon_w var_z \{w_t(z)\} + N^{1+\varphi} \tfrac{\varepsilon_p}{\Theta(1-\alpha)} var_j \{p_t(j)\} + \tfrac{(1+\varphi)(N)^{1+\varphi}}{(1-\alpha)^2} \hat{y}_t^2 + \Xi \sum_{i=\{H,S\}} \tfrac{\hat{\omega}_{i,t}^2}{\bar{\omega}_i}\right] \tag{E.19}$$

Following the approach used in Gali (2015) and again using the definition of Ξ, we can simplify the expression in Equation E.19 as:

$$\sum_{t=0}^{\infty} \beta^t \left(U_t - \bar{U}\right) \approx -\frac{1}{2} N^{1+\varphi} \sum_{t=0}^{\infty} \beta^t \left[\underbrace{\frac{\theta_w \varepsilon_w}{(1-\beta\theta_w)(1-\theta_w)}}_{\kappa_w} \pi_{w,t}^2 + \frac{1}{\Theta(1-\alpha)} \underbrace{\frac{\theta_p \varepsilon_p}{(1-\beta\theta_p)(1-\theta_p)}}_{\kappa_p} \pi_{p,t}^2 + \frac{(1+\varphi)}{(1-\alpha)^2} \hat{y}_t^2 + \frac{1}{(1-\alpha)} \sum_{i=\{H,S\}} \frac{\hat{\omega}_{i,t}^2}{\bar{\omega}_i}\right]$$

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{U_t - \bar{U}}{\bar{U}_C C^A}\right) \approx -\frac{1}{2} \sum_{t=0}^{\infty} \beta^t \left[(1-\alpha) \kappa_w \pi_{w,t}^2 + \frac{1}{\Theta} \kappa_p \pi_{p,t}^2 + \frac{(1+\varphi)}{(1-\alpha)} \hat{y}_t^2 + \sum_{i=\{H,S\}} \frac{\hat{\omega}_{i,t}^2}{\bar{\omega}_i}\right]$$

where $\Theta = \frac{(1-\alpha)}{1-\alpha+\alpha\varepsilon}$.

Since $\omega_{i,t} = c_{it}/c_t$, it follows that

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{U_t - \bar{U}}{\bar{U}_C C^A}\right) \approx -\frac{1}{2} \sum_{t=0}^{\infty} \beta^t \left[(1-\alpha) \kappa_w \pi_{w,t}^2 + \frac{1}{\Theta} \kappa_p \pi_{p,t}^2 + \frac{(1+\varphi)}{(1-\alpha)} \hat{y}_t^2 + \frac{\hat{\omega}_{S,t}^2}{\bar{\omega}_S} + \frac{\hat{\omega}_{H,t}^2}{\bar{\omega}_H}\right]$$

where $\omega_{S,t} = \frac{c_{St}}{c_{At}} = (1-\lambda_t) \frac{C_t^S}{C_t^A}$, $\omega_{H,t} = \frac{c_{Ht}}{c_{At}} = \lambda_t \frac{C_t^H}{C_t^A}$, $\bar{\omega}_S = \frac{(1-\lambda)C^S}{C^A}$, and $\bar{\omega}_H = \frac{\lambda C^H}{C^A}$. After performing some algebra, the last expression can be rewritten as:

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{U_t - \bar{U}}{\bar{U}_C C^A}\right) \approx -\mathcal{L} = -\frac{1}{2} \sum_{t=0}^{\infty} \beta^t \mathcal{L}_t$$

where

$$\mathcal{L}_t \approx \left[\underbrace{\chi_w}_{(1-\alpha)\kappa_w} \pi_{w,t}^2 + \underbrace{\chi_p}_{\frac{(1-\alpha+\alpha\varepsilon)}{(1-\alpha)}\kappa_p} \pi_{p,t}^2 + \underbrace{\chi_y}_{\frac{(1+\varphi)}{(1-\alpha)}} \hat{y}_t^2 + \underbrace{\chi_{c_S}}_{\frac{C^A}{(1-\lambda)C^S}} \hat{\omega}_{S,t}^2 + \underbrace{\chi_{c_H}}_{\frac{C^A}{\lambda C^H}} \hat{\omega}_{H,t}^2 \right] \tag{E.20}$$

