Goethe University Frankfurt

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Master Thesis

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Taking Inequality into Account: A DSGE analysis of Monetary Policy

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Master Money and Finance (MMF)

May 3, 2023

Contents

1 Introduction

In response to the Covid-19 crisis and a decade-long period of low inflation, central banks around the world have implemented numerous unprecedented monetary policy measures, including large scale asset purchase programs and near-zero interest rates for almost a decade. These actions came at a time, when we also observe record high levels of economic inequality[1] and questions about the causes and consequences of this inequality become more and more pressing. This led to a growing body of literature, targeting the distributional implications of monetary policy, as well as raising the question whether monetary policy could and should assist policymakers in dealing with economic inequality.

In this thesis, I aim to further explore the impact of monetary policy on economic inequality, thereby contributing to the expanding body of research on its distributional consequences. To achieve this, I will discuss a Dynamic Stochastic General Equilibrium model (DSGE) that features inequality in the form of a rich and a poor agent, where the latter's consumption can be described as hand-to-mouth. The model incorporates both cyclical and steady state inequality. On this basis, I will analyse the impact of inequality under different policy regimes. More specifically, I will try to answer the following questions, both under Ramsey optimal policy, and under augmented Taylor rules:

- What are the macroeconomic impacts of disproportionate central bank objectives, in the presence of economic inequality?
- What are the types of central bank objectives that incorporate economic inequality, and how well do they fare?
- On what specific objectives does a central bank need to focus in order to reduce inequality?

To address these questions, I will begin by introducing the model from Hansen et al. (2020). In doing so, I will provide an in-depth analysis of the model, outlining the origins of each component. Following that, I will delve into the model's steady state, providing a detailed derivation and conducting log-linearizations. Furthermore, I will examine the model under Ramsey optimal policy, discussing both the welfare objective in quadratic gaps and the response to TFP shocks. Subsequently, I will assess the economy's performance under augmented Taylor rules, following optimal simple rules. Finally, I will summarize the findings, explore practical applications, address limitations, and conduct robustness checks.

[1]See Atkinson et al. (2011) or Piketty (2017).

1.1 Related Literature

The main model presented in this paper is borrowed from Hansen et al. (2020) and employs a Two-Agent New Keynesian (TANK) framework, in order to study inequality. This might surprise at first glance, since usually Heterogeneous Agent (HANK) models, as in Kaplan et al. (2018), are the benchmark for studying inequality. These models are undoubtedly useful, as they deliver much more realistic wealth distributions than their TANK counterparts. However, Debortoli and Galí (2017) showed that TANK models provide a good approximation to their HANK counterparts, when only aggregate shocks, like technology or monetary policy shocks, are studied. At the same time, they are more comprehensible and much easier to handle. The model in Debortoli and Galí (2017) was also used as the basis for the economy discussed here.

Regarding the analysis of different policy regimes, the analysis here is based on Ramsey optimal policy, lending its name from the author of Ramsey (1927), an early work on taxation policy, where welfare was analyzed under quadratic utility functions. This analysis of optimal policy was then brought into the context of DSGE models by Lucas Jr and Stokey (1983). The special application in this model, where welfare in quadratic gaps needs to be derived under a distorted steady state, follows Benigno and Woodford (2005). The study of augmented simple rules is based on the famous Taylor rule from Taylor (1993), where Taylor proposes a simple and straightforward rule for setting the nominal interest rate.

This thesis fits with a large number of studies on the impact of monetary policy on inequality. Other works relating to the same questions are for example Coibion et al. (2017), where the authors find that contractionary monetary policy increases both income and consumption inequality, with the primary channel being the response of labor earnings to monetary shocks. Also closely related is Colciago et al. (2019), where the researchers find, that contractionary monetary policy leads overall to an increase in consumption heterogeneity. I conclude this non-exhaustive list with the already mentioned paper from Kaplan et al. (2018), where the authors show that the presence of household heterogeneity and nominal rigidities can significantly alter the transmission of monetary policy and its impact on inequality.

For all simulations done in this thesis, I utilized the Dynare software package (v5.3) by Adjemian et al. (2022).

2 The model

In this section, I present a detailed description of the model in Hansen et al. (2020), which is based on Debortoli and Galí (2017). The goal of the model is to create an economy with inequality and no idiosyncratic shocks. This is achieved by utilizing the Two-Agent New Keynesian (TANK) framework, where one agent, here a Ricardian agent, has full access to the capital market and holds all equity in the economy, while the other agent, here a Keynesian agent, has no access to the capital market and holds no equity. The Keynesian agent's consumption is therefore not determined by an Euler equation and is instead fully determined by their income equation. This also leads to a zero net supply of bonds. Inequality is achieved in the form of an income inequality, due to the Ricardians receiving dividends on their equity. Since the focus of the model is the demand side, the supply side is kept as simple as possible, with a single final good producer combining all intermediate goods to a final consumption good and acting under perfect competition. There exists, however, monopolistic competition between the intermediate firms, so that the firms earn profits to distribute to Ricardian households. Fiscal Policy exists in the model, first in the form of a perfect lump-sum tax to finance subsidies, in order to get rid of all monopolistic distortions, and second in the form of redistribution taxes and transfers. All households supply labour to the firms in exchange for wages and to study the model's shock behaviour, a productivity shock is used. This shock is biased towards the wages of Ricardian households, in order to introduce transitional inequality in response to a shock, in addition to the already existing steady state inequality.

2.1 The Ricardian Agent

The Ricardian agents' maximization problem is defined as:

$$\begin{aligned} &max\ E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln C_{rt} - \chi \frac{N_t^{1+\phi}}{1+\phi} \right] \\ &s.t.\ C_{rt} + b_{rt} = b_{rt-1} \frac{R_{t-1}}{\Pi_t} + Y_{rt} \end{aligned} \tag{1}$$

, where the household obtains utility from consumption C_{rt} and receives disutility from labour N_t. Bond holdings are presented in real terms b_{rt}[2], β is the consumption discount factor, R_t the gross nominal interest rate and Π_t the gross inflation rate. Solving the

[2]Where $b_{rt} = \frac{B_{rt}}{P_t}$.

maximization problem, I obtain the following first order conditions:

$$E_t \frac{1}{C_{rt}} - \lambda_t \stackrel{!}{=} 0 \tag{2}$$

$$E_{t+1} \frac{1}{C_{rt+1}} - \lambda_{t+1} \stackrel{!}{=} 0 \tag{3}$$

$$-\lambda_t \beta^t + \lambda_{t+1} \beta^{t+1} E_{t+1} \frac{R_t}{\Pi_{t+1}} \stackrel{!}{=} 0 \tag{4}$$

which lead to the following Consumption Euler equation at time t for Ricardian households:

$$C_{rt}^{-1} = \beta R_t E_t \left\{ C_{rt+1}^{-1} \frac{1}{\Pi_{t+1}} \right\} \tag{5}$$

The Ricardian agents' income is composed as follows:

$$Y_{rt} = \frac{1 - \lambda \left(\frac{A_t}{\bar{A}} \right)^{-\gamma}}{1 - \lambda} w_t N_t + \frac{1 - \delta}{1 - \lambda} d_t + t_{rt} - T_p Y_t \tag{6}$$

, where λ represents the fraction of Keynesian Households in the economy, w_t the real wage, d_t the dividends, which are distributed equally among Ricardians and are taxed at a rate δ, t_{rt} are transfers, and $T_p Y_t$ represents the lump sum tax, that is used to undo monopolistic distortions. The first term represents the part of wages that is received by Ricardian households; it is written as the remainder of what is left after distributing the wage income to Keynesian households, divided among Ricardians.[3] The second term consists of dividend payments to Ricardian households, distributed among Ricardians and taxed at a rate δ. The other two terms come from fiscal policy, where t_{rt} are transfers for redistribution purposes and $T_P Y_t$ are the previously mentioned lump-sum taxes, used to offset monopolistic distortions.

2.2 The Keynesian Agent

The Keynesian Agent faces a similar maximization problem to the Ricardian Agent, the only difference being, that the Keynesian agent additionally faces a binding borrowing constraint:

$$\begin{aligned} &max \;\; E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln C_{kt} - \chi \frac{N_t^{1+\phi}}{1+\phi} \right] \\ &s.t. \;\; C_{kt} + b_{kt} = b_{kt-1} \frac{R_{t-1}}{\Pi_t} + Y_{kt} \\ &b_{kt} = 0 \end{aligned} \tag{7}$$

[3]The γ parameter allows for a productivity shock to impact the wages of both types of households differently and is further discussed when the Keynesian households are introduced in section 2.2.

The borrowing constraint $b_{kt} = 0$, prevents the agent from utilizing bonds in the economy, and as a result, the agent is not described with a consumption Euler equation. The relevant condition for determining consumption is the Budget Constraint, which boils down to $C_{kt} = Y_{kt}$. The Keynesian agents' income is similarly defined as the Ricardians', except there is no dividend income, since the Ricardian households hold all equity:

$$Y_{kt} = \left(\frac{A_t}{\bar{A}}\right)^{-\gamma} w_t N_t - T_p Y_t + t_{kt} \tag{8}$$

The term $\left(\frac{A_t}{\bar{A}}\right)^{-\gamma}$ defines the share of labour income, the Keynesian Agent receives. It is chosen in a way that allows the agents' income to be sensitive to productivity shocks. The term creates an effect when productivity A_t deviates from its steady state value. This means, as long as $\gamma > 0$, the Keynesian agents will experience a reduction in labour share following a positive technology shock, and it leads to a form of skill-biased wages that assumes Ricardian households provide higher-skilled labour and therefore will receive a larger share of the labour income following a positive technology shock.[4]

2.3 Labour Supply

Labour Supply is kept as simple as possible in the model. It is assumed that all types of agents supply the same amount of labour. Hansen et al. (2020) used this simplification to stop labour market distortions from indirectly influencing the income inequality. If labour supply would be type-dependent, the different amounts of labour supply would itself be a source of inequality. The Ricardian agent would supply less labour due to higher consumption levels, which would indirectly influence the inequality in the model again. With the assumption of type-independent labour supply, the aggregate rule can be derived by looking at the maximization in equation 1 again and assuming a type-independent agent of the form:

$$\begin{gathered} max \;\; E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln C_t - \chi \frac{N_t^{1+\phi}}{1+\phi} \right] \\ s.t. \;\; C_t + b_t = b_{t-1} \frac{R_{t-1}}{\Pi_t} + w_t N_t + ... \end{gathered} \tag{9}$$

The maximization leads to the following FOCs at time t:

$$\frac{1}{C_t} - \lambda_t \stackrel{!}{=} 0 \tag{10}$$

$$\chi N_t^{\phi} - \lambda_t w_t \stackrel{!}{=} 0 \tag{11}$$

[4]The share of labour income in the Ricardian income equation is defined as the residual of the share distributed to Keynesians, which is distributed equally among Ricardians.

Together with $C_t = Y_t$, because consumption can't be saved in this economy, this leads to the equation for aggregate Labour Supply:

$$w_t = \chi N_t^{\phi} Y_t \tag{12}$$

2.4 Production

Final Goods Producer

The final goods producer combines all outputs of intermediate production into one final good. A standard CES production function is assumed:

$$Y_t = \left[\int_0^1 y_{jt}^{\frac{\theta_p - 1}{\theta_p}} \, dj \right]^{\frac{\theta_p}{\theta_p - 1}} \tag{13}$$

, where θ_p is the elasticity of substitution between the intermediate goods y_{jt}. Since $1 < \theta_p < \infty$, the intermediate goods are imperfect substitutes and the intermediate firms have market power. He maximizes profits each period with:

$$\max_{y_{jt}} \; P_t Y_t - \int_0^1 p_{jt} y_{jt} \, dj \tag{14}$$

Taking the derivative with respect to y_{jt}, leads to the aggregate demand for intermediate goods. Substituting this result into equation 14, together with the assumption of zero profits, then leads to the aggregate price index[5]:

$$y_{jt} = \left(\frac{p_{jt}}{P_t} \right)^{-\theta_p} Y_t \qquad\qquad P_t = \left[\int_0^1 p_{jt}^{1-\theta_p} dj \right]^{\frac{1}{1-\theta_p}} \tag{15}$$

Intermediate Goods Producers

The intermediate goods producers, take as given the final goods producer's demand function, the production function $y_{jt} = A_t L_{jt}^{1-\alpha}$, and the nominal wage W_t set by the supply of labour. Each producer maximizes profits for two periods and faces the following optimization problem:

$$\begin{aligned} \max_{p_{jt}} \, (1+T_p) \frac{p_{jt}^{1-\theta_p}}{P_t^{1-\theta_p}} Y_t - \frac{w_t}{A_t^{\frac{1}{1-\alpha}}} \left(\frac{p_{jt}}{P_t} \right)^{\frac{-\theta_p}{1-\alpha}} Y_t^{\frac{1}{1-\alpha}} - \frac{\psi_p}{2} Y_t \left[\frac{p_{jt}}{p_{jt-1}} - 1 \right]^2 + \beta \left(\frac{C_{rt+1}}{C_{rt}} \right)^{-1} \\ * \left\{ (1+T_p) \frac{p_{jt+1}^{1-\theta_p}}{P_{t+1}^{1-\theta_p}} Y_{t+1} - \frac{w_{t+1}}{A_{t+1}^{\frac{1}{1-\alpha}}} \left(\frac{p_{jt+1}}{P_{t+1}} \right)^{\frac{-\theta_p}{1-\alpha}} Y_{t+1}^{\frac{1}{1-\alpha}} - \frac{\psi_p}{2} Y_{t+1} \left[\frac{p_{jt+1}}{p_{jt}} - 1 \right]^2 \right\} \end{aligned} \tag{16}$$

[5] Detailed derivations can be found in Appendix A.1.

We can dissect the optimization problem as follows[6]:

$(1+T_p)\frac{p_{jt}^{1-\theta_p}}{P_t^{1-\theta_p}}Y_t$: This term comes from the firm's turnover $y_{jt} * p_{jt}$, where the demand function is substituted, and multiplied with the sales subsidies $(1+Tp)$.

$\frac{w_t}{A_t^{\frac{1}{1-\alpha}}}\left(\frac{p_{jt}}{P_t}\right)^{\frac{-\theta_p}{1-\alpha}}Y_t^{\frac{1}{1-\alpha}}$: This term comes from the firm's wage cost, where the real wage w_t is multiplied with the firm's labour demand, derived from the production function, and substituted with the demand function.

$\frac{\psi_p}{2}Y_t\left[\frac{p_{jt}}{p_{jt-1}}-1\right]^2$: This term represents the quadratic price adjustment cost, which leads to sticky prices in the economy. The term becomes greater than zero, for $p_{jt} \neq p_{jt-1}$. ψ_p is a positive parameter for varying the price adjustment cost.

$\beta\left(\frac{C_{rt+1}}{C_{rt}}\right)^{-1}$: This term is known in the literature as the stochastic household discount factor. The firm uses this discount factor to discount between today and future payoffs. Since the firms are owned by the Ricardian households, it can be derived by solving equation 5 for the real rate.

$\left\{...\right\}$: This term is discounted by the stochastic discount factor and contains the firm's payoffs in period $t+1$.

The quadratic price adjustment cost is a common way to introduce price rigidities in DSGE models and follows Rotemberg (1982). Price rigidities are necessary for monetary policy to have an effect since without it, prices would be completely flexible and automatically adjust to any changes in interest rates, keeping the real rate constant. Finally, solving the intermediate goods producers maximization problem with respect to p_{jt}, and assuming symmetry across all firms, so that $\int_0^1 p_{jt} = P_t$, leads to the New-Keynesian Phillips Curve[7]:

$$\begin{aligned}\Pi_t\left[\Pi_t-1\right] =&\beta\left(\frac{C_{rt+1}}{C_{rt}}\right)^{-1}\frac{Y_{t+1}}{Y_t}\Pi_{t+1}\left[\Pi_{t+1}-1\right] \\ &+\frac{\theta_p}{\psi_p}\left[\frac{1}{1-\alpha}\frac{w_t}{A_t^{\frac{1}{1-\alpha}}}Y_t^{\frac{\alpha}{1-\alpha}}-(1+T_p)\frac{\theta_p-1}{\theta_p}\right]\end{aligned} \tag{17}$$

2.5 Market Clearing

There exist three markets, that need to clear. The bond market simply clears to zero, since the Keynesian agents have no access to the bond market and the Ricardians are all

[6]Further derivations in Appendix A.2.

