Monetary Policy with Non-Ricardian Households

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This paper analyzes how the presence of non-Ricardian households can alter the dynamics in a New-Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) model. The model is calibrated using data for the US economy. We focus on two key areas. The first is the link between monetary policy and consumption inequality in the presence of non-Ricardian households. We find that a contractionary monetary policy shock increases consumption inequality. Part of this increase is due to a novel government transfer channel. This channel becomes significantly stronger when steady state debt is positive. We also find that because of this link, the presence of non-Ricardian households amplifies the impact of monetary policy on output and inflation. The second area relates to the choice of monetary policy rule. We compare four monetary policy rules: the Taylor rule, inflation targeting, nominal GDP targeting, and a new labor income targeting rule. We find that labor income targeting outperforms all other rules for most parameter values. Nominal GDP targeting is better than labor income targeting only when the share of non-Ricardian households is large or when the households exhibit low habit persistence.

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Keywords: Non-Ricardian Households, Monetary Policy, Labor Income Targeting, Nominal GDP Targeting, Taylor Rule, Consumption Inequality, Heterogeneous Agent New Keynesian Models.

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1. Introduction

Representative Agent New Keynesian (RANK) models have been the workhorse of modern macroeconomics over the last few decades. While these models are an excellent starting point in the analysis of aggregate macroeconomic behavior, they ignore relevant details. One such crucial detail is the presence of households who only consume their current income and do not have access to credit and borrowing. These agents have been referred to as non-Ricardian or rule-of-thumb households in the literature. Many studies such as Campbell & Mankiw (1989), Coenen & Straub (2005), and Furlanetto & Seneca (2009) among others have concluded that non-Ricardian households make up for a non-trivial share of the population. Hence, it is crucial that our models take into account this empirical reality as it may change certain economic dynamics and related policy prescriptions.

This paper deals with two themes related to the literature on non-Ricardian households. The first theme is the link between monetary policy and inequality in the presence of non-Ricardian households. Areosa & Areosa (2016) find that a contractionary monetary policy shock increases inequality. This happens due to heterogeneity in the labor market. In their model, non-Ricardian households are unskilled. Hence, when interest rates increase, changes in labor hours and wage differs across Ricardian and non-Ricardian households. These differentials in labor hours and wages lead to a rise in inequality. In contrast to Areosa & Areosa (2016), we assume no skill differential between Ricardian and non-Ricardian households, so we close the earnings heterogeneity channel.

Tirelli & Ferrara (2020) focus on the link between disinflation and inequality with a Limited Asset Market Participation (LAMP) model. They propose two channels, which work in opposite directions. The first channel is a cash in advance (CIA) constraint channel. They show that lower inflation leads to "softer" CIA constraint, which in turn reduces inequality. The second channel is a dividend channel, wherein lower inflation raises dividends and hence increases inequality. Unlike our paper, Tirelli & Ferrara (2020) focus on wealth inequality and long run dynamics.

Bilbiie & Ragot (2021) construct a model with non-Ricardian households and money. They develop a "liquidity-insurance" motive and conclude that increasing liquidity (or lower interest rate) would lead to insurance (lower inequality). This motive creates a tradeoff between liquidity provision for insurance and stabilization of inflation and output.

We contribute to the existing literature by identifying a new transfer channel through which an increase in interest rates increases consumption inequality. The intuition is that a rise in interest rates will decrease economic activity and thereby decrease consumption and labor tax revenues. Furthermore, it will also make government debt more costly. The decrease in revenues coupled with an increase in the cost of debt will force the government to decrease transfers, which in turn will increase consumption inequality given that only non-Ricardian households are the recipients of these transfers.

The second strand of literature relates to the choice of monetary policy rules when the economy has non-Ricardian households. Most of the previous literature on non-Ricardian households has focused exclusively on the Taylor rule and how the design of such optimal Taylor rules could change when the economy is populated with non-Ricardian households.

Bilbiie (2008) is one of the earliest contributions in this area. The paper finds that unlike forward looking Ricardian households, non-Ricardian households are insensitive to real interest rates directly. However, they are extremely sensitive to movements in real wage. When interest rates increase, labor and asset markets are affected simultaneously. The impact on these markets determines the impact on aggregate demand. If the share of non-Ricardian households is low or elasticity of labor supply is high, then we get the conventional aggregate demand curve. However, if the conditions are reversed, then we get an inverted aggregate demand curve. In this case, a rise in interest rates *increases* aggregate demand. Thus, the presence of non-Ricardian households can have significant consequences for the conduct of monetary policy.

Taking this work forward, Bilbiie (2020) finds that when the economy is populated with non-Ricardian households, optimal monetary policy consists of an additional inequality stabilization motive. As a result of these distributional concerns, the central bank must tolerate greater levels of price volatility. Other papers such as Debortoli & Gali (2018) and Hansen, Lin, & Mano (2020) also arrive at the same conclusion regarding an inequality motive in the welfare loss function.

Rigon & Zanetti (2018) also build an economy with non-Ricardian households but unlike previous studies, their model consists of non-zero government debt and finitely lived households. They find that when government debt is non-zero, optimal monetary policy has a debt stabilization component. In this case, inflation targeting is superior to discretionary optimal policy.

Marto (2014) builds a similar model for the Portuguese economy. The paper estimates a high share of non-Ricardian households. Furthermore, the paper finds that when the share of non-Ricardian households is low, movements in output growth are driven primarily by productivity shocks. When the share is high, output growth movements depend on price markup shocks. Finally, they also find that when the economy has a high share of non-Ricardian households, using a Taylor rule leads to indeterminacy. This result was previously established by Gali, Lopez-Salido and Valles (2004), and corroborated by other studies such as Motta & Tirelli (2012) and Rossi (Rossi, 2014). Colciago (2011) on the other hand argues that introducing nominal wage stickiness helps to restore the standard results of equilibrium determinacy. Motta and Tirelli (2015) examine the same issue in the context of an exogenous money supply rule. It must be noted that unlike Motta and Tirelli (2015), our model does not consist of monetary aggregates. By including money in our model, one could potentially test monetary policy rules specified in Benchimol & Fourcans (2012). This could be an avenue for further research. Our paper does not focus on determinacy issues of Taylor rules. Rather we focus on welfare properties of various monetary policy rules.

While the literature on nominal GDP targeting with non-Ricardian households is scant, there have been other studies that have evaluated the welfare properties of nominal GDP targeting in standard (full asset market participation) models. For instance, Jensen (2002) and Kim and Henderson (2005) evaluate the relative performance of nominal GDP targeting and inflation targeting in a New Keynesian model. Both studies conclude that nominal GDP targeting has certain desirable properties especially in comparison to inflation targeting. Mitra (2003) examines the performance of these rules with adaptive learning and also finds similar results. Woodford (2012) and Billi (2014) discuss the same in the context of zero lower bound on interest rates. Garin, Lester and Sims (2016) compare nominal GDP targeting with output gap targeting, inflation targeting along with a standard Taylor rule. They conclude that Nominal GDP targeting is associated with smaller welfare losses than a Taylor rule and significantly outperforms inflation targeting. It is also better than output gap targeting if the gap is observed with noise. Chen (2020) performs a similar exercise in a New Keynesian model with positive growth and trend inflation. The paper finds that under most simulations, nominal GDP targeting has desirable welfare properties.

We extend the existing literature by comparing four rules in the presence of non-Ricardian households: A standard Taylor rule, inflation targeting, nominal GDP targeting and a new labor income targeting rule. To the best of our knowledge, this paper is the first to evaluate the performance of a labor income targeting rule. We find that labor income targeting is superior to the other rules for most parameter values. Nominal income targeting works better than labor income targeting only if the share of non-Ricardian households is high or if there is very little habit persistence. Inflation targeting performs well if the economy faces only demand shocks or if there is no wage stickiness. We also find that in our model, the Taylor rule is always inferior to LIT and NGDPT.

The rest of the paper is organized as follows: Section 2 provides details of the New Keynesian DSGE model. In section 3, we look at the choice of calibrated values. Section 4 elaborates on the results and section 5 provides the conclusion.

2. The Model Economy

This paper builds a medium scale New Keynesian model similar to the framework developed by Garin, Lester, & Sims (2016). The key friction in the model is the presence of non-Ricardian agents as seen in Gali, Lopez-Salido and Valles (2004). Households maximize a utility function over an infinite time horizon. The utility function includes consumption and labor. Consumption is subject to habit formation such that the household's marginal utility of consumption today is affected by the quantity of goods consumed in the previous period.