with, $\hat{\omega}_{S,t} = -\frac{1}{1-\lambda}\hat{\lambda}_t + \hat{c}_t^S - \hat{c}_t^A$, $\hat{\omega}_{H,t} = \frac{1}{\lambda}\hat{\lambda}_t + \hat{c}_t^H - \hat{c}_t^A$, and $\hat{\omega}_{S,t} = -\left(\frac{1}{\lambda(1-\lambda)}\right)\hat{\lambda}_t + \hat{c}_t^S - \hat{c}_t^H$.

Consumption equivalence Let $\mathcal{W}^p$ and $\mathcal{W}^b$ represent the planner's welfare under a specific policy p and the benchmark b, respectively. From the derivations above, it follows that $\mathcal{W}^p \propto -\mathcal{L}^p$. Define welfare under the benchmark case as:

$$\mathcal{W}^b = \sum_{t=0}^{\infty} \beta^t \sum_{i=\{H,S\}} \varphi_{i,b} \left(\log\left(\omega_{it,b} C_{t,b}^A (1+\delta)\right) - \frac{(N_{t,b})^{1+\varphi}}{1+\varphi} \right)$$

This expression can be equivalently rewritten as:

$$\mathcal{W}^b = \frac{\log(1+\delta)}{1-\beta} + \sum_{t=0}^{\infty} \beta^t \sum_{i=\{H,S\}} \varphi_{i,b} \left(\log\left(\omega_{it,b} C_{t,b}^A\right) - \frac{(N_{t,b})^{1+\varphi}}{1+\varphi} \right)$$

which is proportional to:

$$\mathcal{W}^b \propto \frac{\log(1+\delta)}{1-\beta} - \mathcal{L}^b$$

Consumption equivalence is defined as the percentage δ change in permanent consumption such that $\mathcal{W}^p = \mathcal{W}^b$. After performing some algebraic manipulations, we obtain:

$$\delta^* = \exp\left[\left(\mathcal{L}^b - \mathcal{L}^p\right)(1-\beta)\right] - 1$$

F Impulse response functions

F.1 Responses to Other Exogenous Shocks

Figure 9: Impulse response functions to a cost-push shock

Note: Impulse responses are constructed using the posterior mode of the structural parameters and are modeled to induce a 1% exit of intermediate goods producers in the economy.

Figure 10: Impulse response functions to an interest rate shock

Note: Impulse responses are constructed using the posterior mode of the structural parameters and are modeled to induce a 0.25% increase in the nominal interest rate.

Figure 11: Impulse response functions to a wage shock

Note: Impulse responses are constructed using the posterior mode of the structural parameters and are modeled to induce a 1% increase in wage inflation.

F.2 Optimal discretionary transfers: Responses to shocks with and without optimal transfers