[7]The detailed derivation can be found in Appendix A.3.

the same, leading to no trade possibilities:

$$\int b_{it} di = 0 \tag{18}$$

The labour market clears, when the aggregate labour supply equals the need for labour for each intermediate goods producer and all intermediate goods producers are the same:

$$N_t = \int_0^1 L_{jt} dj = L_t \tag{19}$$

The goods market clears, when the total output in the economy equals the total consumption of both types of agents, in addition to the loss endured by the price adjustment cost, that was described in section 2.4:

$$Y_t = \lambda C_{kt} + (1-\lambda) C_{rt} + \frac{\psi_p}{2}(\Pi_t - 1)^2 \tag{20}$$

2.6 Aggregate Production equations

Using the symmetry of all intermediate goods producers and equation 19, the aggregate production function can be derived:

$$Y_t = A_t N_t^{1-\alpha} \tag{21}$$

Using the symmetry again, so that $\int_0^1 p_{jt} = P_t$, as well as equation 19, the aggregate profits of firms, which equal the aggregate dividends paid out to Ricardians, can be derived[8]:

$$d_t = (1 + Tp) Y_t - w_t N_t - \frac{\psi_p}{2}(\Pi_t - 1)^2 \tag{22}$$

2.7 Fiscal Policy

The first part of fiscal policy already entered the equations in the sections 2.1, 2.2 and 2.4. The lump-sum tax T_p is subtracted from the income of both types of agents and is added as a sales subside to the profits of intermediate firms. This is done to eliminate monopolistic distortions that would otherwise be caused by the intermediate firms having market power. The second part of fiscal policy concerns the redistribution policies. Profits are taxed at a rate δ and τ governs the share of taxed profits, that is given out to Keynesian agents, leading to the following redistribution rule:

$$t_{kt} = (1-\tau)\delta d_t \tag{23}$$

[8] The second term in the firms' profits is derived using the aggregate production function, so that: $N_t = \frac{1}{A_t^{\frac{1}{1-\alpha}}} Y_t^{\frac{1}{1-\alpha}}$ and substituting it in the firms' payoff from section 2.4

According to this rule, a higher value of τ leads to higher inequality in the model, since fewer profits are redistributed and vice versa. The rest of the taxed profits is returned and equally divided among Ricardian Agents:

$$t_{rt} = \frac{\delta d_t - \lambda t_{kt}}{1-\lambda} \tag{24}$$

2.8 Monetary Policy

Monetary Policy will differ, depending on the current analysis. For completion, a standard Taylor rule, of the type originally proposed by Taylor (1993), is reported:

$$\frac{R_t}{\bar{R}} = \left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\phi_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_y} \tag{25}$$

, where ϕ_π and ϕ_y are parameters governing how strongly the central bank reacts to gaps and $\bar{\Pi}$, $\bar{Y}$ are steady state values. This type of Taylor rule is the nonlinear counterpart to a standard rule, where the central bank reacts to inflation and output gaps.[9] The derivation will become clear in section 3.2.

2.9 Natural Output

Natural output is defined as output that could be obtained if prices were flexible. It can be derived by looking at the economy without the price adjustment cost or with zero net-inflation ($\Pi = 1$). Without the price adjustment and using symmetry, the FOC of the intermediate goods producers maximization problem from equation 16, simplifies to:[10]

$$(1+T_p)(\theta_p - 1) = \frac{\theta_p}{1-\alpha} \frac{w_t}{A_t^{\frac{1}{1-\alpha}}} Y_t^{n\,\frac{\alpha}{1-\alpha}}$$

Substituting equation 12 and 21, this leads to the equation for natural output:[11]

$$Y_t^n = A_t \left[(1+T_p)(1-\alpha)\frac{\theta_P - 1}{\theta_P}\frac{1}{\chi}\right]^{\frac{1-\alpha}{1+\phi}} \tag{26}$$

2.10 Exogenous Process

In order to introduce technology shocks into the model, an exogenous process for technology is assumed and the equation for technology takes the form:

$$A_t = \bar{A}e^{\epsilon_t} \tag{27}$$

[9]When inflation or output deviate from the economies long-run equilibrium (or steady state).
[10]Compare Appendix A.3.
[11]Detailed derivation in Appendix A.4.

, where ϵ_t is an exogenous variable. The shock is deterministic and persistent, depending on the parameter ρ, with $\epsilon_t = \rho\epsilon_{t-1}$. For all shocks studied here $\epsilon_0 = 0.01$ is assumed. The value $\bar{A}$ represents the steady state of the technology level in this economy and enters the model as a parameter, characterizing the production function.

2.11 The nonlinear model

Due to the constant bond positions, $b_{rt} = b_{kt} = 0$, the Budget constraints boil down to $Y_{rt} = C_{rt}$ and $Y_{kt} = C_{kt}$. Utilizing Walras Law, the budget constraint of Ricardian households can be disregarded and the entire economy from Hansen et al. (2020), can be expressed with the Ricardians consumption Euler equation (5); the Keynesian budget constraint, simplified to the income equation (8); the equation for aggregate labour supply (12); the aggregate production function (21); the equation for aggregate profits or dividends (22); the Phillips Curve (17); both fiscal policy rules for redistribution (23 and 24); the market clearing condition for goods (20); the equation for natural output (26); the exogenous process defining technology in the economy (27); and for now the model is closed with the simple Taylor rule (25). For convenience, I will summarize the model here:

$$C_{rt}^{-1} = \beta R_t E_t \left\{ C_{rt+1}^{-1} \frac{1}{\Pi_{t+1}} \right\} \tag{28}$$

$$C_{kt} = \left(\frac{A_t}{\bar{A}} \right)^{-\gamma} w_t N_t - T_p Y_t + t_{kt} \tag{29}$$

$$w_t = \chi N_t^{\phi} Y_t \tag{30}$$

$$Y_t = A_t N_t^{1-\alpha} \tag{31}$$

$$d_t = (1 + Tp) Y_t - w_t N_t - \frac{\psi_p}{2} (\Pi_t - 1)^2 \tag{32}$$

$$\begin{aligned} \Pi_t \left[\Pi_t - 1 \right] =& \beta \left(\frac{C_{rt+1}}{C_{rt}} \right)^{-1} \frac{Y_{t+1}}{Y_t} \Pi_{t+1} \left[\Pi_{t+1} - 1 \right] \\ &+ \frac{\theta_p}{\psi_p} \left[\frac{1}{1-\alpha} \frac{w_t}{A_t^{\frac{1}{1-\alpha}}} Y_t^{\frac{\alpha}{1-\alpha}} - (1 + T_p) \frac{\theta_p - 1}{\theta_p} \right] \end{aligned} \tag{33}$$

$$t_{rt} = \frac{\delta d_t - \lambda t_{kt}}{1 - \lambda} \tag{34}$$

$$t_{kt} = (1 - \tau) \delta d_t \tag{35}$$

$$Y_t = \lambda C_{kt} + (1 - \lambda) C_{rt} + \frac{\psi_p}{2} (\Pi_t - 1)^2 \tag{36}$$

$$Y_t^n = A_t \left[(1 + T_p)(1 - \alpha) \frac{\theta_P - 1}{\theta_P} \frac{1}{\chi} \right]^{\frac{1-\alpha}{1+\phi}} \tag{37}$$

$$A_t = \bar{A} e^{\epsilon_t} \tag{38}$$

$$\frac{R_t}{\bar{R}} = \left(\frac{\Pi_t}{\bar{\Pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{\bar{Y}} \right)^{\phi_y} \tag{39}$$

Henceforth, I will refer to this model as the nonlinear model.

2.12 Calibration

For the calibration, Hansen et al. (2020) mostly use standard values from the literature. For setting the more novel parameters λ, τ and γ, they referred to more specific literature. $\lambda = 0.4$ was set according to Coenen et al. (2012), where 7 different structural policy models of 6 different institutions and 2 models from the academic literature were compared. 0.4 is the share of hand-to-mouth and liquidity constraint households, that was used in an older structural model, contributed by the Board of Governors of the Federal Reserve system. It lies in the middle of the range of parameter values compared in the study. $\tau = 0.93$ matches the ratio of non-labour income of the top 60 percent of households to the bottom 40 percent. This ratio, as reported in Board of Governors of the Federal Reserve System (2016), is 24.5 and so τ was chosen, so that $\frac{\bar{\tau_r}}{\bar{\tau_k}} = 24.5$.[12] $\gamma = 1.67$ is calibrated, so that the effects of a productivity shock on consumption across the income distribution is matched. This effect was estimated by De Giorgi and Gambetti (2017), who studied the responses of the consumption distribution to TFP shocks and discovered, that the right tail of the consumption distribution, consisting mostly of higher educated individuals, has a larger response to shocks, when compared to the rest of the distribution. The entire calibration is reported in Table 1.

Parameter	Value	Note
λ	0.4	Share of Keynesian agents
τ	0.93	Redistribution of Profits
δ	1	Redistribution of Profits
γ	1.67	Degree of Skill Bias
α	0.25	Profits Share
β	0.9925	Discount Factor
χ	1	Labor Disutility
ϕ	1	Inverse Frisch Elasticity
θ_p	9	CES Elasticity
ψ_p	372.8	Price Adjustment
ϕ_π	1.5	Weight on inflation gap
ϕ_y	0.125	Weight on output gap
ρ	0.9	Persistence of Shock
$\bar{A}$	1	Steady state technology level

Table 1: Calibration

It should be noted, that the value of $\bar{A}$ was not originally reported in Hansen et al. (2020), but the results suggest, that it is normalized to the standard value of 1.

[12]Note that $\frac{\bar{\tau_r}}{\bar{\tau_k}}$ is the ratio for the total non-labour income in the model. Since $\delta = 1$, all dividends are taxed and the redistribution variables represent the entire non-labour income in the model.

3 The steady state and log-linearizations

In this section, I will motivate and calculate the steady state of the economy, as well as conducting a log-linearization of the model, which is commonly used in the New-Keynesian literature to achieve an approximate linearized version of the nonlinear model.

3.1 The steady state

The steady state of an economy refers to a long-run equilibrium where all variables are constant over time. This means that under the steady state, the economy has fully adjusted to any shocks or changes in policy, and all variables have reached their long-run equilibrium values. In the following analysis, the steady state provides the benchmark for analysing the effects of different shocks and policy changes.[13] The economy's steady state can be calculated by considering the nonlinear model from section 2.11 and replacing all endogenous variables with their static versions. The steady state value of a variable x_t is denoted by $\bar{x}$. First, it can easily be seen that the nonlinear Taylor rule (39) becomes non-binding in the steady state, making the nominal interest rate only dependent on the Ricardian Euler equation (28). This allows to freely choose a combination of inflation rate and nominal interest rate consistent with the model's real rate, which is only determined by preference. This is a common attribute of almost all DSGE models, and usually, a steady state inflation[14] of zero is assumed for convenience.[15] Even though the zero inflation steady state is not specifically mentioned in Hansen et al. (2020), the results suggest that they stayed true to this convention. Using equation 28, the steady state real rate therefore comes down to:

$$\bar{R} = \frac{1}{\beta} \qquad\qquad \bar{\Pi} = 1 \tag{40}$$

In order to calculate the steady state output, the static equations of the production function (31) and labour supply (30) can be used to derive the steady state values of labour $\bar{N}$ and real wage $\bar{w}$, only dependent on steady state output and model parameters. Substituting these into the Phillips-Curve (33) allows deriving the steady state of output

[13] For further reading about the importance of the steady state for cyclical models, see, for example, section 4 in Kydland and Prescott (1982).

[14] Since Π_t represents the gross inflation rate in this model, a zero inflation steady state means $\bar{\Pi} = 1$.

[15] In this model, this is a necessity, since for a different steady state inflation, the Blanchard-Khan conditions are not satisfied for a large number of parametrizations, including the calibration in section 2.12.

under $\bar{\Pi} = 1$ as follows:

$$
\begin{aligned}
0 &= \frac{\theta_p}{\psi_p}\left[\frac{1}{1-\alpha}\frac{\bar{w}}{\bar{A}^{\frac{1}{1-\alpha}}}\bar{Y}^{\frac{\alpha}{1-\alpha}} - (1+T_p)\frac{\theta_p - 1}{\theta_p}\right] \\
\iff (1+T_p)\frac{\theta_p - 1}{\theta_p} &= \frac{1}{1-\alpha}\frac{\chi\bar{Y}^{\frac{\phi}{1-\alpha}}\bar{A}^{-\frac{\phi}{1-\alpha}}\bar{Y}}{\bar{A}^{\frac{1}{1-\alpha}}}\bar{Y}^{\frac{\alpha}{1-\alpha}} \\
\iff \bar{Y} &= \bar{A}\left[(1-\alpha)(1-T_p)\frac{\theta_p - 1}{\theta_p}\frac{1}{\chi}\right]^{\frac{1-\alpha}{1+\phi}} \qquad (41)
\end{aligned}
$$

Note that, as discussed in section 2.10, $\bar{A}$ enters the model as a parameter. Given this steady state of output $\bar{Y}$ and utilizing $\bar{\Pi} = 1$, the rest of the static model can then be derived relatively easily. Using the static versions of the rest of the nonlinear model equations, displayed in section 2.11, all other steady state values can easily be solved in this order:

$$\bar{N} = \left(\frac{\bar{Y}}{\bar{A}}\right)^{\frac{\phi}{1-\alpha}} \qquad (42)$$

$$\bar{w} = \chi\bar{N}^{\phi}\bar{Y} \qquad (43)$$

$$\bar{d} = (1+T_p)\bar{Y} - \bar{w}\bar{N} \qquad (44)$$

$$\bar{t}_k = (1-\tau)\delta\bar{d} \qquad (45)$$

$$\bar{t}_r = \frac{\delta\bar{d} - \lambda\bar{t}_k}{1-\lambda} \qquad (46)$$

$$\bar{C}_k = \bar{w}\bar{N} - T_p\bar{Y} + \bar{t}_k \qquad (47)$$

$$\bar{C}_r = \frac{\bar{Y} - \lambda\bar{C}_k}{1-\lambda} \qquad (48)$$

At this point, it should be noted that the steady state is dependent on the parameter τ. The model features an inefficient steady state with regard to welfare, as dividends are distributed unequally for $\tau \neq 0$.