2.1 Households

The economy is populated by a continuum of households indexed by $j \in [0,1]$. The utility function of the household is given by:

$$U_t = E_t\{\sum_{i=0}^{\infty} \beta^i a_{t+i} \, [\ln(C_{t+i}(j) - bC_{t+i-1}(j)) - \psi \frac{N_{t+i}(j)^{1+\eta}}{1+\eta}]\} \tag{1}$$

Here, β is the discount factor. The consumption preference shock, a_t, follows an AR (1) process and is common to all households. $C_t(j)$ and $N_t(j)$ are the consumption and labor effort of the j^{th} household. The scaling parameter on the disutility from labor is denoted by ψ, while η represents the inverse of the Frisch elasticity of labor supply. The habit formation parameter is denoted by b.

Ricardian households

Ricardian households account for $1-\lambda$ proportion of the population. These households have access to a one period domestic government bond (B_t). Access to this savings instrument allows these agents to smoothen their consumption. Households also pay a consumption tax (τ_C) as well as a labor income tax (τ_L). The budget constraint of these agents is:

$$
\begin{aligned}
(1+\tau_C)C_t^R(j) + \frac{B_t(j)}{(1+i_t)} \\
= (1-\tau_N)w_t(j)L_t(j) + B_{t-1}(j) + D_t(j)
\end{aligned} \tag{2}
$$

Here, $C_t^R(j)$ is the consumption of the j^{th} Ricardian household and i_t is the interest rate on bonds. D_t is the dividend received from the domestic firm.

Wage setting by the Ricardian households

Ricardian households also have the advantage of setting their real wage ($w_t(j)$). Following Erceg, Henderson, and Levin (2000) we assume that wage setting is subject to nominal rigidities. In every period, each Ricardian household faces a probability $1-\theta_w$ of being able to re-optimize their wage. Hence, θ_w is a measure of wage rigidity. The households who are unable to re-optimize their real wage follow an indexation rule (Garin, Lester, & Sims, 2016) given as:

$$
\begin{aligned}
&w_t(j) = w^{\#}(j) && \text{if } w_t(j) \text{ is chosen optimally} \\
&w_t(j) = (1+\pi_t)^{-1}(1+\pi_{t-1})^{\xi_w} w_{t-1}(j) && \text{otherwise}
\end{aligned} \tag{3}
$$

Here, $w^{\#}(j)$ is the optimal "reset" real wage chosen by the j^{th} household and π_t is the inflation rate in period t. The wage indexation parameter is denoted by ξ_w.

The households supply their labor to a labor-aggregating firm which bundles the labor input as follows:

$$
N_t = \left(\int_0^1 N_t(j)^{\frac{\epsilon_{w-1}}{\epsilon_w}}\, dj\right)^{\frac{\epsilon_w}{\epsilon_w - 1}} \tag{4}
$$

The optimizing problem of the labor-aggregating firm gives the demand for labor as:

$$
N_t(j) = \left(\frac{w_t(j)}{w_t}\right)^{-\epsilon_w} N_t \tag{5}
$$

Non-Ricardian households

The non-Ricardian households don't have access to government bonds and don't receive any dividends. However, they receive transfers from the government (Tr_t). Following Medina and Soto (2016) we assume that each non-Ricardian agent sets its wage equal to the average wage set by the Ricardian agents. Since both the types face the same labor demand schedule, labor services provided by the non-Ricardian agents are equal to the average provided by Ricardian agents. As a result, we can write their consumption identity as follows:

$$(1+\tau_C)C_t^{NR} = (1-\tau_N)w_t L_t + Tr_t \tag{6}$$

2.2 Goods market

The goods market consists of intermediate goods firms and final goods firms. The final goods market is perfectly competitive. The final goods firm uses $Y_t(i)$ units of each intermediate good $i \in [0,1]$ to manufacture Y_t units of final output according to the following technology:

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\epsilon_p-1}{\epsilon_p}} di\right)^{\frac{\epsilon_p}{\epsilon_p-1}} \tag{7}$$

The competitive final goods firm maximizes profit, which gives rise to the following demand function:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon_p} Y_t \tag{8}$$

The intermediate producers operate in a monopolistic setup and can set their own prices. The production function is given as:

$$Y_t(i) = Z_t N_t(i) \tag{9}$$

Z_t is the aggregate productivity shock that follows a random walk with positive drift:

$$Log(Z_t) = Log(1+gy) + Log(Z_{t-1}) + \epsilon_{zt} \tag{10}$$

Here, gy is the growth rate of output in the steady state.

Price setting by the intermediate firm

Each intermediate firm can set its own price. Price setting follows the Calvo (1983) mechanism. In every period, each firm faces a $1-\theta_p$ probability of adjusting its prices. The firms which do not receive the signal will update their prices based on an indexation rule (Garin, Lester, & Sims, 2016) given as:

$$\begin{aligned} P_t(i) &= P^{\#}(i) && \text{if } P_t(i) \text{ is chosen optimally} \\ P_t(i) &= (1+\pi_{t-1})^{\xi_p} P_{t-1}(i) && \text{otherwise} \end{aligned} \tag{11}$$

Here, $P^{\#}(i)$ is the optimal "reset" price chosen by the i^{th} intermediate firm. The price indexation parameter is denoted by ξ_w.

2.3 Fiscal block

The government's revenue depends on income and consumption taxes. Total revenue is given as follows:

$$Rev_t = \tau_N w_t N_t + \tau_C C_t \tag{12}$$

Total expenditure by the government includes government consumption and transfers to non-Ricardian agents:

$$Expd_t = G_t + Tr_t \tag{13}$$

Government expenditure depends solely on total output:

$$G_t = gY_t \tag{14}$$

The government issues domestic bonds, B_g, to finance expenditures. The evolution of net fiscal position of the government is given as:

$$\frac{B_{g,t}}{(1+i_t)} = B_{g,t-1} + Rev_t - Expd_t \tag{15}$$

The fiscal deficit of the government is defined as:

$$FD_t = Expd_t - Rev_t - \left(1 - \frac{1}{1+i_{t-1}}\right) B_{t-1} \tag{16}$$

In the baseline model, we assume that the government follows a balanced budget policy. This means that fiscal deficit would be equal to zero in each period. In the steady state, government debt would be zero and revenue would equal expenditure. In a later section, we also allow the government to run fiscal deficits.

2.4 Monetary policy

We adopt a Taylor rule (Taylor, 1993) in the baseline model as follows:

$$\begin{aligned}\log(1+i_t) = (1-\rho_i)\log(1+i^*) + \rho_i \log(1+i_{t-1}) + \phi_\pi \log\left(\frac{1+\pi_t}{1+\pi^*}\right) \\ + \phi_y \log\left(\frac{Y_t/Y_{t-1}}{1+gy}\right)\end{aligned} \tag{17}$$

Where i^*, π^* and gy are the steady state interest rate, inflation and growth rate respectively.

3. Calibration

We calibrate the model using data for the US economy. We set the share of non-Ricardian households (λ) equal to 0.3. This is consistent with empirical studies for the United States such as Furlanetto & Seneca (2009), who estimate the value to be between 29% and 35%. This value ($\lambda = 0.3$) has also been used in other studies focusing on non-Ricardian households, such as Kaszab (2016) and Tirelli & Ferrara (2020). We calibrate the value of β to arrive at a real interest of 3% (Tirelli & Ferrara (2020)). The steady state inflation rate and growth rate of output have been fixed at 0.005, which implies 2% annual inflation and output growth rate. We calibrate ψ to set the steady state labor hours equal to 1/3 as in Garin, Lester and Sims (2016). The Frisch labor supply elasticity is unity. This implies that η equals 1. Following Motta & Tirelli (2012), we fix the habit formation parameter (b) 0.7. The price and wage stickiness parameters, θ_p and θ_w, along with the indexation parameters, ξ_p and ξ_w, have been sourced from Smets & Wouters (2007). For simplicity, we assume the value of consumption tax rate to be equal to 0.1 The income tax rate is fixed at 0.204 The value is obtained from Fotiou, Shen, & Yang (2020), who calculate the average labor income tax for the US economy between 1980 to 2017. The value for government spending to output ratio (g), is also obtained from Fotiou, Shen, & Yang (2020). The values for the Taylor rule parameters and persistence of preference shock have been taken from Garin, Lester and Sims (2016). These values are commonly seen in the literature[2]. Finally, σ_A and σ_Z have been calibrated to generate a standard deviation of log output of 0.036. This value is close to the observed value for the post-war US economy. Like Garin, Lester and Sims (2016) in our model, the productivity and preference shocks account for 50% of the unconditional variance of log output. This implies that demand and supply shocks contribute equally to movements in output.