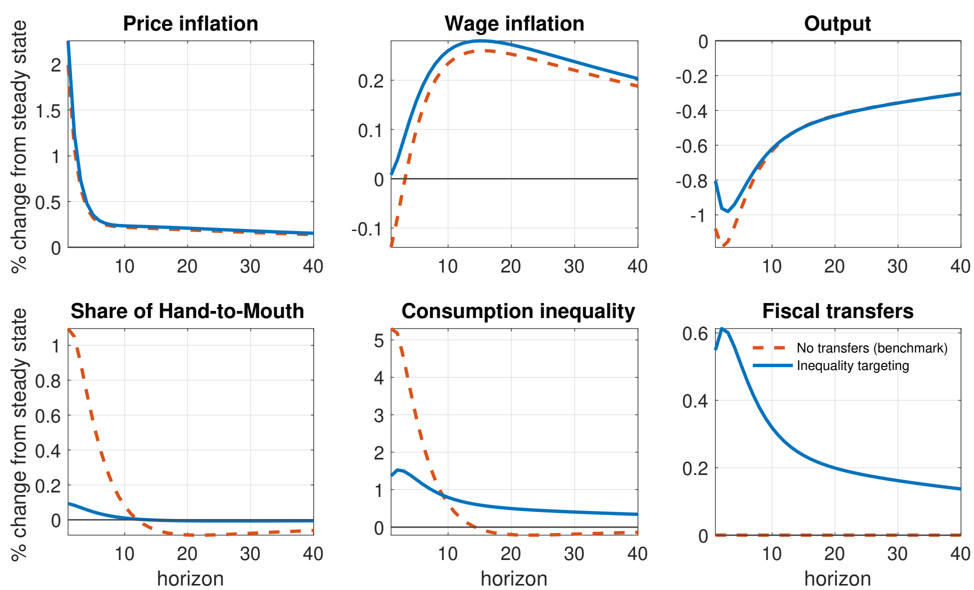


Figure 12: Impulse response functions to a cost-push shock

Note: Impulse responses are constructed using the posterior mode of the structural parameters and are modeled to induce a 1% exit of intermediate goods producers in the economy.

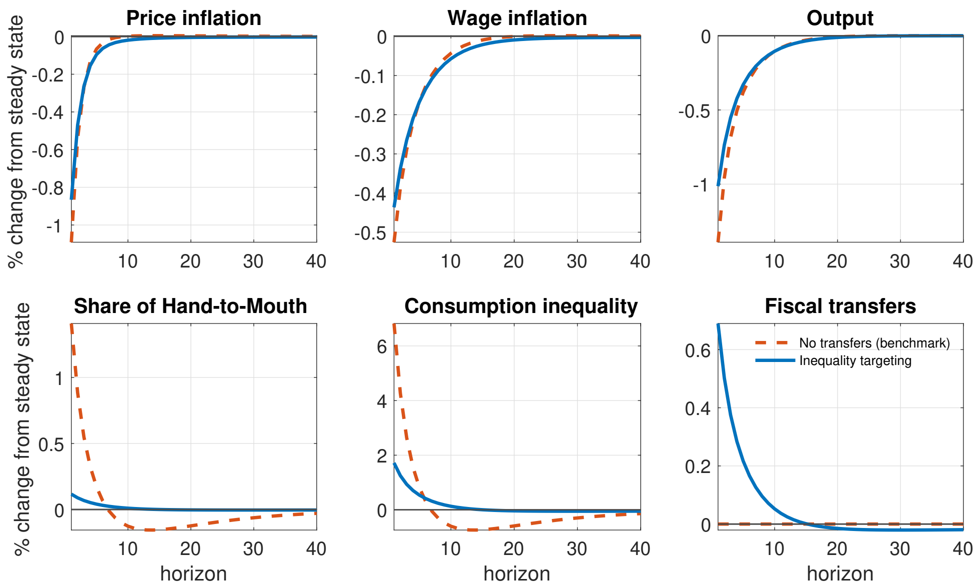


Figure 13: Impulse response functions to an interest rate shock

Note: Impulse responses are constructed using the posterior mode of the structural parameters and are modeled to induce a 0.25% increase in the nominal interest rate.