3.2 Log-linearizations

Log-linearizations have a tradition in the New Keynesian literature, as they allow us to approximate complex nonlinear models with linear functions. These approximations work well, as long as the analysed deviations remain close to the steady state. The chosen reference point for the linearization is usually the economy's steady state. The process of log-linearizing around the steady state, simplifies the model and helps to reveal important economic relationships that might not be immediately apparent in the nonlinear model. In order to write down the log-linearized model, the steady state deviation of a variable

x_t is defined as $\hat{x}_t = \ln x_t - \ln \bar{x}$. The log-linearization of the Phillips Curve, as done in Hansen et al. (2020), appears to entail a small mistake. I will therefore show the correct derivation in more detail here. The results for the other log-linearizations are correct, and I show the exact derivations in Appendix B. Using the most common approach of log-linearization, which is further described in Zietz (2006), the derivation of the approximate linear Phillips-Curve follows:

$$
\begin{aligned}
\Pi_t\left[\Pi_t-1\right] =&\beta\left(\frac{C_{rt+1}}{C_{rt}}\right)^{-1}\frac{Y_{t+1}}{Y_t}\Pi_{t+1}\left[\Pi_{t+1}-1\right]\\
&+\frac{\theta_p}{\psi_p}\left[\frac{1}{1-\alpha}\frac{w_t}{A_t^{\frac{1}{1-\alpha}}}Y_t^{\frac{\alpha}{1-\alpha}}-(1+T_p)\frac{\theta_p-1}{\theta_p}\right]\\
\Longleftrightarrow \bar{\Pi}e^{\hat{\Pi}_t}(\bar{\Pi}e^{\hat{\Pi}_t}-1) =&\beta\frac{e^{-\hat{C}_{rt+1}}e^{\hat{Y}_{t+1}}}{e^{-\hat{C}_{rt}}e^{\hat{Y}_t}}\bar{\Pi}e^{\hat{\Pi}_{t+1}}(\bar{\Pi}e^{\hat{\Pi}_{t+1}}-1)\\
&+\frac{\theta_p}{\psi_p}\left[\frac{1}{1-\alpha}\bar{w}\bar{A}^{-\frac{1}{1-\alpha}}\bar{Y}^{\frac{\alpha}{1-\alpha}}e^{\hat{w}_t}e^{-\frac{1}{1-\alpha}\hat{A}_t}e^{\frac{\alpha}{1-\alpha}\hat{Y}_t}-(1+T_p)\frac{\theta_p-1}{\theta_p}\right]\\
\Longleftrightarrow \bar{\Pi}^2e^{2\hat{\Pi}_t}-\bar{\Pi}e^{\hat{\Pi}_t} =&\beta\bar{\Pi}^2e^{\hat{Y}_{t+1}-\hat{Y}_t-\hat{C}_{rt+1}+\hat{C}_{rt}+2\hat{\Pi}_{t+1}}\\
&-\beta\bar{\Pi}e^{\hat{Y}_{t+1}-\hat{Y}_t-\hat{C}_{rt+1}+\hat{C}_{rt}+\hat{\Pi}_{t+1}}\\
&+\frac{\theta_p}{\psi_p}\left[\frac{1}{1-\alpha}\bar{w}\bar{A}^{-\frac{1}{1-\alpha}}\bar{Y}^{\frac{\alpha}{1-\alpha}}e^{\hat{w}_t-\frac{1}{1-\alpha}\hat{A}_t\frac{\alpha}{1-\alpha}\hat{Y}_t}-(1+T_p)\frac{\theta_p-1}{\theta_p}\right]\\
\overset{Taylor}{\Longleftrightarrow} \bar{\Pi}^2(1+2\hat{\Pi}_t)-\bar{\Pi}(1+\hat{\Pi}_t) =&\beta\bar{\Pi}^2(1+\hat{Y}_{t+1}-\hat{Y}_t-\hat{C}_{rt+1}+\hat{C}_{rt}+2\hat{\Pi}_{t+1})\\
&-\beta\bar{\Pi}(1+\hat{Y}_{t+1}-\hat{Y}_t-\hat{C}_{rt+1}+\hat{C}_{rt}+\hat{\Pi}_{t+1})\\
&+\frac{\theta_p}{\psi_p}\left[\frac{1}{1-\alpha}\bar{w}\bar{A}^{-\frac{1}{1-\alpha}}\bar{Y}^{\frac{\alpha}{1-\alpha}}\left(1+\hat{w}_t-\frac{1}{1-\alpha}\hat{A}_t+\frac{\alpha}{1-\alpha}\hat{Y}_t\right)-...\right]\\
\overset{-static}{\Longleftrightarrow} (2\bar{\Pi}^2-\bar{\Pi})\hat{\Pi}_t =&\beta(\bar{\Pi}^2-\bar{\Pi})(\hat{Y}_{t+1}-\hat{Y}_t-\hat{C}_{rt+1}+\hat{C}_{rt})+\beta(\bar{\Pi}^2-\bar{\Pi})\hat{\Pi}_{t+1}\\
&+\frac{\theta_p}{\psi_p}\left[\frac{1}{1-\alpha}\bar{w}\bar{A}^{-\frac{1}{1-\alpha}}\bar{Y}^{\frac{\alpha}{1-\alpha}}\left(\hat{w}_t-\frac{1}{1-\alpha}\hat{A}_t+\frac{\alpha}{1-\alpha}\hat{Y}_t\right)-...\right]\\
\overset{\bar{\Pi}=1}{\Longleftrightarrow} \hat{\Pi}_t =& \beta\hat{\Pi}_{t+1}+\frac{\theta_p}{\psi_p}\left[\frac{1}{1-\alpha}\bar{w}\bar{A}^{-\frac{1}{1-\alpha}}\bar{Y}^{\frac{\alpha}{1-\alpha}}*\right.\\
&\left.*\left(\hat{w}_t+\frac{\alpha}{1-\alpha}\hat{Y}_t-\frac{1}{1-\alpha}\hat{A}_t\right)-(1+T_p)\frac{\theta_p-1}{\theta_p}\right]
\end{aligned}
$$

Short of the constants $\frac{1}{1-\alpha}\bar{w}\bar{A}^{-\frac{1}{1-\alpha}}\bar{Y}^{\frac{\alpha}{1-\alpha}}$, this comes down to the log-linearized Phillips Curve as described in Hansen et al. (2020). The derivation also demonstrates how important the zero-inflation steady state is for the described economy since the Phillips Curve becomes simplified significantly and in fact, without it, the forward-looking variables for consumption that appear in the rule for inflation, would turn the model's solution indeterminate.

The entire log-linearized model is collected by:

$$\hat{C}_{rt} = E_t\hat{C}_{rt+1} - \hat{R}_t + E_t\hat{\Pi}_{t+1} \tag{49}$$

$$\hat{C}_{kt} = \frac{\bar{w}\bar{N}}{\bar{C}_k}(\hat{w}_t + \hat{N}_t - \gamma\hat{A}_t) - \frac{T_p\bar{Y}}{\bar{C}_k}\hat{Y}_t + \frac{\bar{t}_k}{\bar{C}_k}\hat{t}_{tk} \tag{50}$$

$$\hat{w}_t = \phi\hat{N}_t + \hat{Y}_t \tag{51}$$

$$\hat{Y}_t = \hat{A}_t + (1-\alpha)\hat{N}_t \tag{52}$$

$$(1+T_p)\hat{Y}_t = \frac{\bar{d}}{\bar{Y}}\hat{d}_t + \frac{\bar{w}\bar{N}}{\bar{Y}}(\hat{w}_t + \hat{N}_t) \tag{53}$$

$$\begin{aligned}\hat{\Pi}_t = \beta\hat{\Pi}_{t+1} + \frac{\theta_p}{\psi_p}\Bigg[&\frac{1}{1-\alpha}\bar{w}\bar{A}^{-\frac{1}{1-\alpha}}\bar{Y}^{\frac{\alpha}{1-\alpha}} * \\ &* \left(\hat{w}_t + \frac{\alpha}{1-\alpha}\hat{Y}_t - \frac{1}{1-\alpha}\hat{A}_t\right) - (1+T_p)\frac{\theta_p - 1}{\theta_p}\Bigg]\end{aligned} \tag{54}$$

$$\hat{d}_t = \frac{(1-\lambda)\bar{t}_r}{\delta\bar{d}}\hat{t}_{rt} + \frac{\lambda\bar{t}_k}{\delta\bar{d}}\hat{t}_{kt} \tag{55}$$

$$\hat{t}_{kt} = \hat{d}_t \tag{56}$$

$$\hat{Y}_t = \lambda\frac{\bar{C}_k}{\bar{Y}}\hat{C}_{kt} + (1-\lambda)\frac{\bar{C}_r}{\bar{Y}}\hat{C}_{rt} \tag{57}$$

$$\hat{Y}^n_t = \hat{A}_t \tag{58}$$

$$\hat{A}_t = \epsilon_t \tag{59}$$

$$\hat{R}_t = \phi_\pi\hat{\Pi}_t + \phi_y\hat{Y}_t \tag{60}$$

4 Optimal policy regimes

In this section, I will examine the economy from section 2 under optimal policy. Hansen et al. (2020) already analysed and compared optimal policy under a central bank taking inequality into account and under a RANK optimal policy. I will extend the analysis by evaluating the outcome of optimal policy under two additional optimal policy regimes, one where the central bank's objective only entails Ricardian households ($\lambda = 0$)[16] and one where the central bank only focuses on Keynesian households ($\lambda = 1$).

4.1 Social Welfare

Function

In order to compare different policy regimes, it is first necessary to describe welfare in the economy. Total welfare in the economy is described by the weighted and discounted sum of consumption available to both agents, minus the disutility of labour:

$$\mathbf{W} = E_0 \sum_{t=0}^{\infty} \beta^t \left[\lambda \ln C_{kt} + (1-\lambda) \ln C_{rt} - \frac{N_t^{1+\phi}}{1+\phi} \right] \tag{61}$$

A second order expansion of total welfare usually leads to an approximate representation of welfare in quadratic gaps[17]. Using this method, the welfare can be decomposed into a part dependent on monetary policy and a part independent of monetary policy. The part dependent on monetary policy can usually be expressed in the form of weighted quadratic gaps. The quadratic gaps measure the deviation of endogenous variables from their steady state values in response to a shock and, therefore, they represent the loss inflicted on the economy, due to the deviation from the equilibrium path. The weights' of each gap represent the impact that each deviation has on the underlying economy. Due to the distorted steady state, as briefly mentioned in section 3.1, it is not possible to describe the entire monetary policy dependent part of welfare, in the form of quadratic gaps. An additional term T_0 is therefore needed to capture the distortions, caused by the inefficient steady state. A detailed derivation of the second order expansion, following Benigno and Woodford (2005), can be found in the Appendix of Hansen et al. (2020).[18] The derivation

[16] This is a similar approach to the RANK-optimal policy in Hansen et al. (2020) and, in fact, it utilizes the same policy weights on gaps. However, for the RANK-optimal policy, the T_0 term from section 4.1, is constrained to be the same value attained under optimal policy. This is not the case for the Dynare assisted simulation in this paper.

[17] See, for example, Galí (2015).

[18] For easier access, the exact definitions for the resulting weights and the T_0 term, can also be found in Appendix C.1.

leads to the following quadratic gaps equation for welfare:

$$\mathbf{W} \approx E_0 \sum_{t=0}^{\infty} \beta^t \left\{ -\frac{1}{2} W_\Pi \hat{\Pi}_t^2 - \frac{1}{2} W_Y \left(\hat{Y}_t - \hat{Y}_t^* \right)^2 - \frac{1}{2} W_{\Delta_c} \hat{\Delta}_{ct}^2 \right\} + T_0 + t.i.p. \tag{62}$$

, where t.i.p. sums up all terms independent of monetary policy. At this point, it should also be noted that the output gap is not simply defined with the natural level of output. Instead, the central bank has a different output target, due to the distortions caused by the skill-bias in wages. The skill-bias was introduced in section 2.2 and is controlled by the parameter γ. It only comes into effect during deviations from steady state and, since it is not reflected in the natural level, the central bank's new output target is slightly above the usual natural level of output. However, the deviation is very small, and for the standard calibration, it differs only in the realm of 0.017 percent from the natural level.[19]

Welfare Comparison

In order to conduct a meaningful analysis of different approaches to monetary policy, it is necessary to define a metric on which the different policies can be ranked. I will compare different welfare outcomes in terms of consumption equivalence. Consumption equivalence refers to the amount of additional consumption the average agent needs, in order to be indifferent between both policy regimes. More formally, consider two economies a and b, where $W^a > W^b$ and let ξ denote the additional fraction of yearly consumption an average agent from economy a would need to be indifferent between living in both economies. Then, considering the welfare from equation 61 for the average agent, and choosing ξ as the fraction of additional consumption, so that $W^a = W^b$, the Welfare in economy a can be calculated by:

$$\mathbf{W}^a = \sum_{t=0}^{\infty} \beta^t \left[\ln(1+\xi) C_t^b - \frac{N_t^{b\,1+\phi}}{1+\phi} \right] \tag{63}$$

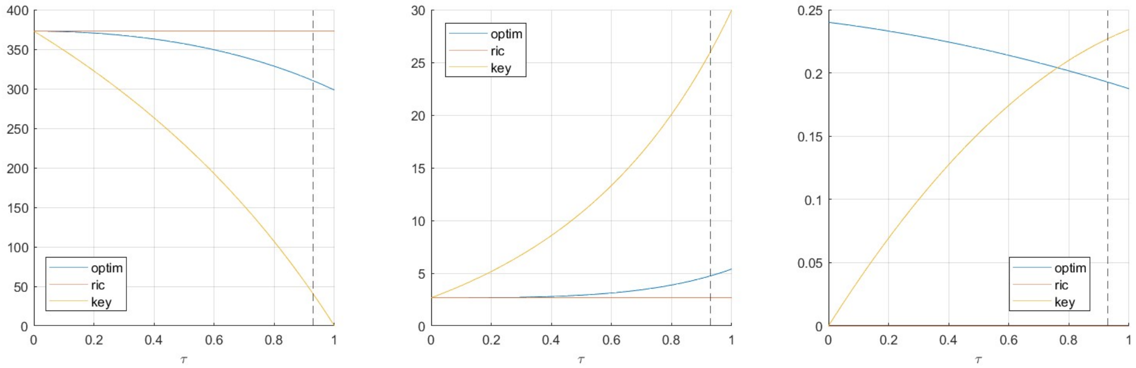
Utilizing the geometric series and solving for ξ, leads to the expression:

$$\mathbf{W}^a = \frac{1}{1-\beta} \ln(1+\xi) + \mathbf{W}^b$$

$$\Longleftrightarrow \xi = \exp[(1-\beta)(\mathbf{W}^a - \mathbf{W}^b)] - 1 \tag{64}$$

This approach follows the idea from Schmitt-Grohé and Uribe (2007).

[19]The new output gap also results from the second order expansion done by Hansen et al. (2020) and the term can be found in Appendix C.1.



(a) Weight on Inflation Gap (b) Weight on Output Gap (c) Weight on Consumption Inequality Gap

Figure 1: The three panels show the 3 weights from the quadratic gaps equation (62), for each of the three policy regimes discussed. "ric" and "key" refer to the Ricardian and the Keynesian regime, respectively, while "optim" refers to the optimal monetary policy, which accurately reflects the underlying economy. The weights are shown as a function of the parameter τ, which governs the distribution of dividends and therefore the steady state inequality in the model. The dashed line shows the value for the standard calibration $\tau = 0.93$.

4.2 Different policy regimes

Setting $\lambda = 0$ for the welfare function (61), the objective function for the Ricardian policy regime follows:

$$\mathbf{W} = E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln C_{rt} - \frac{N_t^{1+\phi}}{1+\phi} \right] \tag{65}$$

And setting $\lambda = 0$, the objective function for the Keynesian policy regime follows:

$$\mathbf{W} = E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln C_{kt} - \frac{N_t^{1+\phi}}{1+\phi} \right] \tag{66}$$

Similarly, the new policy weights for the quadratic gaps equation, can be found by manipulating the λ parameter. The exact definitions for the weights can be found in Appendix C.2. Figure 1 shows the weights depending on the parameter τ from equation 62 for all three policy regimes. τ governs the degree of steady state inequality in the model, where $\tau = 1$ means maximum inequality, since no redistribution is taking place and all the dividends are channelled to Ricardian agents. Lower τ means more and more redistribution, until the dividends are equally distributed to Keynesian and Ricardian agents for $\tau = 0$. Since for the standard calibration, there exist more Keynesian than Ricardian agents, this means that Keynesians receive a disproportionate amount of dividends. It should be noted that the inequality discussed in this section is not representative for the entire inequality in the model, since the dynamic inequality is caused by the skill-bias in wages and is governed by the parameter γ. The weights on gaps, however, only depend on the steady state inequality, which is dependent on the parameter τ, since the dynamic part of inequality only shows in response to a TFP shock and is therefore reflected in the gaps themselves, which fluctuate in size in response to a shock. Overall, it can be observed that while the weights on inflation and output gap vary widely depending on regime type, the weights on the consumption gap remain small. This is because the consumption gap only captures second-order effects, while the different regime types' redistribution influences mostly take place via the output and inflation gap. Regarding the weights for the Ricardian regime, Hansen et al. (2020) showed that the weights collapse to the weights for the standard RANK literature[20]. This makes intuitive sense, since with $\lambda = 0$, the model only consists of Ricardian agents and the model collapses to the standard RANK model. It also clarifies why the Ricardian regime acts independent of τ, while the weights for the Keynesian regime are influenced by redistribution. Since the labour market is modelled without rigidities and both types of agents contribute a constant fraction of labour supply, Keynesians don't change the dynamics of the model. They are "hand-to-mouth" and essentially only take a fraction out of the Ricardian income. Since all dividends belong to the Ricardians by default and there is nothing the Ricardian policy regime can do about the taxed dividends, it acts as if the model is devoid of Keynesian agents and all its policy weights are independent of τ.