All parameter values are provided in Table 1.

Table 1: Calibrated parameter values

Parameter	Description	Value
λ	Share of non-Ricardian households	0.3
β	Discount factor	0.997
π^*	Inflation target	0.005
gy	Steady state growth rate of output	0.005
ψ	Scaling parameter on the disutility from labor	6

[2] It must be noted that following Garin, Lester and Sims (2016), we have also written the Taylor rule as one of partial adjustment. The long run response of inflation and output growth would be $\phi_\pi/(1-\rho_i)$ and $\phi_y/(1-\rho_i)$ respectively.

η	Inverse of the Frisch elasticity of labor supply	1
b	Habit formation parameter	0.7
θ_p	Price stickiness parameter	0.66
θ_w	Wage stickiness parameter	0.70
ξ_p	Price indexation parameter	0.24
ξ_w	Wage indexation parameter	0.58
τ_C	Consumption tax rate	0.1
τ_L	Income tax rate	0.204
g	Government spending to output	0.08
ρ_i	Interest rate smoothing (Taylor rule)	0.7
ϕ_π	Response to inflation (Taylor rule)	0.45
ϕ_y	Response to output (Taylor rule)	0.0375
ρ_A	Persistence of preference shock	0.700
σ_A	Standard deviation of preference shock	0.033
σ_Z	Standard deviation of productivity shock	0.038

In addition to the above calibration, we also conduct a moment matching exercise for certain key economic variables, namely: output growth, inflation, and interest rate. We use quarterly data from the third quarter of 1954 through the second quarter of 2022. The data for all the three variables has been sourced from the FRED database for the US economy. To calculate inflation, we use the log difference of the GDP deflator.

Table 2 provides results for the moment matching exercise. We find that while the model captures some features of the economy, it misses others as is common with basic DSGE models. In particular, it provides a great fit for inflation. Average output growth in the model (around 2% annual growth) is lower than that observed in the data (2.8% annual growth) for this period, while the standard deviation is higher. The reverse is true for interest rate. Average interest rate is higher in the model as compared to what we see in the data. However, it must be noted that if we restrict the dataset to include only pre-2008 observations, then average interest rate in the data exactly matches the model-generated average (0.015).

Table 2: Moment matching

Variable	**Mean**		**Standard Deviation**	
	Model	**Data**	**Model**	**Data**
Output Growth	1.005	1.007	0.024	0.011
Inflation	0.007	0.008	0.005	0.005
Interest Rate	0.015	0.011	0.008	0.004

4. Results

4.1 Monetary policy and consumption inequality

The first set of results deals with the link between monetary policy and consumption inequality. Here, we measure consumption inequality using a consumption inequality index, which is the ratio of Ricardian consumption to non-Ricardian consumption. Figure 1 depicts the impulse response of the consumption inequality index to a monetary policy shock. The result is a spike in CI index followed by a gradual decline over twenty quarters. Hence, when interest rates go up, consumption inequality increases.

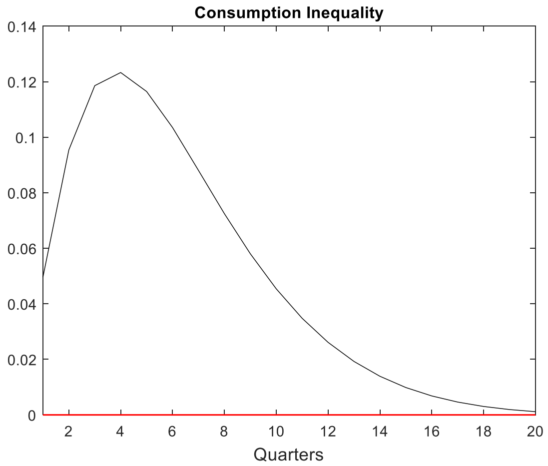

Figure 1: Impulse response of consumption inequality to a one standard deviation monetary policy shock. Note: Responses are reported in deviations from the steady state.

Why does contractionary monetary policy increase inequality? We can trace the impact of a monetary policy shock by looking at Figure 2, which plots the impulse responses of certain key variables. As expected, we see a fall in output, inflation, and consumption due to an increase in interest rates. There is a decrease in labor demand by firms, which causes aggregate labor and wages to fall. This decline in economic activity leads to a fall in consumption and labor income tax revenue. Since the government is following a balanced budget constraint, there is a simultaneous reduction in government spending and transfers. The burden of a fall in transfers rests solely on the non-Ricardian households since only they receive these unilateral transfers. This reduction in transfers, coupled with a decrease in labor income causes non-Ricardian consumption to shrink more than Ricardian consumption and hence inequality rises.

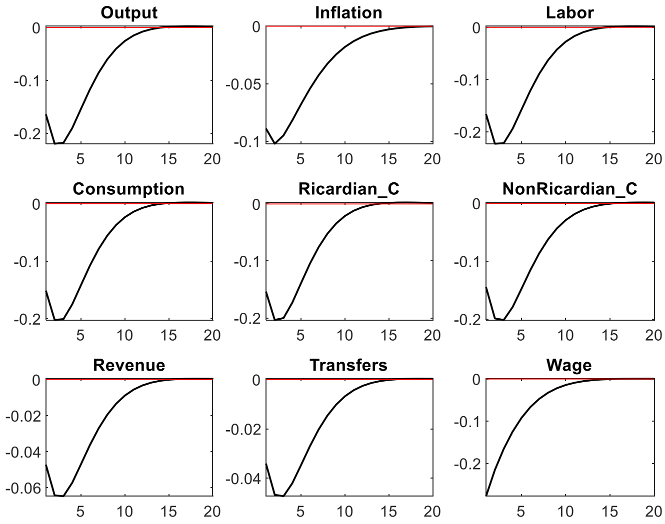

Figure 2: Impulse responses of selected variables to a one standard deviation monetary policy shock. Note: Responses are reported in deviations from the steady state.

Impact of government debt

In the baseline model, the government follows a strict balanced budget rule. This means that steady state fiscal deficit and government debt are both equal to zero. However, most governments around the world in fact allow for non-zero fiscal deficit and government debt. In this section, we explore how that could potentially impact the relationship between monetary policy and consumption inequality.

The government follows a fiscal deficit rule as follows:

$$\ln\left(\frac{\frac{FD_t}{Y_t}}{FD_{GDP_{target}}}\right) = \rho_{FD} \ln\left(\frac{\frac{FD_{t-1}}{Y_{t-1}}}{FD_{GDP_{target}}}\right) \tag{18}$$

For simplicity, we assume that the fiscal deficit to GDP target ($FD_{GDP_{target}}$) is 1% and the value of ρ_{FD} is 0.9. In this environment, steady state debt (B_g) is no longer zero.

Figure 3 and Figure 4 depict the impulse responses of consumption inequality and government transfers respectively to a one standard deviation monetary policy shock. The black solid line represents the baseline scenario, where the government follows a balanced budget rule. The blue dashed line represents the scenario where the government has a 0.01 fiscal deficit to GDP target.

Clearly, the increase in consumption inequality is significantly higher in the case where the government allows for non-zero fiscal deficit. This is particularly due to the transfer channel. In the economy with positive steady state fiscal deficit, government debt is also positive. In this scenario, when interest rates increase, government debt becomes more expensive. In order to reduce the interest repayment burden, the government decreases transfers sharply as seen in Figure 4. This leads to an equally sharp and significant rise in consumption inequality.

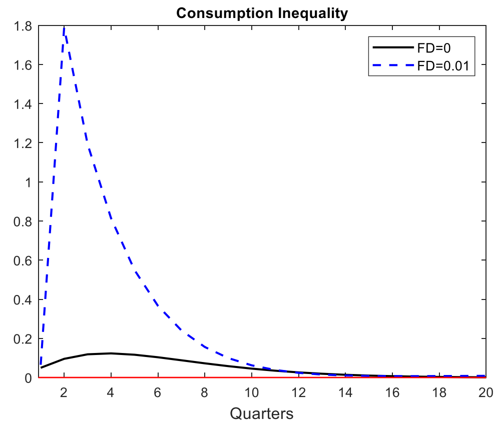

Figure 3: Impulse response of consumption inequality to a one standard deviation monetary policy shock under different fiscal deficit rules. Note: Responses are reported in deviations from the steady state.