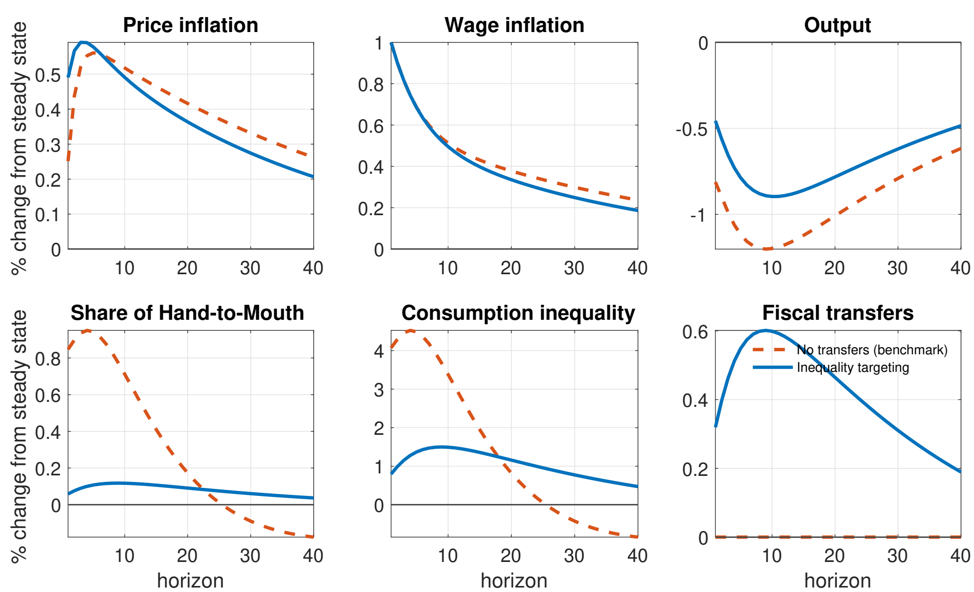


Figure 14: Impulse response functions to a wage shock

Note: Impulse responses are constructed using the posterior mode of the structural parameters and are modeled to induce a 1% increase in nominal wages.

G COVID-19 counterfactuals: Broader effects

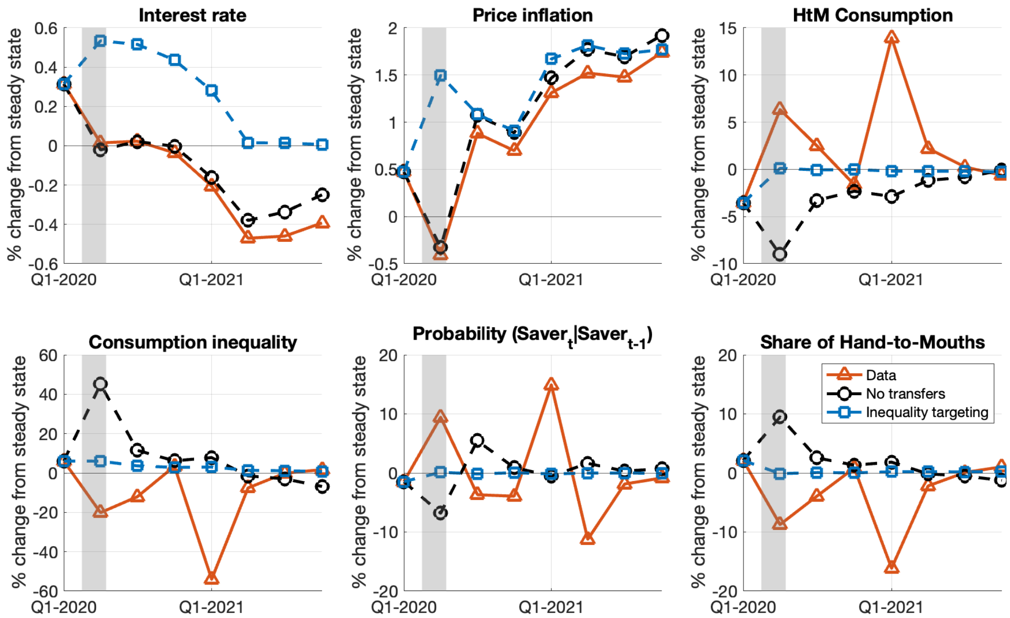


Figure 15: Actual versus optimal fiscal transfers: Broader effects

Note: These counterfactual scenarios are constructed by applying smoothed shocks to the calibrated D-THANK model, with calibration based on the mode posteriors of the estimated parameters, to match the observed dynamics in real GDP growth per capita (y_t^{obs}), government social benefits to individuals (t_t^{obs}), the nominal interest rate (i_t^{obs}), and inflation (π_t^{obs}), as detailed in Subsection D.1 in the Appendix. The model is utilized to predict economic dynamics if the U.S. government had followed an optimal transfer rule targeting consumption inequality from 2020Q2 onward.