Weight on Inflation Gap

Looking at Figure 1a and considering the optimal policy case, it becomes immediately apparent that the weight on the inflation gap is decreasing in τ. Hansen et al. (2020) already observed that the cost of inflation is directly born by the firms, via the Rotemberg pricing, and higher inflation decreases profits (dividends). A larger τ means more of the profits are accrued to Ricardian agents, and since they are already the better-off agents, the CB starts accepting a higher inflation, as it disproportionately hurts Ricardian agents. This also makes intuitive sense when considering the Ricardian regime, since a central bank focusing only on Ricardian agents doesn't care how much dividends are redistributed. It will always prefer the most optimal outcome for Ricardians and therefore maximize dividends, independent of τ. For the standard calibration, this translates to a 30 percent increase in the inflation gap's weight. The opposite starts to happen when we consider the Keynesian regime. Here, we see large differences in values depending on τ. For $\tau = 0$, we can observe, that the weight equals the Ricardian regime. This makes sense, considering, that when all dividends are redistributed equally, Keynesians gain the same share of dividends, and the central bank therefore acts the same way as under the

[20]See Galí (2015) for the standard RANK weights.

Ricardian regime. However, the central bank cares progressively less about the cost of inflation, the fewer dividends are distributed to Keynesian agents, until the CB eventually puts zero weight on the inflation gap for $\tau = 1$, since all the costs of inflation are borne by Ricardian agents. For the standard calibration, this leads to a large difference compared to the optimal welfare case, of about 86 percent.

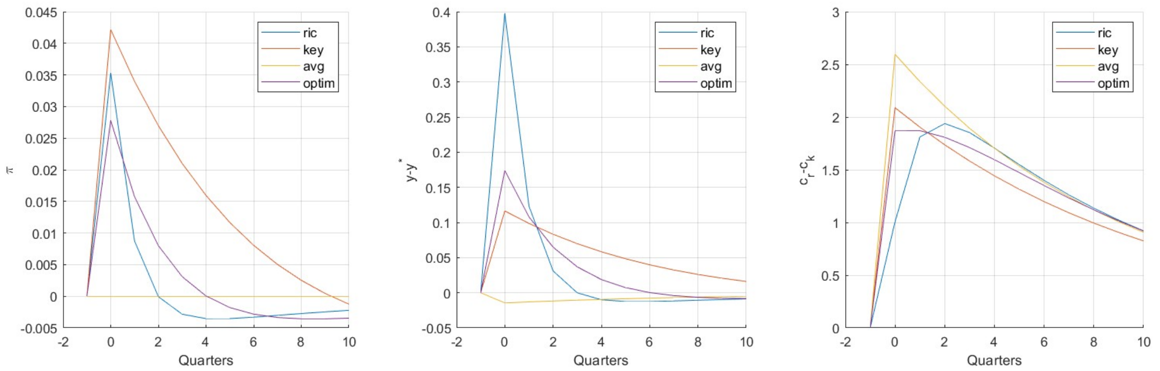
Weight on Output Gap

Considering now Figure 1b. The optimal welfare case was also analysed in Hansen et al. (2020), where it was observed that the higher the inequality, the more Keynesian households solely depend on wage income. Since Keynesians are the worse-off agents, and the poorer the agent, the more important even small income gains become, a higher output gap becomes less and less acceptable for the central bank. In other words, the more "hand-to-mouth" Keynesian agents become, the more the central bank has to focus on the output gap to not "starve" Keynesian agents. Unsurprisingly, the Ricardian regime puts a constant weight on the output gap, because Keynesians are not considered, and the weight is therefore independent of τ. Compared to the welfare optimal regime, this leads to an approximate decrease of 54 percent for the weight on the output gap. Conversely, the Keynesian regime puts a much larger weight on the output gap in general. It starts to disregard dividend income and care more and more about wage income, the fewer dividends are redistributed to Keynesian agents. For the standard calibration, this leads to a huge increase of approximately 350 percent, compared to the welfare optimal regime.

Weight on Consumption Inequality Gap

Regarding Figure 1c, the interpretation for the Ricardian regime is trivial: irrespective of the degree of inequality, it will always assign a weight of zero to consumption inequality, as it has no interest in shifting resources from Ricardian to Keynesian agents, no matter the inequality level. The optimal welfare case is harder to understand. It seems counterintuitive that the welfare optimal planner would value the consumption gap less, the higher the inequality in the model. To understand this behaviour, it is necessary to recall that the consumption inequality gap mostly captures second-order effects. In the model, the Keynesian agents act as "hand-to-mouth" agents, and due to the lack of intertemporal substitution, their consumption doesn't follow an Euler equation. Therefore, in order to stimulate consumption via monetary policy, the Ricardian households are instrumental. The higher the amount of dividends distributed to the Ricardian agents, the more important wage income becomes for Keynesians, and the less acceptable the output gap becomes, since higher output means higher wages.[21] Nonetheless, the higher the inequal-

[21] Hansen et al. (2020) seem to explain this decline in τ with (i) the fact that Keynesians form the smaller group and (ii) that it becomes even less appealing to transfer resources to Keynesians the higher



(a) Inflation Gap

(b) Output Gap

(c) Consumption Inequality Gap

Figure 2: The three panels show impulse response functions under Ramsey optimal policy, for the Ricardian regime (blue), the Keynesian regime (red), the welfare optimal regime (purple) and the average consumption regime (yellow). The y-axis refers to the deviation from steady state in percent, for each of the three gaps from equation 62.

ity in the model, the more attractive it becomes for the social planner to shift resources to Keynesian agents. This becomes more relevant, when Keynesians form a larger group in the economy, and the second effect starts to dominate for higher λ. When looking at the Keynesian regime, this becomes clear as the weight on the consumption inequality gap follows a concave path. Since the social planner acts as if only Keynesian agents are present in the model, shifting resources to them becomes more important, the higher τ, which leads to an increase in the weight for the consumption inequality gap. However, the concave shape shows that even when Ricardian consumption is not considered at all by the social planner, the first effect is still active and lowers the social planner's willingness to shift resources from Ricardians to Keynesians for higher τ. For the standard calibration, this still leads to an overall increase in the weight on consumption inequality of about 9 percent, compared to the optimal welfare regime.

4.3 Optimal policy regimes, responses to TFP shocks

Figure 2 shows the impulse functions for the three policy regimes from section 4.2 in response to a positive technology shock, as discussed in section 2.10. It also contains an additional policy regime, referred to as the average consumption regime. Focusing first on the three already discussed regimes, the response functions for the Keynesian regime show that it allows for much higher inflation in exchange for pushing output higher. This is, what was expected, since Keynesians bear only a small part of the inflation cost while

τ, since redistribution involves taking from the majority and more than proportionally benefiting the minority. The first effect (i) is clearly in play, but doesn't explain why the weight would decline with increasing inequality, while the second effect (ii), also doesn't seem to be able to explain the decline properly, since as Appendix D.1 shows, the relationship doesn't immediately turn at the point of $\lambda = 0.5$, where Keynesians no longer form a minority, suggesting that other effects contribute as well.

depending heavily on wages for the standard calibration. In doing so, the Keynesian regime maintains the lowest Consumption Inequality Gap on average compared to all other regimes. Ricardians bear most of the cost of inflation for the standard calibration, and therefore we can observe in Figure 2a that the Ricardian regime stabilizes inflation significantly faster than the Keynesian or the welfare optimal regime. We can also see that under Ricardian control, inflation is controlled so heavily and quickly that the response even overshoots a little bit, and the inflation gap turns negative despite the positive technology shock. Figure 2b shows that in the trade-off for controlling inflation and the fact that Ricardians depend on wage income less than Keynesians, the Ricardians stabilize the output gap much faster than all other regimes. However, there is an obvious spike in the output gap for $t = 0$. To understand this spike, it is necessary to understand that the T_0 term from section 4.1 depends crucially on the output gap in $t = 0$. It therefore represents the regime's effort to maximize T_0. Since the steady state distortion arises due to the unequal distribution of dividends towards Ricardian agents, the term has greater significance for a social planner who is considering solely Ricardian households. This also leads to the one-period lag in consumption inequality, as the spike in output actually reduces consumption inequality as a side effect, due to higher wages disproportionately benefiting Keynesian agents. The T_0 term is part of the loss function; however, it is difficult to interpret since the output gap enters T_0 linearly, which can lead to negative losses. When considering welfare losses later, I will therefore only consider the dynamic part of the welfare loss, which is represented by the part of welfare that is quadratic in gaps.[22] Of course, the T_0 term arises naturally in the model with inequality, and the surprising result of why the Ricardian regime would push the Output Gap initially even higher than Keynesians still needs to be explained. The behaviour makes sense, when considering the skill-bias in wages. Due to a positive technology shock, Ricardians now suddenly receive a larger fraction of wages. Since they are now rewarded disproportionately by higher output (via higher wages), they aggressively push the output gap. As the shock wears off, they lose the advantage on wages while simultaneously bearing the cost of higher inflation. This leads them to aggressively correct the output gap again, creating the visible spike. The main difference between the Ricardian and the Keynesian push in the output gap is timing. The Ricardians push output heavily during early periods, since they receive a larger share of wages. The Keynesians need the wage increase to balance out the shrinking consumption under the technology shock. Therefore, the Keynesian regime prefers a lower but more continuous increase of output to smooth consumption, while the Ricardian regime opts for an early push.

Regarding the optimal policy regime, it considers both Ricardian and Keynesian agents

[22] Hansen et al. (2020) effectively do the same thing when comparing their RANK-optimal and optimal policies. They do this by constraining the T_0 term to always be equivalent to T_0 under optimal policy, effectively eliminating the term when considering differences.

proportionally, and therefore it can be interpreted as a compromise between both regimes, slightly tilted towards Ricardians.

The average consumption regime

Hansen et al. (2020) frame what is discussed here as the Ricardian regime, as RANK-optimal policy.[23] They use it to compare a social planner who incorporates inequality and one who does not consider inequality. This is understandable, since for $\lambda = 0$, the weights on gaps collapse to the standard weights in the RANK literature, as discussed in section 4.2. They claim, that a social planner following the welfare equation 65, while keeping T_0 constrained, "[...] focuses on maximizing the average consumption in the economy rather than internalizing the differences in consumption across two agents." (Hansen et al., 2020, p.12/13). I argue, that this is not the proper way to interpret the RANK-optimal policy, and instead it should be viewed as the Ricardian regime. To show this, I define a social planner, who is actively trying to maximize the average consumption in the economy, following the Welfare function:

$$\mathbf{W} = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln[\lambda C_{kt} + (1-\lambda) C_{rt}] - \frac{N_t^{1+\phi}}{1+\phi} \right\} \tag{67}$$

, where the agents are treated as a single agent consuming the average consumption in the economy. It is clear, that a social planner following this objective, will maximize the average consumption $\lambda C_{kt} + (1-\lambda)C_{rt}$. The impulse response functions of such a regime are represented by the yellow line in Figure 2. As can be seen, such a regime behaves quite differently. It doesn't consider differences in agents and therefore opts to completely stabilize the inflation and output gap. A central claim in Hansen et al. (2020), that the impulse responses of optimal and RANK-optimal policies are nearly identical, no longer holds. The slight deviation from complete stabilization in the output gap, can be explained by the differing definitions of natural output. The average consumption regime doesn't make a difference between both agents, and therefore doesn't respect the different output gap, that is caused by the skill-bias in wages. It therefore stabilizes output to the natural level of $\hat{A}_t$ and not the welfare optimal target $\hat{Y}_t^*$ from section 4.1. This leads to the slight downward deviation in Figure 2b.

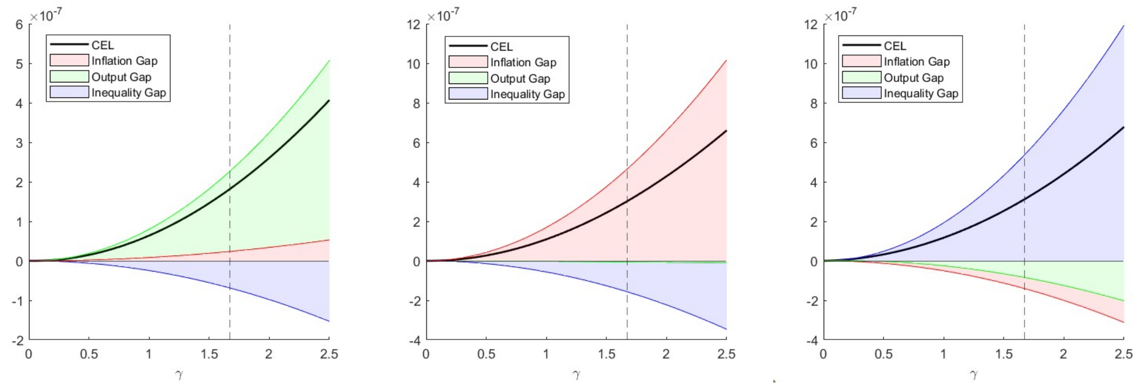
4.4 Consumption Equivalent Loss

To calculate the consumption equivalent loss for each regime, I use the equation for consumption equivalent welfare (64) and consider the difference in quadratic gaps between each regime and the optimal welfare regime. The results can be seen in Table 2.

[23] At least regarding the weights on Gaps, the computations differ on T_0.

Regime	Ricardian	Keynesian	Average Cons.
Cons. Equiv. Loss	18.122	30.097	31.072
Inflation	2.3728	46.354	-14.008
Output	22.598	-0.6239	-8.4032
Inequality	-6.8489	-15.633	53.484

Table 2: The table shows the consumption equivalent loss, calculated from gaps, as a fraction of yearly steady state consumption for the Ricardian, Keynesian, and average consumption regime, when compared to the optimal welfare regime. Inflation, Output, and Inequality refer to the loss resulting from each gap, respectively. All results are under the standard calibration and need to be taken $\times 10^{-8}$.



(a) Ricardian (b) Keynesian (c) Average Cons.

Figure 3: The three panels show the consumption equivalent loss, calculated from gaps, as a fraction of yearly steady state consumption for the Ricardian, Keynesian, and average consumption regime, when compared to the optimal welfare regime. On the x-axis, the calculations are varied for the parameter γ, controlling the cyclical inequality in the model. The panels also break down the consumption equivalent loss per gap. The dotted line represents the standard calibration.

While the differences are clearly small, it is unsurprisingly shown that for the standard calibration, all other regimes produce a welfare loss compared to the welfare optimal regime. The Ricardian regime hereby produces a smaller loss than the Keynesian regime. Since the Ricardians represent a majority in the standard calibration, it is unsurprising, that a monetary policy regime, which only considers the majority of agents, fares better than one only considering a minority, when both are measured on total welfare. More surprising is the fact that the average consumption regime actually seems to create the worst results. It appears that considering only one type of agent is actually the superior policy compared to considering the average consumption over all agents. This becomes more clear when focusing on the loss per gap. Since both radical regimes opt to not completely stabilize the output gap, which reduces inequality, the average consumption regime actually can't make up the additional loss in the inequality gap by completely stabilizing both inflation and output.

Figure 3 shows the loss on gaps, when varying the parameter of cyclical inequality γ. It is clearly visible that for all three regimes, the loss compared to the welfare optimal regime increases with higher cyclical inequality. This is the least surprising for the average consumption regime (Figure 3c), since it doesn't internalize any inequality and therefore the loss increases, the higher the impact of inequality. For the Keynesian regime (Figure 3b) it is probably more surprising. Under concave utility functions, a regime only focusing on the poorer part of the economy could be thought of as being more welfare enhancing, the poorer the agents are. And of course, such a regime does actually decrease the inequality gap by pushing the Keynesian agent, and the loss on inequality shrinks in γ. However, overall the loss increases, since the gain in the inequality gap is taken over by the decreased control of inflation. Even though Keynesians receive a lower share of wages, they become poorer with higher γ and thus rely more heavily on wage income. Since the cost of inflation is still largely born by Ricardians, the inflation gap is more easily tolerated. For the Ricardian regime (Figure 3a), it might seem surprising that the inequality gap actually decreases for higher inequality, but it can be easily explained when considering the regime's behaviour from section 4.3. The increased loss resulting from the Ricardian regime stems almost entirely from the early push in the output gap, while the decreased loss in the inequality gap, comes from the lag observed in Figure 2c. These reactions increase in γ, as a bigger skill-bias leads to higher early spikes for the output gap, which inadvertently helps out Keynesians.