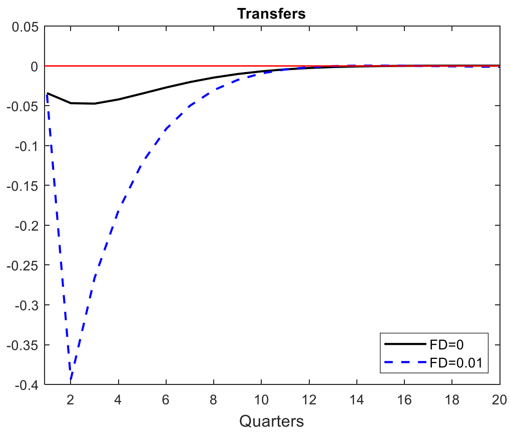

Figure 4: Impulse response of government transfers to a one standard deviation monetary policy shock under different fiscal deficit rules. Note: Responses are reported in deviations from the steady state.

Figure 5 and Figure 6 plot the impulse responses of consumption inequality and government transfers respectively to a one standard deviation monetary policy shock under various fiscal deficit to GDP targets. We set fiscal deficit targets at 0.01, 0.03 and 0.05. A higher fiscal deficit target leads to higher steady state government debt. Higher debt amplifies the government transfer channel of consumption inequality. Clearly, government debt plays a crucial role in the link between monetary policy and inequality. When steady state debt is high, consumption inequality is extremely sensitive to changes in monetary policy.

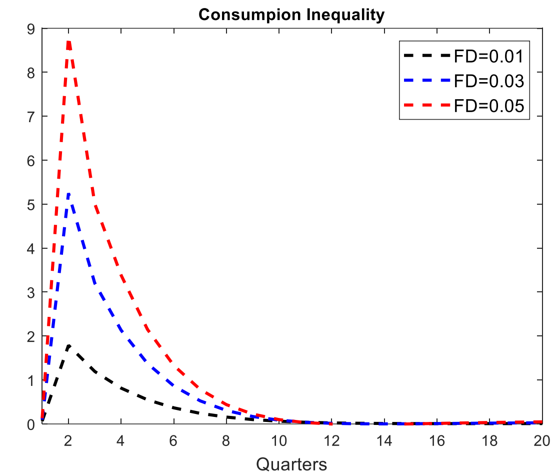

Figure 5: Impulse response of consumption inequality to a one standard deviation monetary policy shock under different fiscal deficit rules. Note: Responses are reported in deviations from the steady state

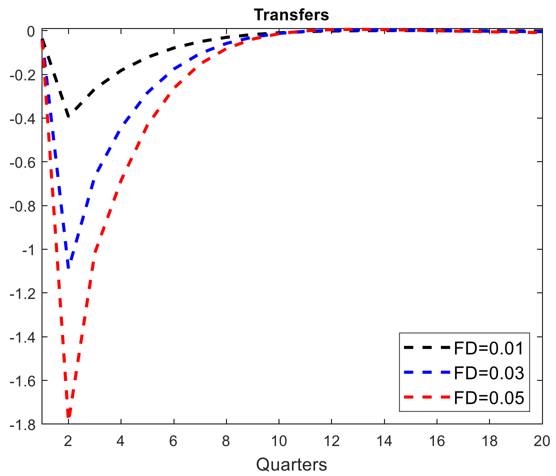

Figure 6: Impulse response of government transfers to a one standard deviation monetary policy shock under different fiscal deficit rules. Note: Responses are reported in deviations from the steady state.

Impact of Non-Ricardian households on monetary policy transmission

The link between monetary policy and inequality highlighted above has broader implications for aggregate variables as well. Figure 7 depicts the response of output and inflation to a one standard deviation monetary policy shock. The black solid line represents the baseline economy with Non-Ricardian households. The blue dashed line is for the economy without Non-Ricardian households. We can see that the presence of Non-Ricardian households augments the impact of monetary policy. This follows directly from our earlier result since we concluded that a monetary policy shock has a greater impact on non-Ricardian agents than on Ricardian agents. Hence, aggregate consumption (and by extension aggregate output and inflation) falls more in the baseline case where we include the non-Ricardian agents. The difference is greater for output as compared to inflation.

There is an even starker difference when we compare the economy without Non-Ricardian households (blue dashed line) to the economy which includes Non-Ricardian households *and* has a 5% fiscal deficit target (blue line circle markers). Once again, these results follow directly from our earlier conclusions about the link between monetary policy and inequality, and the fact that the link is amplified when debt is positive.

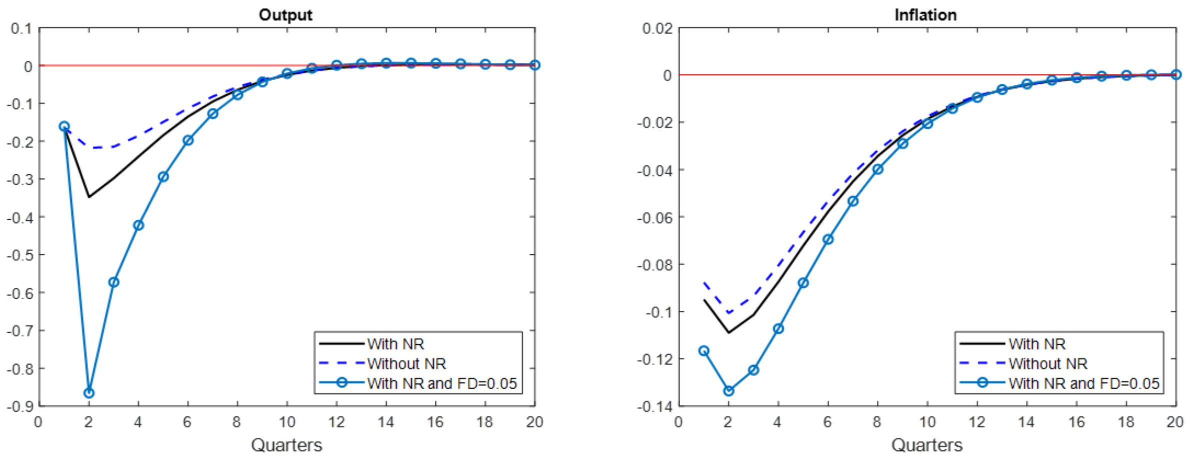

Figure 7: Impulse response of output (left) and inflation (right) to a one standard deviation monetary policy shock.

4.2 Choice of monetary policy rule

The second set of results deals with the choice of monetary policy rules. We compare four monetary policy rules: A standard Taylor rule (TR), Inflation Targeting (IT), Nominal GDP Targeting (NGDPT), and Labor Income Targeting (LIT). The Taylor rule has been described in the baseline model. Inflation targeting is defined as follows:

$$\pi_t = \pi^* \tag{19}$$

Nominal GDP targeting is defined as follows:

$$(1+\pi_t)\frac{Y_t}{Y_{t-1}} = (1+gy)(1+\pi^*) \tag{20}$$

Labor income targeting is defined as follows:

$$(1+\pi_t)\frac{w_t}{w_{t-1}}\frac{N_t}{N_{t-1}} = (1+gy)(1+\pi^*) \tag{21}$$

The specifications of the inflation targeting rule and the NGDP rule are similar to Garin, Lester and Sims (2016). The inflation target rule implies that the central bank wants to achieve the inflation target in every period, while the NGDP rule implies that the central bank wants to achieve the nominal income growth target in every period. The labor income rule keeps the growth of nominal labor income constant.

In order to evaluate the four policy rules, we define welfare recursively in our model as follows:

$$V_t = U(C_t, N_t) + \beta E_t(V_{t+1})$$

Then, we solve the model using a second order approximation around the model's steady state and obtain the unconditional mean of welfare for each policy rule. This is then compared to the unconditional mean of welfare in the flexible price economy where there is no price or wage stickiness ($\theta_p = 0 \ and \ \theta_w = 0$).

Based on these unconditional means, we calculate consumption equivalent welfare losses as follows:

$$CE = \exp\Big((1-\beta) * (E\big(V_{flex}\big) - E(V_1))\Big) - 1$$

Here $E\big(V_{flex}\big)$ is the unconditional mean of welfare in the flexible price economy and $E(V_1)$ is welfare under the chosen monetary policy rules (TR, IT, NGDPT, or LIT). Consumption equivalent welfare loss can be interpreted as the amount of consumption households would be willing to give up in each period to live in the flexible price economy as opposed to living in the economy with nominal rigidities. Hence, these CE values are essentially welfare losses that arise due to frictions.

Table 3 provides the consumption equivalent welfare loss under each policy. We can see that adopting labor income targeting produces the lowest welfare loss. Nominal GDP targeting is a close second. Taylor rule and inflation targeting produces higher welfare losses. It must be noted that the rankings of TR, NGDPT and IT are the same as those obtained by Garin, Lester and Sims (2016).

Table 3: Consumption equivalent welfare loss

	TR	**LIT**	**NGDPT**	**IT**
Welfare Loss	1.492	0.538	0.555	2.037

Demand vs supply shocks

Previous literature in the area of optimal monetary policy suggests that the performance of monetary policy rules depends on which shocks hit the economy. Hence, in this section, we analyze the performance of the four policy rules under different shocks. Our model consists of a demand shock (preference shock a_t) and a supply shock (productivity shock z_t).

Table 4 reports the welfare loss under each shock. We notice that when the model includes only a demand shock, the welfare differentials are quite low. In other words, the choice of monetary policy rule is not as relevant. This is very much in line with the findings of Garin, Lester, & Sims (2016). IT, LIT and NGDPT produce the same welfare loss, while TR is slightly worse.

Table 4: Consumption equivalent welfare loss by shock

	TR	**LIT**	**NGDPT**	**IT**
Both shocks	1.492	0.538	0.555	2.037
Only demand shock	0.261	0.240	0.240	0.240
Only supply shock	1.450	0.537	0.554	2.036

Under a supply shock, the choice of monetary policy rule plays a significant role. LIT and NGDPT have substantially lower welfare losses. Inflation targeting is the worst rule in this scenario. This is due to the fact that under our supply shock, inflation and output move in opposite directions. Sumner (2014) and others argue that this is exactly the kind of situation where nominal GDP targeting is most required since it places equal emphasis on output and price movements. Our contribution here is to show that LIT also possesses the same strengths and in fact works better than NGDPT under both supply as well as demand shocks.

Relationship between share of non-Ricardian households and welfare loss

How does the share of non-Ricardian households (λ) influence the choice of policy rule? Table 5 reports consumption equivalent welfare loss under each rule. We can see that excluding non-Ricardian households from the model does not alter the results. This is especially because the US economy has a small share of non-Ricardian households (0.3).

Table 5: Consumption equivalent welfare loss when $\lambda = 0$

	TR	**LIT**	**NGDPT**	**IT**
Baseline ($\lambda = 0.3$)	1.492	0.538	0.555	2.037

Only Ricardian households ($\lambda = 0$)	1.593	0.577	0.608	2.195

On the other hand, when λ increases, the best policy rule changes from LIT to NGDPT. We can see this result in Figure 8, which captures the welfare loss under NGDPT and LIT. When λ is more than 0.5, NGDPT becomes better than LIT. Hence, the share of non-Ricardian households plays a crucial role in the selection of the optimal monetary policy.

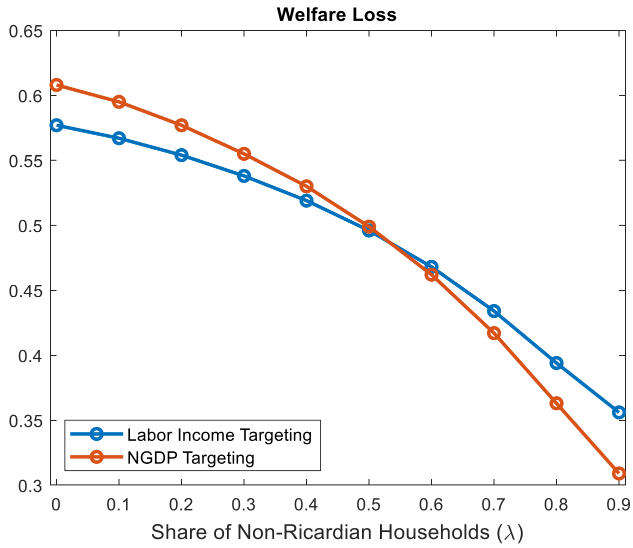

Figure 8: Consumption equivalent welfare loss under LIT and NGDPT. Impact of share of non-Ricardian households.

Impact of household parameters

Next, we look at the impact of household parameters on the performance of the monetary policy rules. Table 6 provides the welfare loss values. We first decrease the labor disutility parameter (ψ) from 6 to 1.5, which increases the steady state value of labor hours from 1/3 to 2/3. This has no impact on welfare loss. We then increase the inverse Frisch elasticity parameter (η) from 1 to 1.5. This would imply a Frisch labor supply elasticity of two-third. This value has been observed in previous US based studies such as Smets & Wouters (2007) and Garin, Lester, & Sims (2016). The rankings remain the same in this case as well.

Table 6: Consumption equivalent welfare loss. Impact of household parameters.

	TR	**LIT**	**NGDPT**	**IT**
Baseline	1.492	0.538	0.555	2.037
$\boldsymbol{\psi = 1.5}$	1.492	0.538	0.555	2.037
$\boldsymbol{\eta = 1.5}$	4.718	1.030	1.054	6.834
$\boldsymbol{b = 0}$	1.686	0.580	0.571	100.000

Next, we look at the habit formation parameter. In our baseline model, the habit formation parameter is set at 0.7. In the absence of any habit formation, NGDPT is slightly better than LIT as seen in Table 6. Furthermore, the performance of inflation target deteriorates substantially.

Figure 9 depicts the performance of LIT and NGDPT under different values of the habit formation parameter. When the households have no or low habit formation, NGDPT works better. When the habit formation parameter exceeds 0.5, LIT becomes the best policy rule. It must be noted that most empirical studies based on the US economy find that habit formation exists. Furthermore, the literature finds that the value of the habit formation parameter is usually in the range of 0.65-0.75.

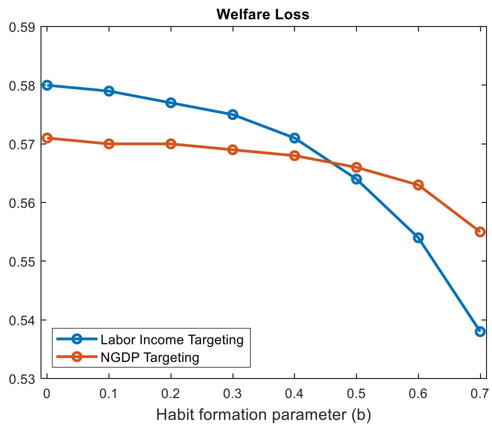

Figure 9: Consumption equivalent welfare loss under LIT and NGDPT. Impact of habit formation.

Impact of firm parameters

Table 7 repeats the exercise for firm parameters. First, we assume complete price indexation, $\xi_p = 1$. This improves the performance of the Taylor rule and substantially increases the welfare loss under inflation targeting. The welfare rankings remain the same. Assuming complete wage indexation, i.e. $\xi_w = 1$, does not alter the welfare performance significantly.

Next, we change the Calvo probabilities, θ_p and θ_w. When there is no price stickiness ($\theta_p = 0$), welfare losses under LIT and NGDPT are identical. Inflation targeting becomes much worse. Assuming no wage stickiness ($\theta_w = 0$) affects the welfare outcomes markedly. Under this specification, inflation targeting becomes the best policy rule. This is particularly because the problem with inflation targeting is that it creates high volatility in wage inflation. When there wages are completely flexible, wage inflation does not enter the loss function. As a result, inflation targeting becomes the best rule. These findings are in line with Garin, Lester, & Sims (2016) who also report that inflation targeting outperforms other rules when there is no wage stickiness.

We find that LIT is the second best rule. This is followed by the Taylor rule and then Nominal GDP targeting. It must be noted that even a small value of $\theta_w = 0.1$ is sufficient to make LIT better than inflation targeting. Most prominent US DSGE studies (such as Christiano, Eichenbaum, & Evans (2005) and Smets & Wouters (2007)) place the value of θ_w in the range of 0.6-0.75.