Figure 3 also nicely visualizes how each of the three different regimes accumulates almost its entire loss by neglecting one of the three gaps. Only the loss of Ricardians is also at least slightly impacted by a second gap, which gives another insight as to why the Ricardian regime is able to assume the lowest overall welfare losses. Pushing the output gap higher to profit from skill-bias hurts them later by creating a higher cost of inflation, keeping their behaviour in check. The higher γ, however, the more are they willing to accept a higher inflation gap.

5 Optimal simple rules

In this section, we shift our focus from optimal monetary policy to simple Taylor rules. Historically, simple rules have effectively captured central bank decisions, as demonstrated by Bernanke (2015). Although, the zero lower bound has hindered predictability in recent years, rising interest rates could soon restore the alignment with simple Taylor rules. This section aims to explore the effects of augmenting the Taylor rule from section 2.8 to include targeting consumption gaps. Hansen et al. (2020) has already investigated an augmented Taylor rule that considers the consumption inequality gap between Ricardian and Keynesian households. Here, we briefly replicate their findings and extend the analysis with two additional augmentations, in which the central bank exclusively targets consumption deviations of either Keynesian or Ricardian households. Consequently, this section will examine the following three augmented Taylor rules.

The first rule, which accounts for consumption inequality and was already discussed in Hansen et al. (2020):[24]

$$\hat{R}_t = \phi_\pi \hat{\Pi}_t + \phi_y \hat{Y}_t + \phi_c (\hat{C}_{rt} - \hat{C}_{kt}) \tag{68}$$

The augmented Taylor rule, considering only the consumption gap of Ricardian households:

$$\hat{R}_t = \phi_\pi \hat{\Pi}_t + \phi_y \hat{Y}_t + \phi_c \hat{C}_{rt} \tag{69}$$

And the augmented Taylor rule, considering only the consumption gap of Keynesian households:

$$\hat{R}_t = \phi_\pi \hat{\Pi}_t + \phi_y \hat{Y}_t + \phi_c \hat{C}_{kt} \tag{70}$$

Regarding the welfare analysis, I will follow Hansen et al. (2020) and ignore the T_0 term when calculating welfare for this section. The qualitative results are unchanged by this simplification. The welfare differences, therefore, only depend on the part of welfare that is quadratic in gaps.

5.1 Weight on consumption gaps

Regarding the Taylor rule weights on the standard deviations, the common calibration $\phi_\pi = 1,5$ and $\phi_y = 0.125$ will be used, while for the weight on consumption gaps, the following analysis will use the optimal weights ϕ_c^*, given the quadratic loss function in

[24] Note that slight differences between the results in Hansen et al. (2020) and this section, regarding the inequality rule, are due to the corrected steady state from section 3.2. These differences were not apparent in previous sections, since the not approximated nonlinear model was used to calculate all results.

ϕ_c^*	Welfare optimal	Regime specific
$\hat{C}_{rt} - \hat{C}_{kt}$	-0.1220	-0.1220
$\hat{C}_{rt}$	-0.1748	-0.1746
$\hat{C}_{kt}$	0.3366	0.3807

Table 3: The table shows the optimal values for the weight on consumption gaps ϕ_c^*, for each of the Taylor rules from section 2.8. It differentiates between the optimal ϕ_c^*, given the welfare optimal weights on gaps, and the regimes specific weights analysed in section 4.2.

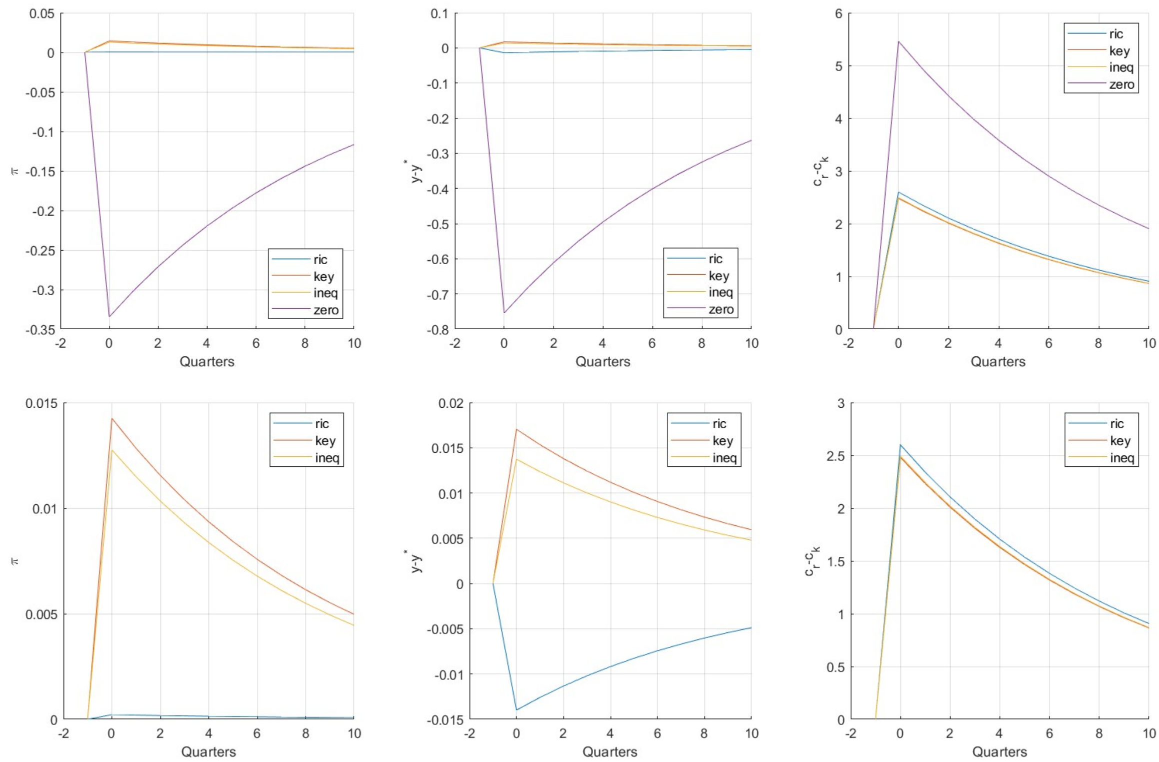
.

equation 62. This might seem counter-intuitive, since the use of Taylor rules should indicate a simplification of monetary policy, and implementing perfect weights on the consumption gap would require just as extensive information about the economy as optimal monetary policy. However, for examination purposes, it is still useful to evaluate how well such rules could fare under the assumption of perfect implementation. For a realistic application, some additional error of implementation would need to be assumed. Regarding how optimal ϕ_c^* is calculated, it is possible to assume a welfare optimal approach for all three Taylor rules or instead assume regimes in the spirit of section 4, where the optimal weights are chosen, given the regime-specific weights from Appendix C.2. The latter would be reminiscent of a monetary policy only considering one type of agent, but in the form of a Taylor rule. The different optimal weights can be found in Table 3. The table demonstrates, that weights on the consumption gaps don't change significantly for the regime-specific weights on gaps, especially in the Ricardian case. Compared to a standard Taylor rule with zero weight on consumption gaps, the results are almost indistinguishable, but in the comparison between augmented Taylor rules, some differences are visible, especially for the Keynesian regime. In the spirit of section 4, I will continue the analysis from the perspective of a regime-oriented central bank, and therefore utilize the regime-specific weights for the consumption gaps. The configurations for the Taylor rules 69 and 70, will therefore represent a central bank following a standard Taylor rule, augmented with the respective consumption gap they care about, and maximizing the weight on the gap under their respective agents' utility. Note, that the sign of ϕ_c^* changes for the Keynesian gap, as the gap itself turns negative in response to a positive technology shock.

5.2 Impulse response functions

The impulse response functions in response to a positive TFP shock can be seen in Figure 4[25]. It is clearly visible that all three augmentations deliver a strong reduction in gaps

[25] For comparison, the impulse responses, when utilizing the welfare optimal weights, can be found in Appendix D.2.



(a) Inflation Gap (b) Output Gap (c) Consumption Gap

Figure 4: The three panels show the impulse responses to a positive TFP shock, with regard to the inflation, output, and consumption gap, respectively. The purple line corresponds to the standard Taylor rule with a calibration of $\phi_\pi = 1.5, \phi_y = 0.125, \phi_c = 0$, while the yellow, blue, and black lines correspond to the rules from 68, 69, and 70 respectively, with a calibration of $\phi_\pi = 1.5, \phi_y = 0.125, \phi_c = \phi_c^*$, where ϕ_c^* for the Ricardian and Keynesian case, is calculated using the regime-specific weights in Appendix C.2. In order to better differentiate between the augmented Taylor rules, the lower panels show the same data, but without the standard rule.

when compared to a standard Taylor rule. Hansen et al. (2020) already analysed that the additional focus on inequality in the Taylor rule is able to massively reduce the loss on all three gaps. Before discussing the mechanism through which this takes place, it is helpful to first sketch out what is happening in the economy due to a positive technology shock. In general, output increases via the boost in productivity, and the boost in productivity leads initially to a price decrease (lower marginal cost). Due to the sticky-prices, however, prices don't decrease by as much as they normally would, leaving actual output behind potential output and leading to a negative output gap. The decrease itself still leads to a negative inflation gap. The inequality gap is caused by the skill-bias in wages, where Ricardians suddenly receive a larger share of wage income. The main mechanism through which the gap stabilization now takes place is well-known in the New-Keynesian literature.[26] For the model featured here, this mechanism can be explained, using the collected log-linearized model in section 3.2. In response to negative gaps, monetary policy decreases interest rates via the Taylor rule (60). This decrease in interest rates leads to a decrease of the real rate, which stimulates Ricardian consumption via the Euler equation (49). The additional increase in demand helps to close the output gap and increases wages (51). The closing of the output gap and the increase in wages then helps close the inflation gap by pushing inflation via the Phillips Curve (54). Finally, the increase in wages help to close the consumption gap, by disproportionately helping the poorer agent, as already discussed in section 4. The focus on an additional gap leads to a stronger reaction by the central bank, which leads to a more aggressive lowering of interest rates, strengthening the mechanism explained above. Whether this additional goal comes in the form of a consumption inequality gap or just a focus on a consumption gap for each agent, hardly matters. The core mechanism of a stronger central bank reaction stays the same.

Differences only become apparent when zooming in on the three augmented rules. The lower panels in Figure 4 show that, for augmented Taylor rules, the Ricardian configuration now actually behaves close to what I argue the RANK-optimal policy in Hansen et al. (2020) tried to capture, or what I argue in section 4.3 the average consumption regime represents. This happens since the weights on the objective function determining ϕ_c^* are the standard weights in the RANK literature.[27] We therefore see almost complete stabilization in the inflation and output gap.[28] The Keynesian and inequality configurations instead trade off complete macro stabilization in exchange for a lower inequality gap. This follows again the same reasoning that appeared already many times in this paper, where Keynesians benefit disproportionately from an increase in output, while they are only lightly effected by the cost of inflation. Naturally, this effect is even stronger, when the Keynesian regime weights are used to calculate ϕ_c^*.

[26]Compare Galí (2015).

[27]See section 4.2.

[28]The reason for the slight downward deviation is the same as it is for the deviation by the average consumption regime in section 4.3, where the optimal output gap differs from natural output.

Gap	$\hat{C}_{rt}$	$\hat{C}_{kt}$	$\hat{C}_{rt} - \hat{C}_{kt}$
Loss decrease in %	96.982	97.107	97.108
Cons. Equiv. Loss	-8.0020	-8.0123	-8.0125
Inflation	-6.6368	-6.6247	-6.6271
Output	-0.5162	-0.5161	-0.5162
Inequality	-0.8484	-0.8709	-0.8685

Table 4: The table shows the consumption equivalent loss, calculated from gaps, as a fraction of yearly steady state consumption, for the augmented Taylor rule with a Ricardian, Keynesian, and Inequality configuration, when compared to the standard Taylor rule where $\phi_c^* = 0$. Inflation, output, and inequality refer to the consumption equivalent loss resulting from each gap respectively. Loss decrease in %, refers to the total loss reduction when switching from the standard to an augmented Taylor rule. All results, except percentages, need to be taken $\times 10^{-5}$.

The same effects can also be seen in Table 4, where the results regarding the consumption equivalent loss are collected. It also shows that the loss decrease for switching to an augmented Taylor rule is large, at about 97% for all augmentations.[29] Hereby, the actual inequality configuration shows the largest benefit, closely followed by the Keynesian configuration. This happens due to the latter configurations also targeting consumption inequality both directly and indirectly. The result differs from the policy counterparts in section 4, where the Ricardian regime delivered higher welfare than the Keynesian regime. This was possible, since the Ricardian regime indirectly helped out Keynesians by strongly pushing the output gap early on. They did this in response to the skill-bias, which is only indirectly present here in the measure of potential output and through the economy's equilibrium dynamics. Another way to think about this difference would be that, under optimal policy, the Ricardian regime was able to push output early and then stabilize quickly. However, such a dynamic response is not possible under Taylor rules, since the strength of the response is predetermined for all periods.

[29]Due to the different log-linear model used in Hansen et al. (2020), as explained in section 3.2, they reported only a decrease of about 96% for the inequality configuration.

6 Critical Appraisal

In this section, I will briefly summarize the main results and try to draw some practical implications for monetary policy. I will also discuss the model assumptions and resulting limitations, as well as conduct some robustness checks.

6.1 Limitations and practical implications

Practical implications

In order to assess practical implications, it is useful to first summarize the main findings. Regarding Ramsey optimal policy, I find:

- A Keynesian regime will accept a higher inflation and push output more, the lower their participation in dividends. Higher inflation and higher output help in reducing the consumption inequality gap.
- All regimes discussed, notably including the Ricardians, help to stabilize the consumption inequality gap more than a monetary policy with a focus on the average consumption in the economy.
- Of the regimes discussed, the Ricardians come closest to the welfare optimal regime in terms of total welfare. However, they also represent a majority in the model.
- The Ricardian regime also helps to close the consumption inequality gap, since they inadvertently help out Keynesians while capitalizing on the skill-bias in wages.
- Increasing cyclical inequality increases the additional loss of all three regimes, when compared to the welfare optimal regime. Notably, this includes the Keynesian regime.

Considering augmented Taylor rules, I find:

- All three suggested augmentations significantly improve welfare when compared to a standard Taylor rule. This happens via a stronger reaction of monetary policy, and it is largely irrelevant whether the augmentation happens in the form of a consumption inequality gap or just a regular consumption gap.
- In contrast to the above results, a Keynesian regime trying to optimize Keynesian utility with an augmentation on the Keynesian consumption gap fares slightly better in terms of total Welfare as a Ricardian regime doing the same.
- In the Keynesian and Inequality configuration of Taylor rules, the central bank chooses the weight on the consumption gap in a way that trades off complete macro stabilization for a lower inequality gap. This is not the case for the Ricardian configuration, which explains the above result.

These results align in principle with a growing body of literature that examines the distributional implications of monetary policy and the potential role of central banks in addressing inequality. For example, Colciago et al. (2019) showed in a much richer model that contractionary monetary policy increases consumption heterogeneity overall,[30] while expansionary policy leads to a decrease.[31] The results suggest that central banks should consider the welfare implications of different policy regimes and understand that a single-minded focus on average consumption may not be the most effective approach. Instead, they should also focus on incorporating the effects of inequality. This may involve accepting higher inflation and promoting higher output in order to reduce the consumption inequality gap. In doing so, understanding the behaviour of different policy regimes can help inform the decisions made by policymakers. The comparison of the Ricardian, Keynesian, and average consumption regimes highlights the importance of selecting an appropriate policy target. By understanding the effects of each regime on welfare and inequality, central banks can better design their monetary policy frameworks to achieve desired outcomes. This showcasing of extreme cases, highlights the existence of trade-offs between macroeconomic stabilization and reducing consumption inequality. Central banks can use this insight to better manage these trade-offs and strike an appropriate balance between competing objectives. However, as is visible in the Ricardian regime, economics is not a zero-sum game. Even when Ricardians have control in the central bank, they inadvertently help out Keynesians.