Table 7: Consumption equivalent welfare loss. Impact of firm parameters.

	TR	**LIT**	**NGDPT**	**IT**
Baseline	1.492	0.538	0.555	2.037
$\boldsymbol{\xi_p = 1}$	0.568	0.463	0.493	18.050
$\boldsymbol{\xi_w = 1}$	1.746	0.664	0.673	2.315
$\boldsymbol{\theta_p = 0}$	1.231	0.468	0.468	26.935
$\boldsymbol{\theta_w = 0}$	0.007	0.005	0.007	0.000

Impact of general economy-wide parameters

In our baseline scenario, we assume that the economy has a positive steady state inflation (π^*) and positive trend growth (gy). In this section, we will see how relaxing these assumptions might affect the welfare comparison. Table 8 provides the welfare loss for the four monetary policy rules. When steady state inflation target is zero, the performance all inflation targeting worsens considerably, while welfare losses decrease under other rules. When steady state growth rate is equal to zero, inflation targeting improves as compared to the baseline scenario of positive growth. However, we can see that in both cases, the welfare rankings are preserved.

Table 8: Consumption equivalent welfare loss. Impact of economy wide parameters.

	TR	**LIT**	**NGDPT**	**IT**
Baseline	1.492	0.538	0.555	2.037
$\boldsymbol{\pi^* = 0}$	0.564	0.260	0.269	9.248
$\boldsymbol{gy = 0}$	0.646	0.564	0.565	0.781

Impact of fiscal parameters

Next, we look at the impact of fiscal parameters on the performance of each monetary policy rule. Table 9 presents the consumption equivalent welfare loss. The second row shows the welfare loss for an economy where there is no government spending and in the third row we set consumption tax (τ_C) equal to zero. In both these cases, the performance of all the rules improves. When we assume no labor income tax (τ_N), the performance of all four rules worsens slightly. Over all, we can conclude that fiscal parameters do not alter our results significantly.

Table 9: Consumption equivalent welfare loss. Impact of fiscal parameters.

	TR	**LIT**	**NGDPT**	**IT**
Baseline	1.492	0.538	0.555	2.037
g=0	1.325	0.496	0.509	1.890
$\boldsymbol{\tau_C = 0}$	1.483	0.534	0.550	2.022
$\boldsymbol{\tau_N = 0}$	2.141	0.689	0.727	2.603

Conclusion

This paper examines how the introduction of Non-Ricardian agents in a New-Keynesian model can alter the dynamics of an economy and influence policy choices. We engage in two exercises. First, we examine the link between monetary policy and consumption inequality in the presence of Non-Ricardian agents. We find that a contractionary monetary policy shock can increase consumption inequality. This happens in part due to endogenous changes in government transfers. This transfer channel is amplified when steady state debt is positive. We also find that the presence of non-Ricardian households intensifies the impact of monetary policy on output and inflation.

Second, we identify the best monetary policy rule for this economy. We compare four policy rules namely: The Taylor rule, labor income targeting, nominal GDP targeting, and inflation targeting. Labor income targeting outperforms the other three rules in the baseline economy. Nominal GDP targeting is better than LIT only when either i) more than half the economy is made up of non-Ricardian agents or ii) when the habit formation parameter is less than 0.5. Neither of these conditions are true for the US economy. Inflation targeting generates the lowest welfare losses under two conditions: i) when the economy only includes demand shocks, or ii) when there is no wage stickiness. Once again, empirical evidence suggests that neither of these two conditions hold for the US economy.

Our results suggest that labor income targeting has desirable welfare properties and must be scrutinized as a viable policy alternative. However, it is important to note that these results are based on a stylized DSGE model, which incorporates non-Ricardian households and a complex fiscal block. As such, it would be critical to evaluate this rule in other scenarios. We would need to test our findings by adopting a standard model that is widely accepted. It would also be useful to assess the performance of labor income targeting by employing estimated DSGE models with more granular details that can match the actual data more closely. Furthermore, it would be vital to understand what makes labor income targeting better than other policy rules. We explore these themes in a forthcoming paper (Bhatnagar, 2022).

References

Areosa, W. D., & Areosa, M. B. (2016). The inequality channel of monetary transmission. *Journal of Macroeconomics*.

Benchimol, J., & Fourcans, A. (2012). Money and risk in a DSGE framework: A Bayesian application. *Journal of Macroeconomics*.

Benchimol, J., & Fourcans, A. (2019). Central bank losses and monetary policy rules: A DSGE investigation. *International review of economics and finance*.

Bhatnagar, A. (2022). Labor Income Targeting.

Bilbiie, F. (2008). Limited asset markets participation, monetary policy and (inverted) aggregate demand logic. *Journal of Economic Theory*.

Bilbiie, F. (2020). Monetary Policy and Heterogeneity: An Analytical Framework. *Society for Economic Dynamics*.

Bilbiie, F., & Ragot, X. (2021). Optimal monetary policy and liquidity with heterogeneous households. *Review of Economic Dynamics*.

Bilbiie, F., Monacelli, T., & Perotti, R. (2020). Stabilization vs. Redistribution: the Optimal Monetary-Fiscal Mix . *CEPR Discussion Paper* .

Billi, R. M. (2014). Nominal GDP Targeting and the Zero Lower Bound: Should We Abandon Inflation Targeting. *Sveriges Riksbank Working Paper Series.*

Calvo, G. (1983). Staggered prices in a utility-maximizing framework. *Journal of monetary economics*, 383-398.

Campbell, J., & Mankiw, G. (1989). Consumption, Income, and Interest Rates: Reinterpreting Time Series Evidence. *NBER Macroeconomics Annual*.

Chen, H. (2020). Nominal GDP targeting, real economic activity and inflationstabilization in a new Keynesian framework. *The Quarterly Review of Economics and Finance*.

Christiano, L., Eichenbaum, M., & Evans, C. (2005). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of political economy*.

Coibion, O., Gorodnichenko, Y., Kueng, L., & Silvia, J. (2017). Innocent bystanders? Monetary policy and inequality. *Journal of Monetary Economics*.

Colciago, A. (2011). Rule-of-thumb consumers meet sticky wages. *Journal of Money, Credit and Banking*, 43(2): 325–353.

Colciago, A., Samarina, A., & Haan, J. d. (2019). Central bank policies and income and wealth inequality: A survey. *Journal of Economic Surveys*, Vol. 33, No. 4, pp. 1199–1231.

Cumner, S. (2014). Nominal GDP targeting: A simple rule to improve Fed performance. *Cato Journal*.

Debortoli, D., & Gali, J. (2017). Monetary policy with heterogeneous agents: Insights from TANK models. *Manuscript*.

Debortoli, D., & Gali, J. (2018). Monetary policy with heterogeneous agents: Insights from TANK models. *Economics Working Papers, Department of Economics and Business, Universitat Pompeu Fabra*.

Erceg, C., Henderson, D., & Levin, A. (2000). Optimal monetary policy with staggered wage and price contracts. *Journal of monetary economics*, Volume 46, pp. 281-313.

Fotiou, A., Shen, W., & Yang, S.-C. S. (2020). The Fiscal State-Dependent Effects of Capital Income Tax Cuts. *IMF working paper*.

Furlanetto, F., & Seneca, M. (2009). Fiscal shocks and real rigidities. *Journal of Macroeconomics*.

Gali, J., Lopez-Saldio, D., & Valles, J. (2005). Understanding the effects of government spending on consumption. *mimeo Banco de España*.

Gali, J., Lopez-Salido, D., & Valles, J. (2004). Rule-of-Thumb Consumers And The Design Of Interest Rate Rules. *Journal of Money, Credit and Banking*, volume 36, 739-763.

Garin, J., Lester, R., & Sims, E. (2016). On the desirability of nominal GDP targeting. *Journal of economic dynamics and control*.

Hansen, N.-J., Lin, A., & Mano, R. (2020). Should Inequality Factor into Central Banks' Decisions? *IMF working papers*.

Inui, M., Sudo, N. .., & Yamada, T. (2017). Effects of monetary policy shocks on inequality in Japan. *Bank of Japan working paper*.

Jensen, H. (2002). Targeting Nominal Income Growth or Inflation? *The American Economic Review*, 92, 928-956.

Kaplan, G., Moll, B., & Violante, G. (2018). Monetary policy according to HANK. *American Economic Review*.

Kaszab, L. (2016). Rule-of-Thumb Consumers and Labor Tax Cut Policy at the Zero Lower Bound. *International Journal of Central Banking*.

Kim, J., & Henderson, D. (2005). Inflation Targeting and Nominal-Income-Growth Targeting: When and Why are They Suboptimal? *Journal of Monetary Economics,*, 52, 1463-1495.

Mankiw, G. (2000). The Savers-Spenders Theory of Fiscal Policy. *American Economic Review*.

Marto, R. (2014). Assessing the Impacts of Non-Ricardian Households in an Estimated New Keynesian DSGE Model. *Swiss journal of economics and statistics*.

Medina, J. P., & Soto, C. (2016). Commodity prices and fiscal policy in a commodity exporting economy. *Economic Modelling*.

Mitra, K. (2003). Desirability of Nominal GDP Targting under Adaptive Learning. *Journal of Money, Credit, and Banking, 35, 197-220.*

Motta, G., & Tirelli, P. (2012). Optimal Simple Monetary and Fiscal Rules under Limited Asset Market Participation. *Journal of money, credit and banking*.

Motta, G., & Tirelli, P. (2015). Money targeting, heterogeneous agents and dynamic instability. *Macroeconomic dynamics*.

Rigon, M., & Zanetti, F. (2018). Optimal Monetary Policy and Fiscal Policy Interaction in a Non-Ricardian Economy. *Interntaional journal of central banking*.

Rossi, R. (2014). Designing monetary and fiscal policy rules in a new Keynesian model with rule-of-thumb consumers. *Macroeconomic dynamics*.

Smets, F., & Wouters, R. (2007). Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. *American Economic Review*, Volume 97, No. 3, 586-606.

Straub, R., & Coenen, G. (2005). Non-Ricardian Households and Fiscal Policy in an Estimated DSGE Model of the Euro Area. *Computing in Economics and Finance 102, Society for Computational Economics*.

Sumner, S. (1995). Using Monetary Policy to Target a Nominal Wage Index. *Journal of economics and business*, 205-215.

Sumner, S. (2014). Nominal GDP Targeting: A Simple Rule to Improve Fed Performance. *Cato Journal*.

Taylor, J. (1993). Descretion versus policy rules in practice. *Carnergie-Rochester conference series on public policy*, 195-214.

Tcherneva, P. (2011). The Case for Labor Demand Targeting. *Journal of economic issues*.

Tirelli, P., & Ferrara, M. (2020). Disinflation, inequality, and welfare in a tank model. *Economic inquiry*.

Woodford, M. (2012). Methods of Policy Accommodation at the Interest-Rate Lower Bound. *Proceedings Economic Policy Symposium - Jackson Hole, Federal Reserve Bank of Kansas City*.

Appendix A: Equilibrium

1. Total Consumption

$$C_t = (1-\lambda)C_t^R + \lambda C_t^{NR} \tag{A.1}$$

2. Marginal utility of consumption

$$\Lambda_t = \frac{a_t}{C_t^R - bC_{t-1}^R} - \frac{\beta b a_{t+1}}{C_{t+1}^R - bC_t^R} \tag{A.2}$$

3. Euler equation

$$\frac{\Lambda_t}{\Lambda_{t+1}} = \frac{\beta(1+i_t)}{1+\pi_{t+1}} \tag{A.3}$$

4. Non-Ricardian consumption

$$(1+\tau_C)C_t^{NR} = (1-\tau_N)w_t L_t + Tr_t \tag{A.4}$$

5. Reset wage

$$w_t^* = \frac{\frac{\epsilon_w}{\epsilon_w - 1}\left(\frac{H_{1,t}}{H_{2,t}}\right)}{1-\tau_N} \tag{A.5}$$

6. $H_{1,t}$

$$\begin{aligned} H_{1,t} &= \psi a_t \left(\frac{w_t^\#}{w_t}\right)^{-\epsilon_w(1+\eta)} N_t^{1+\eta} \\ &\quad + \theta_w \beta \left(\frac{w_{t+1}^\#}{w_t^\#}\right)^{\epsilon_w(1+\eta)} (1+\pi_t)^{-\xi_w \epsilon_w(1+\eta)}(1+\pi_{t+1})^{\epsilon_w(1+\eta)} H_{1,t+1} \end{aligned} \tag{A.6}$$

7. $H_{2,t}$

$$H_{2,t} = \Lambda_t \left(\frac{w_t^{\#}}{w_t}\right)^{-\epsilon_w} N_t + \theta_w \beta \left(\frac{w_{t+1}^{\#}}{w_t^{\#}}\right)^{\epsilon_w} (1+\pi_t)^{\xi_w(1-\epsilon_w)} (1+\pi_{t+1})^{(\epsilon_w-1)} H_{2,t+1} \tag{A.7}$$

8. Evolution of wages

$$w_t^{1-\epsilon_w} = (1-\theta_w) w_t^{\#,(1-\epsilon_w)} + \theta_w (1+\pi_t)^{\epsilon_w-1} (1+\pi_{t-1})^{\xi_w(1-\epsilon_w)} w_{t-1}^{1-\epsilon_w} \tag{A.8}$$

9. Wage dispersion

$$v_t^w = (1-\theta_w)\left(\frac{w_t^{\#}}{w_t}\right)^{-\epsilon_w(1+\eta)} + \theta_w \left(\left(\frac{w_t}{w_{t-1}}\right)(1+\pi_t)\right)^{\epsilon_w(1+\eta)} (1+\pi_{t-1})^{-\xi_w \epsilon_w(1+\eta)} v_{t-1}^w \tag{A.9}$$

10. Reset price

$$\frac{1+\pi^{\#}}{1+\pi_t} = \frac{\epsilon_p}{\epsilon_p - 1} X_{1,t} / X_{2,t} \tag{A.10}$$

11. $X_{1,t}$

$$X_{1,t} = \Lambda_t mc_t Y_t + \theta_p \beta (1+\pi_t)^{-\xi_p \epsilon_p} (1+\pi_{t+1})^{\epsilon_p} X_{1,t+1} \tag{A.11}$$

12. $X_{2,t}$

$$X_{2,t} = \Lambda_t Y_t + \theta_p \beta (1+\pi_t)^{\xi_p(1-\epsilon_p)} (1+\pi_{t+1})^{\epsilon_p - 1} X_{2,t+1} \tag{A.12}$$

13. Evolution of prices

$$(1+\pi_t)^{1-\epsilon_p} = (1-\theta_p)(1+\pi_t^{\#})^{1-\epsilon_p} + \theta_p (1+\pi_{t-1})^{\xi_p(1-\epsilon_p)} \tag{A.13}$$

14. Price dispersion

$$v_t^p = (1+\pi_t)^{\epsilon_p}[\left(1-\theta_p\right)(1+\pi_t^{\#})^{-\epsilon_p} + \theta_p(1+\pi_{t-1})^{-\epsilon_p \xi_p} v_{t-1}^p] \tag{A.14}$$

15. Production function

$$Y_t = \frac{Z_t N_t}{v_t^P} \tag{A.15}$$

16. Goods market first order condition

$$w_t = Z_t mc_t \tag{A.16}$$

17. Total output

$$Y_t = C_t + G_t \tag{A.17}$$

18. Government spending

$$G_t = gY_t \tag{A.18}$$

19. Total revenue

$$Rev_t = \tau_C C_t + \tau_N w_t N_t \tag{A.19}$$

20. Total expenditure

$$Expd_t = G_t + Tr_t \tag{A.20}$$

21. Evolution of government debt

$$\frac{B_{g,t}}{1+i_t} = \frac{B_{g,t-1}}{(1+\pi_t)} + Rev_t - Expd_t \tag{A.21}$$

22. Fiscal deficit

$$Fd_t = Expd_t - Rev_t - \left(\frac{B_{g,t-1}}{1+\pi_t}\right)\left(1 - \frac{1}{1+i_{t-1}}\right) \tag{A.22}$$

23. Fiscal deficit rule

$$Fd_t = 0$$

Or

$$\log(\frac{\left(\frac{Fd_t}{Y_t}\right)}{\frac{Fd}{Y}}) = \rho_{FD}\log(\frac{\left(\frac{Fd_{t-1}}{Y_{t-1}}\right)}{\frac{Fd}{Y}}) \tag{A.23}$$

24. Consumption inequality index

$$h = C_t^R / C_t^{NR} \tag{A.24}$$

25. Preference shock

$$\log(a_t) = \rho_a \log(a_{t-1}) + \epsilon_{a,t} \tag{A.25}$$

26. Productivity shock

$$Log(Z_t) = Log(1+gy) + Log(Z_{t-1}) + \epsilon_{zt} \tag{A.26}$$

27. Monetary policy rule

$$\log(1+i_t) = (1-\rho_i)\log(1+i^*) + \rho_i \log(1+i_{t-1}) + \phi_\pi \log\left(\frac{1+\pi_t}{1+\pi^*}\right) + \phi_y \log\left(\frac{Y_t/Y_{t-1}}{1+gy}\right) \tag{A.27}$$

Appendix B: Stationary Equilibrium

In our model, most real variables are non-stationary due to the productivity shock (Z_t). Hence, we de-trend these variables by dividing by Z_{t-1}. The de-trended variable is denoted as $\hat{X}_t$. Furthermore, $Z_t/Z_{t-1} = z_t$.