More specifically, the results suggest that the central bank should act more aggressively when setting rates in the face of inequality, and in order to support wage-dependent agents, it could be helpful to push output more than usual and face a higher cost of inflation in return. The fact that even a Keynesian regime fares worse and worse in comparison to welfare optimal policy under growing cyclical inequality, could suggest that a focus on poorer households should not necessarily increase with higher inequality, but instead, it depends on the dynamics within the economy. Expending the focus on the inequality gap under growing inequality could therefore prove detrimental. Considering now the result that Ricardians fare better under optimal policy, it mostly shows that it makes sense for the central bank to put a higher focus on the majority of the population. However, when considering more simple rules, this advice seems to shift. Overall, it can be said that at least taking some form of inequality or consumption gap into account seems to be a better approach than ignoring differences between agents entirely, and just focusing on the average consumption in the economy.

[30] Even though there exists substantial heterogeneity within richer and poorer households, which are impacted quite differently by monetary policy.

[31] See also Coibion et al. (2017).

Limitations

Overall, the underlying model is very simplistic, and all results, therefore, depend heavily on assumptions. The TANK model simplifies the economy by considering only two types of agents. In reality, the economy is more complex, with various types of agents and interactions that are not captured in this model. The advantage of the model's comprehensibility comes with the cost of not being able to capture realistic wealth distributions or the effects of heterogeneity within richer and poorer households. Also, the heterogeneity of portfolios is not considered, due to the lack of capital in the model. For example, Ampudia et al. (2018) show how asset price increases due to expansionary monetary policy disproportionately help the poor, since they hold a higher percentage of assets in the form of housing. Such complexities cannot be captured in a model without diverse asset classes.

Additionally, the model only focuses on technology shocks in a perfect foresight setting. Woodford (2001), for example, shows how imperfect information can lead to a delayed effect on inflation, which could influence the results shown here quite significantly, considering how important the inflation levels are for curbing the inequality gap.

Another blindspot in regard to technology shocks, can be found in their homogeneous effects. In reality, different sectors are impacted differently by technology shocks, and therefore, also the skill-bias is sector-dependent. For example, Bresnahan et al. (2002) found that IT adoption has led to an increase in the demand for skilled labour in industries that have adopted new workplace organizational practices, but less so in others. This means that actual wealth shifts in response to a skill-bias are dependent on the underlying economy's industrial composition.

Last but not least, it should be noted that the labour market was simplified heavily, and no wage rigidities exist in the model. However, Hansen et al. (2020) show that the basic results they reach don't change under wage rigidities, and most of the effects are even stronger. Since the same model was employed here, it is quite possible that this result extends. Though, to be sure, further research is necessary.

This is, of course, not an exhaustive list of all the limitations with regard to real-world applicability. DSGE models possess the inherent weakness of being model-specific, which is a limitation arising from the unique assumptions and relationships within each model, as well as the calibration of numerous parameters that can vary across models.

6.2 Robustness

Since the results obtained via DSGE models are usually heavily dependent on parameters, it is important to check whether a variation of parameters significantly changes the direction of results. It would be optimal to check all results against all calibration variations. However, since most parameters in this model are set to standard values from the literature, I will focus on the three main novel parameters λ, τ, and γ. For these parameters, I will check whether the basic results, concerning the consumption equivalent loss for the different regimes and configuration types, hold under varying parameters.

Ramsey results

For the results under Ramsey optimal policy, varying the parameter of cyclical inequality γ was already extensively discussed in section 4.4 and is displayed in Figure 3. For the fraction of Keynesian households λ, it first needs to be said that not all regimes can be successfully calculated under all configurations of λ, since some parameter configurations lead to indeterminacy. Here, the limiting regime is the Ricardian regime, which is only defined for values in the range of about $\lambda \in [0.25, 0.6]$. Also, the direction of results actually starts to differ, since for different levels of τ, the average consumption regime begins to outperform the other regimes in terms of welfare in both directions.[32] Regarding the parameter on steady state inequality τ, the limiting regime in terms of determinacy is the Keynesian regime. It is only defined for all values in the range of about $\tau \in [0.75, 0.1]$. Again, the direction of results actually starts to differ, since for different levels of τ, the average consumption regime continues to outperform the other regimes in terms of welfare in both directions. The visualizations can be found in Appendix E.1.

While the robustness checks conducted here, prove that the results are only lightly impacted by variable changes, the directional changes of some results, seem to contradict some major points made in this thesis. Therefore, it should be noted that it is not surprising, that the average consumption regime starts to outperform the other two regimes in terms of welfare when varying the parameters on inequality. All three parameters discussed here heavily influence the endogenous variable path taken by the Ricardian and Keynesian regime, since the inequality in the model is important for their decision-making. The average consumption regime, on the other hand, only considers the aggregate agent, and therefore, its variable path proves naturally more robust to parameter changes concerning inequality.

OSR results

Within the results of optimal simple rules, there exists another novel parameter, namely the Taylor weight on consumption gaps ϕ_c. While for the above results, the parameter is always chosen to be the optimal ϕ_c^* given the respective regime, the parameter cannot be chosen freely, since the model becomes undetermined under some specifications. This indeterminacy can be explained by the Blanchard-Khan conditions, which are a set of criteria used to determine whether a linear rational expectations model has a unique

[32]Note that this doesn't necessarily translate to economies with different agent compositions, since the Ramsey model is not calculated again and just the parameter value is varied.

and stable solution.[33] For the Ricardian configuration in section 5, the parameter ϕ_c has no restrictions; for the Keynesian and Inequality configuration, the parameter is undetermined in the intervals around $\phi_c \in [-0.871, -0.045]$ and $\phi_c \in [0.043, 0.867]$, respectively.[34]

Regarding the other three novel parameters, it first has to be said that the linear model, used for the results under optimal simple rules, no longer depends on τ. The parameter only influences the steady state, and since the linear model only contains deviations from the steady state, it is no longer present. For the other two parameters, the results regarding the consumption equivalent loss change in size, but stay largely the same in direction.[35] The most limiting factor in terms of determinacy is the Keynesian configuration, which is only defined for values smaller than the standard calibration in the range of $\lambda \in [0, 0.4]$.

[33] See Blanchard and Kahn (1980).

[34] These intervals are heavily dependent on the Taylor weights for inflation and output, but in this thesis only the standard calibration of $\phi_\pi = 1.5$ and ϕ_y=0.125 was used. The full sensitivity analysis, based on a Monte-Carlo simulation, can be found in Appendix E.3.

[35] With a small one-value exception, visible in Appendix E.2.

7 Conclusion

In conclusion, it can be said, that disproportionate central bank objectives, such as focusing exclusively on Ricardian or Keynesian agents, have significant implications for inflation, output, and consumption inequality. In the Keynesian regime, the central bank tolerates higher inflation and pushes output more to reduce the consumption inequality gap. All regimes considered, including the Ricardian regime, contribute to stabilizing the consumption inequality gap more than a monetary policy defined via average consumption. The Ricardian regime inadvertently benefits Keynesian agents when capitalizing on the skill-bias in wages, leading to a reduction in the consumption inequality gap.

Both the Keynesian and Ricardian regimes incorporate inequality more effectively than a regime focused on the average consumption in the economy, resulting in better welfare outcomes. The Ricardian regime comes closest to the welfare optimal regime in terms of total welfare, but also represents a majority in the model. When considering augmented Taylor rules, the Keynesian regime, which optimizes Keynesian utility with an emphasis on the Keynesian consumption gap, achieves slightly better total welfare than a Ricardian regime doing the same.

To reduce inequality, central banks should focus on objectives that take into account the welfare of both Ricardian and Keynesian agents. The results indicate that accepting higher inflation and supporting output, as can be seen in the Keynesian regimes' behaviour, can help to reduce the consumption inequality gap. Additionally, central banks can consider augmented Taylor rules that incorporate consumption inequality gaps or consumption gaps, as these augmentations considerably improve welfare compared to a standard Taylor rule. In the Keynesian and Inequality configurations of Taylor rules, the central bank chooses the weight on the consumption gap in a way that trades off complete macro stabilization for a smaller consumption inequality gap.

It is important to note that, considering the model-specific limitations of the research presented here, the practical implications are limited. Nevertheless, it provides initial insights into how central banks could and should act in the face of inequality. However, I see the primary contribution of this thesis in strengthening the foundation of further research. A better insight into the workings of a model with inequality, as well as a clearer understanding of how an average consumption regime relates to RANK-optimal policy, can support further research on similar models. Building on the insights gained from this study, future research could explore various new directions to enhance our understanding of monetary policy, welfare, and inequality. One approach would be to investigate how the presence of financial frictions, labour market imperfections, or dynamic fiscal policy would alter the conclusions of the current model. Additionally, researchers could explore the applicability of the findings to alternative types of DSGE models, such as introducing more heterogeneous agents to capture more realistic wealth distributions. Lastly, analysing the interaction between monetary policy and macroprudential policy tools when addressing economic inequality would offer valuable insights into the optimal mix of policies for central banks and regulators.

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A Model Derivations

A.1 Final Goods Producer

The demand for intermediate goods and the aggregate price index follow basic results in the New-Keynesian literature. See for example Galí (2015).

Demand for intermediate goods

$$
\begin{aligned}
FOC: \qquad & P_t \frac{\theta_p}{\theta_p - 1}\left[\int_0^1 y_{jt}^{\frac{\theta_p-1}{\theta_p}}\, dj\right]^{\frac{\theta_p}{\theta_p-1}-1} \frac{\theta_p - 1}{\theta_p} y_{jt}^{\frac{\theta_p-1}{\theta_p}-1} \overset{!}{=} p_{jt} \\
\iff & P_t \left[\int_0^1 y_{jt}^{\frac{\theta_p-1}{\theta_p}}\, dj\right]^{\frac{\theta_p}{\theta_p-1}-\frac{\theta_p-1}{\theta_p-1}} \frac{\theta_p - 1}{\theta_p} y_{jt}^{\frac{\theta_p-1}{\theta_p}-\frac{\theta_p}{\theta_p}} = p_{jt} \\
\iff & P_t \left[\int_0^1 y_{jt}^{\frac{\theta_p-1}{\theta_p}}\, dj\right]^{\frac{1}{\theta_p-1}} \frac{\theta_p - 1}{\theta_p} y_{jt}^{\frac{1}{\theta_p}} = p_{jt} \\
\iff & y_{jt}^{-\frac{1}{\theta_p}} = \left(\frac{p_{jt}}{P_t}\right) \left[\int_0^1 y_{jt}^{-\frac{\theta_p-1}{\theta_p}}\, dj\right]^{\frac{1}{\theta_p-1}} \\
\iff & y_{jt} = \left(\frac{p_{jt}}{P_t}\right)^{-\theta_p} \left[\int_0^1 y_{jt}^{\frac{\theta_p-1}{\theta_p}}\, dj\right]^{\frac{1}{\theta_p-1}} \\
\iff & y_{jt} = \left(\frac{p_{jt}}{P_t}\right)^{-\theta_p} Y_t
\end{aligned}
$$

Aggregate Price index

$$
\begin{aligned}
P_t Y_t &= \int_0^1 p_{jt} y_{jt}\, dj \\
\iff P_t Y_t &= \int_0^1 p_{jt} \left(\frac{p_{jt}}{P_t}\right)^{-\theta_p} Y_t dj \\
\iff P_t^{1-\theta_p} &= \int_0^1 p_{jt}^{1-\theta_p} dj \\
\iff P_t &= \left[\int_0^1 p_{jt}^{1-\theta_p} dj\right]^{\frac{1}{1-\theta_p}}
\end{aligned}
$$

A.2 Intermediate Goods Producer optimization terms

Turnover

$$\frac{(1+T_p)y_{jt}p_{jt}}{P_t}$$

$$\Longleftrightarrow \frac{(1+T_p)\left(\frac{p_{jt}}{P_t}\right)^{-\theta_p} Y_t p_{jt}}{P_t}$$

$$\Longleftrightarrow (1+T_p)\frac{p_{jt}^{1-\theta_p}}{P_t^{1-\theta_p}}Y_t$$

Wage cost

$$\frac{W_t}{P_t}L_{jt}$$

$$\Longleftrightarrow w_t\left(\frac{y_{jt}}{A_t}\right)^{\frac{1}{1-\alpha}}$$

$$\Longleftrightarrow w_t\left(\frac{\left(\frac{p_{jt}}{P_t}\right)^{-\theta_p} Y_t}{A_t}\right)^{\frac{1}{1-\alpha}}$$

$$\Longleftrightarrow \frac{w_t}{A_t^{\frac{1}{1-\alpha}}}\left(\frac{p_{jt}}{P_t}\right)^{-\frac{\theta_p}{1-\alpha}} Y_t^{\frac{1}{1-\alpha}}$$

A.3 Intermediate Goods Producer

$$
\begin{aligned}
FOC: \qquad & (1+T_p)(1+\theta_p)\frac{p_{jt}^{-\theta_p}}{P_t^{1-\theta_p}}Y_t - \frac{w_t}{A_t^{\frac{1}{1-\alpha}}}\frac{-\theta_p}{1-\alpha}\left(\frac{p_{jt}}{P_t}\right)^{-\frac{\theta_p}{1-\alpha}-1} P_t^{-1}Y_t^{\frac{1}{1-\alpha}} \\
& - \frac{\psi_p}{2}Y_t * 2 * \left[\frac{p_{jt}}{p_{jt-1}} - 1\right]\frac{1}{p_{jt-1}} \\
& + \beta\left(\frac{C_{rt+1}}{C_rt}\right)^{-1}\frac{\psi_p}{2}Y_{t+1} * 2 * \left[\frac{p_{jt+1}}{p_{jt}} - 1\right]p_{jt+1}p_{jt}^{-2} \stackrel{!}{=} 0
\end{aligned}
$$

$$
\begin{aligned}
\iff & (1+T_p)(1+\theta_p)P_t^{-1}Y_t + \frac{w_t}{A_t^{\frac{1}{1-\alpha}}}\frac{-\theta_p}{1-\alpha}P_t^{-1}P_t^{-1}Y_t\frac{1}{1-\alpha} \\
& - \psi_p Y_t\left[\frac{P_t}{P_{t-1}} - 1\right]P_{t-1}^{-1} + \beta\left(\frac{C_{rt+1}}{C_{rt}}\right)^{-1}\psi_p Y_t t + 1\left[\frac{P_{t+1}}{P_t} - 1\right]P_{t+1}P_t^{-2} \stackrel{!}{=} 0
\end{aligned}
$$

$$
\begin{aligned}
\iff & -(1+T_p)(\theta_p - 1) + \frac{w_t}{A_t^{\frac{1}{1-\alpha}}}\frac{-\theta_p}{1-\alpha}Y_t^{\frac{1}{1-\alpha}}\beta\left(\frac{C_{rt+1}}{C_{rt}}\right)^{-1}\frac{Y_{t+1}}{Y_t}\left[\Pi_{t+1} - 1\right]\Pi_{t+1} \\
& = \psi_p[\Pi_t - 1]\Pi_t
\end{aligned}
$$

$$
\begin{aligned}
\iff & \Pi_t\left[\Pi_t - 1\right] = \beta\left(\frac{C_{rt+1}}{C_{rt}}\right)^{-1}\frac{Y_{t+1}}{Y_t}\Pi_{t+1}\left[\Pi_{t+1} - 1\right] \\
& + \frac{\theta_p}{\psi_p}\left[\frac{1}{1-\alpha}\frac{w_t}{A_t^{\frac{1}{1-\alpha}}}Y_t^{\frac{\alpha}{1-\alpha}} - (1+T_p)\frac{\theta_p - 1}{\theta_p}\right]
\end{aligned}
$$

A.4 Natural Output

First derive an expression w_t, by substituting the aggregate labour supply (12) with the aggregate production function (21):

$$w_t = \chi A_t^{-\frac{1}{1-\alpha}}Y_t^{n\,\frac{\phi+1-\alpha}{1-\alpha}}$$

Then consider the FOC from Appendix A.3 without the price adjustment cost and substitute w_t:

$$
\begin{aligned}
FOC: \qquad & (1+T_p)(\theta_p - 1) = \frac{\theta_p}{1-\alpha}\frac{w_t}{A_t^{\frac{1}{1-\alpha}}}Y_t^{n\,\frac{\alpha}{1-\alpha}} \\
\iff & (1+T_p)(\theta_p - 1) = \frac{\theta_p}{1-\alpha}\chi A_t^{-\frac{\phi}{1-\alpha}}A_t^{\frac{1}{1-\alpha}}Y_t^{n\,\frac{\phi+1-\alpha}{1-\alpha}}Y_t^{n\,\frac{1}{1-\alpha}} \\
\iff & (1+T_p)(\theta_p - 1) = \frac{\theta_p}{1-\alpha}\chi A_t^{-\frac{1+\phi}{1-\alpha}}Y_t^{n\,\frac{1+\phi}{1-\alpha}} \\
\iff & Y_t^n = A_t\left[(1-\alpha)(1-T_p)\frac{\theta_p - 1}{\theta_p}\frac{1}{\chi}\right]^{\frac{1-\alpha}{1+\phi}}
\end{aligned}
$$

B Log-linearizations

Ricardian consumption euler equation

$$
\begin{aligned}
C_{rt}^{-1} =& \beta R_t E_t \left\{ C_{rt+1}^{-1} \frac{1}{\Pi_{t+1}} \right\} \\
\iff \bar{C}_r^{-1} e^{-\hat{C}_{rt}} &= \beta \frac{\bar{R}}{\bar{C}_r \bar{\Pi}} e^{\hat{R}_t} e^{-E_t \hat{C}_{rt+1}} e^{-E_t \hat{\Pi}_{t+1}} \\
\iff \bar{C}_r^{-1} e^{-\hat{C}_{rt}} &= \beta \frac{\bar{R}}{\bar{C}_r \bar{\Pi}} e^{\hat{R}_t - E_t \hat{C}_{rt+1} - E_t \hat{\Pi}_{t+1}} \\
\overset{Taylor}{\iff} \bar{C}_r^{-1}(1 - \hat{C}_{rt}) &= \beta \frac{\bar{R}}{\bar{C}_r \bar{\Pi}} (1 + \hat{R}_t - E_t \hat{C}_{rt+1} - E_t \hat{\Pi}_{t+1}) \\
\overset{-static}{\iff} \bar{C}_r^{-1}(-\hat{C}_{rt}) &= \beta \frac{\bar{R}}{\bar{C}_r \bar{\Pi}} (\hat{R}_t - E_t \hat{C}_{rt+1} - E_t \hat{\Pi}_{t+1}) \\
\overset{/static}{\iff} \hat{C}_{rt} &= E_t \hat{C}_{rt+1} - \hat{R}_t + E_t \hat{\Pi}_{t+1}
\end{aligned}
$$

Keynesian Budget constraint

$$
\begin{aligned}
C_{kt} &= \left(\frac{A_t}{\bar{A}} \right)^{-\gamma} w_t N_t - T_p Y_t + t_{kt} \\
\iff \bar{C}_k e^{\hat{C}_{kt}} &= e^{-\gamma \hat{A}_t} \bar{w} \bar{N} e^{\hat{w}_t} e^{\hat{N}_t} - T_p \bar{Y} e^{\hat{Y}_t} + \bar{t}_k e^{\hat{t}_{tk}} \\
\iff \bar{C}_k e^{\hat{C}_{kt}} &= \bar{w} \bar{N} e^{\hat{w}_t + \hat{N}_t - \gamma \hat{A}_t} - T_p \bar{Y} e^{\hat{Y}_t} + \bar{t}_k e^{\hat{t}_{tk}} \\
\overset{Taylor}{\iff} \bar{C}_k(1 + \hat{C}_{kt}) &= \bar{w} \bar{N}(1 + \hat{w}_t + \hat{N}_t - \gamma \hat{A}_t) - T_p \bar{Y}(1 + \hat{Y}_t) + \bar{t}_k(1 + \hat{t}_{tk}) \\
\overset{-static}{\iff} \hat{C}_{kt} &= \frac{\bar{w} \bar{N}}{\bar{C}_k} (\hat{w}_t + \hat{N}_t - \gamma \hat{A}_t) - \frac{T_p \bar{Y}}{\bar{C}_k} \hat{Y}_t + \frac{\bar{t}_k}{\bar{C}_k} \hat{t}_{tk}
\end{aligned}
$$

Labour Supply

$$\begin{aligned}
w_t =& \chi N_t^{\phi} Y_t \\
\Longleftrightarrow \bar{w} e^{\hat{w}_t} =& \chi \bar{N}^{\phi} \bar{Y} e^{\phi \hat{N}_t} e^{\hat{Y}_t} \\
\Longleftrightarrow \bar{w} e^{\hat{w}_t} =& \chi \bar{N}^{\phi} \bar{Y} e^{\phi \hat{N}_t \hat{Y}_t} \\
\overset{Taylor}{\Longleftrightarrow} \bar{w}(1 + \hat{w}_t) =& \chi \bar{N}^{\phi} \bar{Y}(1 + \phi \hat{N}_t + \hat{Y}_t) \\
\overset{-static}{\Longleftrightarrow} \bar{w}\hat{w}_t =& \chi \bar{N}^{\phi} \bar{Y}(\phi \hat{N}_t + \hat{Y}_t) \\
\overset{/static}{\Longleftrightarrow} \hat{w}_t =& \phi \hat{N}_t + \hat{Y}_t
\end{aligned}$$

Aggregate Production Function

$$\begin{aligned}
Y_t =& A_t N_t^{1-\alpha} \\
\Longleftrightarrow \bar{Y}\hat{Y}_t =& \bar{A}\bar{N}^{1-\alpha} e^{\hat{A}_t} + e^{(1-\alpha)\hat{N}_t} \\
\Longleftrightarrow \bar{Y}\hat{Y}_t =& \bar{A}\bar{N}^{1-\alpha} e^{\hat{A}_t + (1-\alpha)\hat{N}_t} \\
\overset{Taylor}{\Longleftrightarrow} \bar{Y}(1 + \hat{Y}_t) =& \bar{A}\bar{N}^{1-\alpha}(1 + \hat{A}_t + (1-\alpha)\hat{N}_t) \\
\overset{-static}{\Longleftrightarrow} \bar{Y}\hat{Y}_t =& \bar{A}\bar{N}^{1-\alpha}(\hat{A}_t + (1-\alpha)\hat{N}_t) \\
\overset{/static}{\Longleftrightarrow} \hat{Y}_t =& \hat{A}_t + (1 - \alpha \hat{N}_t)
\end{aligned}$$

Dividends

$$\begin{aligned}
d_t =& (1 + Tp)Y_t - w_t N_t - \frac{\psi_p}{2}(\Pi_t - 1)^2 \\
\Longleftrightarrow \bar{d} e^{\hat{d}_t} =& (1 + T_p)\bar{Y} e^{\hat{Y}_t} - \bar{w}\bar{N} e^{\hat{w}_t} e^{\hat{N}_t} - \frac{\psi_p}{2} \bar{Y} e^{\hat{Y}_t} (\bar{\Pi} e^{\hat{\Pi}_t} - 1)^2 \\
\Longleftrightarrow \bar{d} e^{\hat{d}_t} =& (1 + T_p)\bar{Y} e^{\hat{Y}_t} - \bar{w}\bar{N} e^{\hat{w}_t + \hat{N}_t} \\
& - \frac{\psi_p}{2}\left[\bar{Y}\bar{\Pi}^2 e^{2\hat{\Pi}_t + \hat{Y}_t} - 2\bar{Y}\bar{\Pi} e^{\hat{\Pi}_t + \hat{Y}_t} + \bar{Y} e^{\hat{Y}_t}\right] \\
\overset{Taylor}{\Longleftrightarrow} \bar{d}(1 + \hat{d}_t) =& (1 + T_p)\bar{Y}(1 + \hat{Y}_t) - \bar{w}\bar{N}(1 + \hat{w}_t + \hat{N}_t) \\
& - \frac{\psi_p}{2}\bar{Y}\left[\bar{\Pi}^2(1 + 2\hat{\Pi}_t + \hat{Y}_t) - 2\bar{\Pi}(1 + \hat{\Pi}_t + \hat{Y}_t) + (1 + \hat{Y}_t)\right] \\
\overset{-static}{\Longleftarrow} \bar{d}\hat{d}_t =& (1 + T_p)\bar{Y}\hat{Y}_t - \bar{w}\bar{N}(\hat{w}_t - \hat{N}_t) \\
& - \frac{\psi_p}{2}\bar{Y}\left[\bar{\Pi}^2(2\hat{\Pi}_t + \hat{Y}_t) - 2\bar{\Pi}(\hat{\Pi}_t + \hat{Y}_t) + \hat{Y}_t\right] \\
\overset{\bar{\Pi}=1}{\Longleftrightarrow} (1 + T_p)\hat{Y}_t =& \frac{\bar{d}}{\bar{Y}}\hat{d}_t + \frac{\bar{w}\bar{N}}{\bar{Y}}(\hat{w}_t + \hat{N}_t)
\end{aligned}$$

Ricardian Fiscal Policy

$$
\begin{aligned}
t_{rt} =& \frac{\delta d_t - \lambda t_{kt}}{1-\lambda} \\
\bar{t}_r e^{\hat{t}_{rt}} =& \frac{1}{1-\lambda}(\delta \bar{d} e^{\hat{d}_t} - \lambda \bar{t}_k e^{\hat{t}_{kt}}) \\
\overset{Taylor}{\iff} \bar{t}_r(1+\hat{t}_{rt}) =& \frac{\delta \bar{d}(1+\hat{d}_t) - \lambda \bar{t}_k(1+\hat{t}_{kt})}{1-\lambda} \\
\overset{-static}{\iff} \bar{t}_r \hat{t}_{rt} =& \frac{\delta \bar{d}\hat{d}_t - \lambda \bar{t}_k \hat{t}_{kt}}{1-\lambda} \\
\iff \hat{d}_t =& \frac{(1-\lambda)\bar{t}_r}{\delta \bar{d}} \hat{t}_{rt} + \frac{\lambda \bar{t}_k}{\delta \bar{d}} \hat{t}_{kt}
\end{aligned}
$$

Keynesian Fiscal Policy

$$
\begin{aligned}
t_{kt} =& (1-\tau)\delta d_t \\
\iff \bar{t}_k e^{\hat{t}_{kt}} =& (1-\tau)\delta \bar{d} e^{\hat{d}_t} \\
\overset{Taylor}{\iff} \bar{t}_k(1+\hat{t}_{kt}) =& (1-\tau)\delta \bar{d}(1+\hat{d}_t) \\
\overset{-static}{\iff} \bar{t}_k \hat{t}_{kt} =& (1-\tau)\delta \bar{d}\hat{d}_t \\
\overset{/static}{\iff} \hat{t}_{kt} =& \hat{d}_t
\end{aligned}
$$

Goods Market Clearing

$$
\begin{aligned}
Y_t =& \lambda C_{kt} + (1-\lambda)C_{rt} + \frac{\psi_p}{2}(\Pi_t - 1)^2 \\
\iff \bar{Y} e^{\hat{Y}_t} =& \lambda \bar{C}_k e^{\hat{C}_{kt}} + (1-\lambda)\bar{C}_r e^{\hat{C}_{rt}} + \frac{\psi_p}{2}(\bar{\Pi} e^{\hat{\Pi}_t} - 1)^2 \\
\iff \bar{Y} e^{\hat{Y}_t} =& \lambda \bar{C}_k e^{\hat{C}_{kt}} + (1-\lambda)\bar{C}_r e^{\hat{C}_{rt}} \\
&+ \frac{\psi_p}{2}\left(\bar{Y}\bar{\Pi}^2 e^{2\hat{\Pi}_t + \hat{Y}_t} - 2\bar{Y}\bar{\Pi} e^{\hat{\Pi}_t + \hat{Y}_t} + \bar{Y} e^{\hat{Y}_t}\right) \\
\overset{Taylor}{\iff} \bar{Y}(1+\hat{Y}_t) =& \lambda \bar{C}_k(1+\hat{C}_{kt}) + (1-\lambda)\bar{C}_r(1+\hat{C}_{rt}) \\
&+ \frac{\psi_p}{2}\bar{Y}\left(\bar{\Pi}^2(1+2\hat{\Pi}_t + \hat{Y}_t) - 2\bar{\Pi}(1+\hat{\Pi}_t + \hat{Y}_t) + (1+\hat{Y}_t)\right) \\
\overset{-static}{\iff} \bar{Y}\hat{Y}_t =& \lambda \bar{C}_k \hat{C}_{kt} + (1-\lambda)\bar{C}_r \hat{C}_{rt} \\
&+ \frac{\psi_p}{2}\bar{Y}\left(\bar{\Pi}^2(2\hat{\Pi}_t + \hat{Y}_t) - 2\bar{\Pi}(\hat{\Pi}_t + \hat{Y}_t) + \hat{Y}_t\right) \\
\overset{\bar{\Pi}=1}{\iff} \bar{Y}\hat{Y}_t =& \lambda \bar{C}_k \hat{C}_{kt} + (1-\lambda)\bar{C}_r \hat{C}_{rt} \\
\iff \hat{Y}_t =& \lambda \frac{\bar{C}_k}{\bar{Y}} \hat{C}_{kt} + (1-\lambda)\frac{\bar{C}_r}{\bar{Y}} \hat{C}_{rt}
\end{aligned}
$$

Natural Output

$$
\begin{aligned}
Y_t^n =& A_t \left[(1+T_p)(1-\alpha)\frac{\theta_P-1}{\theta_P}\frac{1}{\chi}\right]^{\frac{1-\alpha}{1+\phi}} \\
\Longleftrightarrow \bar{Y}_t^n e^{\hat{Y}_t^n} =& \bar{A} e^{\hat{A}_t} \left[(1+T_p)(1-\alpha)\frac{\theta_P-1}{\theta_P}\frac{1}{\chi}\right]^{\frac{1-\alpha}{1+\phi}} \\
\overset{Taylor}{\Longleftrightarrow} \bar{Y}_t^n(1+\hat{Y}_t^n) =& \bar{A}(1+\hat{A}_t) \left[(1+T_p)(1-\alpha)\frac{\theta_P-1}{\theta_P}\frac{1}{\chi}\right]^{\frac{1-\alpha}{1+\phi}} \\
\overset{-static}{\Longleftrightarrow} \bar{Y}_t^n \hat{Y}_t^n =& \bar{A}\hat{A}_t \left[(1+T_p)(1-\alpha)\frac{\theta_P-1}{\theta_P}\frac{1}{\chi}\right]^{\frac{1-\alpha}{1+\phi}} \\
\overset{/static}{\Longleftrightarrow} \hat{Y}_t^n =& \hat{A}_t
\end{aligned}
$$

Exogenous Process

$$
\begin{aligned}
A_t =& \bar{A} e^{\epsilon_t} \\
\Longleftrightarrow \bar{A} e^{\hat{A}_t} =& \bar{A} e^{\epsilon_t} \\
\Longleftrightarrow \hat{A}_t =& \epsilon_t
\end{aligned}
$$

Taylor Rule

$$
\begin{aligned}
\frac{R_t}{\bar{R}} =& \left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\phi_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_y} \\
\Longleftrightarrow e^{\hat{R}_t} =& e^{\phi_\pi \hat{\Pi}_t} e^{\phi_y \hat{Y}_t} \\
\Longleftrightarrow e^{\hat{R}_t} =& e^{\phi_\pi \hat{\Pi}_t + \phi_y \hat{Y}_t} \\
\overset{Taylor}{\Longleftrightarrow} (1+\hat{R}_t) =& (1+\phi_\pi \hat{\Pi}_t + \phi_y \hat{Y}_t) \\
\Longleftrightarrow \hat{R}_t =& \phi_\pi \hat{\Pi}_t + \phi_y \hat{Y}_t
\end{aligned}
$$