1. Total Consumption

$$\hat{C}_t = (1-\lambda)\hat{C}_t^R + \lambda\hat{C}_t^{NR} \tag{B.1}$$

2. Marginal utility of consumption

$$\widehat{\Lambda}_t = \frac{a_t}{\hat{C}_t^R - b\hat{C}_{t-1}^R/z_{t-1}} - \frac{\beta b a_{t+1}}{\hat{C}_{t+1}^R z_t - b\hat{C}_t^R} \tag{B.2}$$

3. Euler equation

$$\frac{\widehat{\Lambda}_t}{\widehat{\Lambda}_{t+1}} = \frac{\beta(1+i_t)}{1+\pi_{t+1}} \tag{B.3}$$

4. Non-Ricardian consumption

$$(1+\tau_C)\hat{C}_t^{NR} = (1-\tau_N)\widehat{w}_t L_t + \widehat{Tr}_t \tag{B.4}$$

5. Reset wage

$$\widehat{w}_t^* = \frac{\frac{\epsilon_w}{\epsilon_w - 1}\left(\frac{H_{1,t}}{\widehat{H}_{2,t}}\right)}{1-\tau_N} \tag{B.5}$$

6. $H_{1,t}$

$$\begin{aligned} H_{1,t} = {} & \psi a_t \left(\frac{\widehat{w}_t^{\#}}{\widehat{w}_t}\right)^{-\epsilon_w(1+\eta)} N_t^{1+\eta} \\ & + \theta_w \beta \left(\frac{\widehat{w}_{t+1}^{\#}}{\widehat{w}_t^{\#}}\right)^{\epsilon_w(1+\eta)} (1+\pi_t)^{-\xi_w\epsilon_w(1+\eta)}(1+\pi_{t+1})^{\epsilon_w(1+\eta)} H_{1,t+1} \end{aligned} \tag{B.6}$$

7. $H_{2,t}$

$$\widehat{H}_{2,t} = \widehat{\Lambda}_t \left(\frac{\widehat{w}_t^{\#}}{\widehat{w}_t}\right)^{-\epsilon_w} N_t + \theta_w \beta \left(\frac{\widehat{w}_{t+1}^{\#}}{\widehat{w}_t^{\#}}\right)^{\epsilon_w} (1+\pi_t)^{\xi_w(1-\epsilon_w)}(1+\pi_{t+1})^{(\epsilon_w-1)}\widehat{H}_{2,t+1}/z_t \tag{B.7}$$

8. Evolution of wages

$$\widehat{w}_t^{1-\epsilon_w} = (1-\theta_w)\widehat{w}_t^{\#,(1-\epsilon_w)} + \theta_w(1+\pi_t)^{\epsilon_w-1}(1+\pi_{t-1})^{\xi_w(1-\epsilon_w)}\widehat{w}_{t-1}^{1-\epsilon_w} \tag{B.8}$$

9. Wage dispersion

$$v_t^w = (1-\theta_w)\left(\frac{\widehat{w}_t^{\#}}{\widehat{w}_t}\right)^{-\epsilon_w(1+\eta)} + \theta_w\left(\left(\frac{w_t}{w_{t-1}}\right)(1+\pi_t)\right)^{\epsilon_w(1+\eta)} (1+\pi_{t-1})^{-\xi_w\epsilon_w(1+\eta)}v_{t-1}^w \tag{B.9}$$

10. Reset price

$$\frac{1+\pi^{\#}}{1+\pi_t} = \frac{\epsilon_p}{\epsilon_p - 1} X_{1,t}/X_{2,t} \tag{B.10}$$

11. $X_{1,t}$

$$X_{1,t} = \widehat{\Lambda}_t mc_t \widehat{Y}_t + \theta_p \beta (1+\pi_t)^{-\xi_p\epsilon_p}(1+\pi_{t+1})^{\epsilon_p}X_{1,t+1} \tag{B.11}$$

12. $X_{2,t}$

$$X_{2,t} = \widehat{\Lambda}_t \widehat{Y}_t + \theta_p \beta (1+\pi_t)^{\xi_p(1-\epsilon_p)}(1+\pi_{t+1})^{\epsilon_p-1}X_{2,t+1} \tag{B.12}$$

13. Evolution of prices

$$(1+\pi_t)^{1-\epsilon_p} = (1-\theta_p)(1+\pi_t^{\#})^{1-\epsilon_p} + \theta_p(1+\pi_{t-1})^{\xi_p(1-\epsilon_p)} \tag{B.13}$$

14. Price dispersion

$$v_t^p = (1+\pi_t)^{\epsilon_p}[\left(1-\theta_p\right)(1+\pi_t^{\#})^{-\epsilon_p} + \theta_p(1+\pi_{t-1})^{-\epsilon_p\xi_p}v_{t-1}^p] \tag{B.14}$$

15. Production function

$$\hat{Y}_t = \frac{z_t N_t}{v_t^P} \tag{B.15}$$

16. Goods market first order condition

$$\widehat{w}_t = z_t mc_t \tag{B.16}$$

17. Total output

$$\hat{Y}_t = \hat{C}_t + \hat{G}_t \tag{B.17}$$

18. Government spending

$$\hat{G}_t = g\hat{Y}_t \tag{B.18}$$

19. Total revenue

$$\widehat{Rev_t} = \tau_C\hat{C}_t + \tau_N\widehat{w}_t N_t \tag{B.19}$$

20. Total expenditure

$$\widehat{Expd}_t = \hat{G}_t + \widehat{Tr}_t \tag{B.20}$$

21. Evolution of government debt

$$\frac{\hat{B}_{g,t}}{1+i_t} = \frac{\hat{B}_{g,t-1}}{(1+\pi_t)z_{t-1}} + \widehat{Rev_t} - \widehat{Expd}_t \tag{B.21}$$

22. Fiscal deficit

$$\widehat{Fd}_t = \widehat{Expd}_t - \widehat{Rev_t} - \left(\frac{\hat{B}_{g,t-1}}{(1+\pi_t)z_{t-1}}\right)\left(1 - \frac{1}{1+i_{t-1}}\right) \tag{B.22}$$

23. Fiscal deficit rule

$$\widehat{Fd}_t = 0$$

Or

$$\log\left(\frac{\left(\frac{\widehat{Fd_t}}{\hat{Y}_t}\right)}{\frac{Fd}{Y}}\right) = \rho_{FD}\log\left(\frac{\left(\frac{\widehat{Fd_{t-1}}}{\hat{Y}_{t-1}}\right)}{\frac{Fd}{Y}}\right) \tag{B.23}$$

24. Consumption inequality index

$$h = \frac{\hat{C}_t^R}{\hat{C}_t^{NR}} \tag{B.24}$$

25. Preference shock

$$\log(a_t) = \rho_a \log(a_{t-1}) + \epsilon_{a,t} \tag{B.25}$$

26. Productivity shock

$$\log(z_t) = \log(1+gy) + \epsilon_{z,t} \tag{B.26}$$

27. Monetary policy rule

$$\begin{aligned}\log(1+i_t) = (1-\rho_i)\log(1+i^*) + \rho_i \log(1+i_{t-1}) + \phi_\pi \log\left(\frac{1+\pi_t}{1+\pi^*}\right) \\ + \phi_y \log\left(\frac{\hat{Y}_t z_t/\hat{Y}_{t-1}}{1+gy}\right)\end{aligned} \tag{B.27}$$