C Definitions

C.1 Welfare: Quadratic gaps equation

$$
\begin{aligned}
W_{\Delta_c} =& \tilde{\lambda}(1-\tilde{\lambda}) \\
W_{\Pi} =& \psi_p \left[1 - \frac{(\lambda-\tilde{\lambda})}{1-\tilde{\lambda}}\left[1-\frac{(1-\tau)\delta}{\tilde{C}_k}\right]\right] \\
W_Y =& \frac{1+\phi}{1-\alpha} + \frac{(\lambda-\tilde{\lambda})}{(1-\tilde{\lambda})^2}\left(\frac{(1-\alpha)(1-(1-\tau)\delta)}{\tilde{C}_k}\right)^2\left(\frac{1+\phi}{1-\alpha}\right)^2 \\
T_0 =& \frac{(\lambda-\tilde{\lambda})}{1-\tilde{\lambda}}\frac{[1-(1-\tau)\delta](1-\alpha)}{\bar{\tilde{C}}_k} * \\
& \sum_{t=0}^{\infty}\beta^t\left\{\hat{LS}_t + \left(\frac{1}{2}+\frac{\tilde{\lambda}}{1-\tilde{\lambda}}\frac{[1-(1-\tau)\delta](1-\alpha)}{\bar{\tilde{C}}_k}\right)\hat{LS}_t^2 - \frac{\tilde{\lambda}}{1-\tilde{\lambda}}\gamma\frac{(1-\alpha)}{\bar{\tilde{C}}_k}\hat{A}_t\hat{LS}_t\right\} \\
W_{AY} =& \frac{1+\phi}{1-\alpha} + \frac{(\lambda-\tilde{\lambda})}{(1-\tilde{\lambda})^2}\left[\frac{[1-(1-\tau)\delta](1-\alpha)}{\bar{\tilde{C}}_k}\right]^2\left(\frac{1+\phi}{1-\alpha}\right)^2 - \\
& \frac{(\lambda-\tilde{\lambda})}{1-\tilde{\lambda}}\gamma\frac{1-\alpha}{\bar{\tilde{C}}_k}\left[1-\frac{[1-(1-\tau)\delta](1-\alpha)}{\bar{\tilde{C}}_k}\right]\frac{1+\phi}{1-\alpha} \\
\hat{Y}^* =& \frac{W_{AY}}{W_Y}\hat{A}_t
\end{aligned}
$$

, where $\tilde{\lambda} = \lambda\frac{\bar{C}_k}{\bar{Y}} = \lambda\bar{\tilde{C}}_k$ and $\hat{LS}_t = \frac{1+\phi}{1-\alpha}(\hat{Y}_t - \hat{A}_t)$.

C.2 Weights on Gaps for alternative policy regimes

Ricardian policy regime

$$
\begin{aligned}
W_{\Delta_c} =& 0 \\
W_{\Pi} =& \psi_p \\
W_Y =& \frac{1+\phi}{1-\alpha}
\end{aligned}
$$

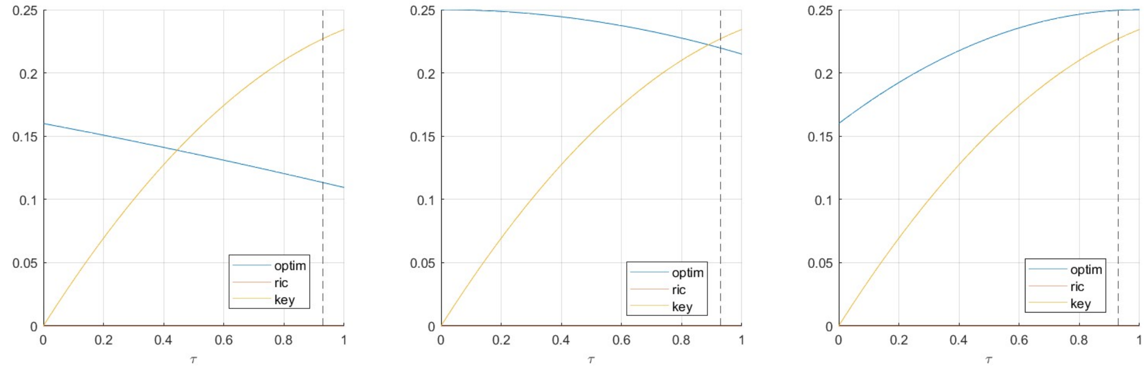
Keynesian policy regime

$$
\begin{aligned}
W_{\Delta_c} =& \tilde{\lambda}(1-\tilde{\lambda}) \\
W_{\Pi} =& \psi_p \left[1 - \left[1 - \frac{(1-\tau)\delta}{\tilde{C}_k} \right] \right] \\
W_Y =& \frac{1+\phi}{1-\alpha} + \frac{1}{(1-\tilde{\lambda})} \left(\frac{(1-\alpha)(1-(1-\tau)\delta)}{\tilde{C}_k} \right)^2 \left(\frac{1+\phi}{1-\alpha} \right)^2
\end{aligned}
$$

, where $\tilde{\lambda} = \frac{\bar{C}_k}{\bar{Y}} = \overline{\tilde{C}}_k$.

D Additional Results

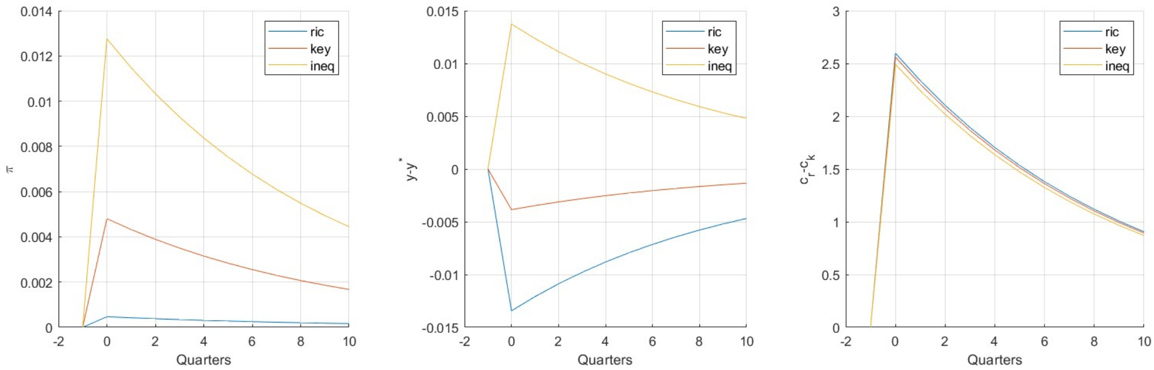
D.1 Weight on Consumption Inequality Gap when varying λ



(a) $\lambda = 0.2$ (b) $\lambda = 0.5$ (c) $\lambda = 0.8$

Figure 5: Different weights for the consumption inequality gap, depending on τ, for the different optimal policy regimes discussed in section 4. The weight for the welfare optimal regime, "optim", is varied by different fractions of Keynesian agents λ for each of the three panels.

D.2 Impulse response functions on augmented Taylor rules, utilizing welfare optimal weights on gaps



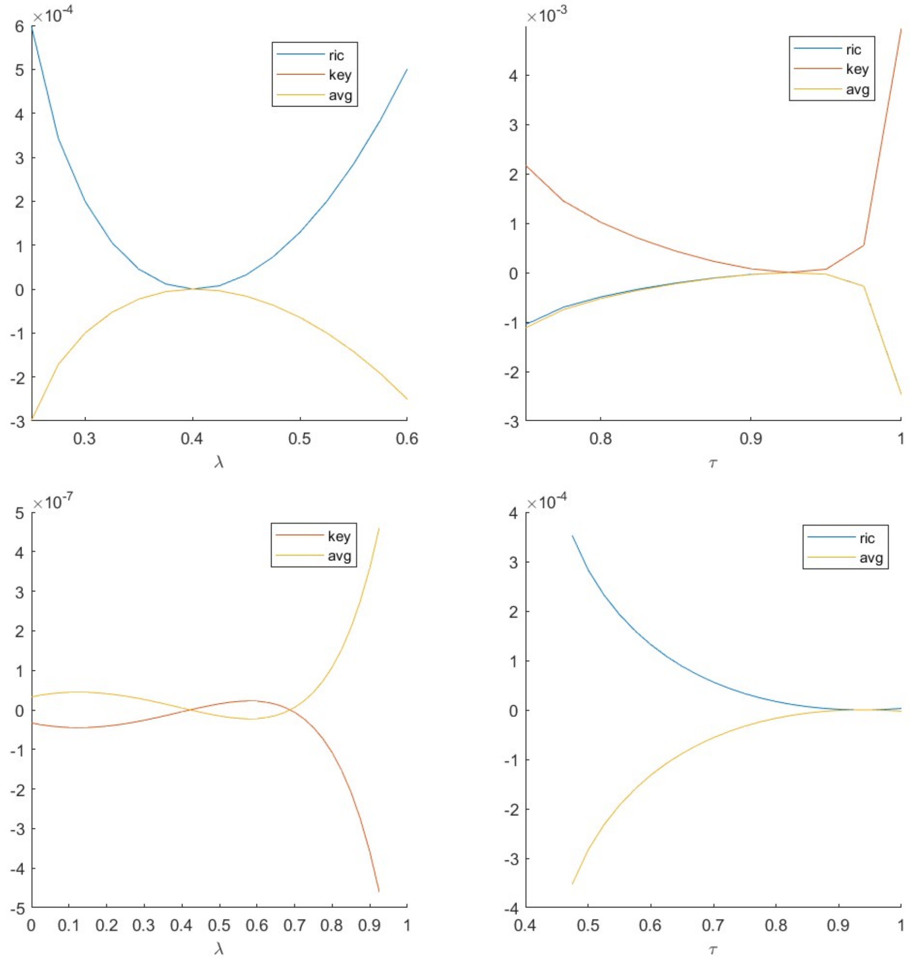
(a) Inflation Gap (b) Output Gap (c) Consumption Gap

Figure 6: The three panels show the impulse responses to a positive TFP shock with regard to the inflation, output and consumption gap, respectively. The yellow, blue, and black line correspond to the rules from 68, 69, and 70, respectively, with a calibration of $\phi_\pi = 1.5, \phi_y = 0.125, \phi_c = \phi_c^*$, where ϕ_c^* is calculated using the welfare optimal weights from Appendix C.1 for all cases.

E Robustness checks

The robustness checks on Ramsey and OSR results show the differences compared to a reference line. This is done in order to visualize minuscule differences between the lines. The differences, therefore, look exaggerated here, but note that actual differences are very small.

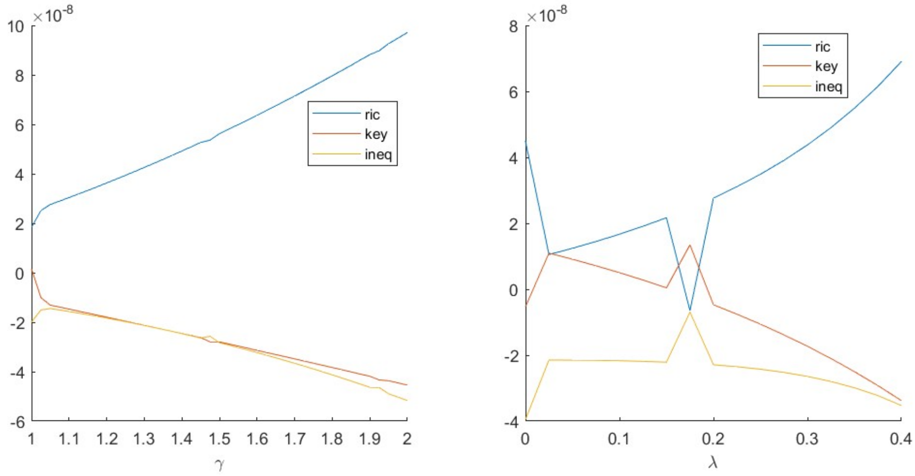
E.1 Robustness checks on Ramsey results



(a) Fraction of Keynesians (b) Steady state Inequality

Figure 7: The figure visualizes differences in the consumption equivalent loss when compared to the optimal welfare regime between the Ricardian 'ric', the Keynesian 'key' and the average consumption regime 'avg'. The CES results are varied on the parameter λ (left panel) and parameter τ (right panel). For better visualizations, the differences between the regimes are plotted against a reference line. The reference line consists of the average consumption equivalent loss of all three regimes. The lower panels show the same for the Keynesian/Ricardian and the Average consumption regime since they are indistinguishable on the scale of the upper panels.

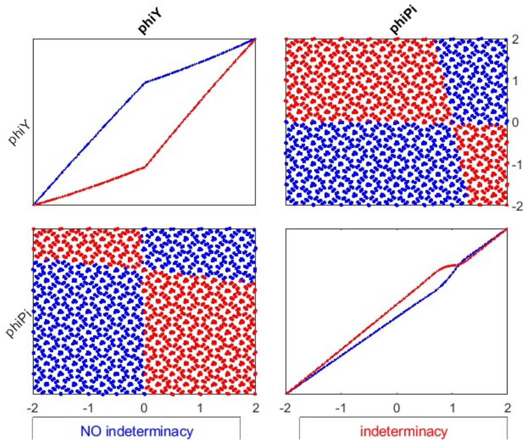
E.2 Robustness checks on OSR results



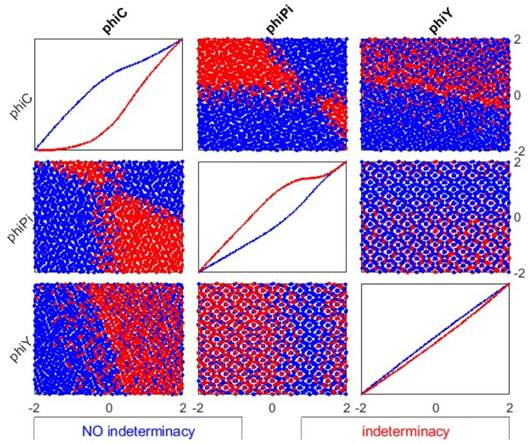
(a) Cyclical Inequality (b) Fraction of Keynesians

Figure 8: The figure visualizes differences in the consumption equivalent loss when compared to the standard Taylor rule between the Ricardian 'ric', the Keynesian 'key', and the inequality 'ineq' configurations. The CES results are varied on the parameters γ and λ. For Figure b, the differences between the configurations are plotted against a reference line. The reference line consists of the average consumption equivalent loss under all three configurations.

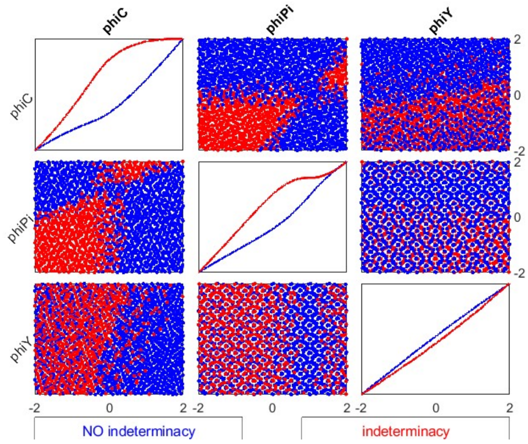
E.3 Sensitivity Analysis on the weights of different Taylor rules



(a) Ricardian configuration



(b) Keynesian configuration



(c) Inequality configuration

Figure 9: The figure shows the sensitivity analysis on the weights of the different Taylor rule configurations from section 5. The analysis is based on a Monte-Carlo simulation, checking whether the Blanchard-Khan conditions are satisfied for the given weight configuration or not (n=2048). Blue dots refer to the simulations where the conditions were fulfilled, while the red dots mark the opposite.

Statutory Declaration

"I herewith declare that I have composed the present thesis myself and without use of any other than the cited sources and aids. Sentences or parts of sentences quoted literally are marked as such; other references with regard to the statement and scope are indicated by full details of the publications concerned. The thesis in the same or similar form has not been submitted to any examination body and has not been published. This thesis was not yet, even in part, used in another examination or as a course performance. Furthermore I declare that the submitted written (bound) copies of the present thesis and the version submitted on a data carrier are consistent with each other in contents."

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