Pontifícia Universidade Católica
do Rio de Janeiro

Lucas Maneschy Costa Ferreira

Monetary Policy and Welfare Outcomes from Heterogeneity

Dissertação de Mestrado

Dissertation presented to the Programa de Pós–graduação em Economia of PUC-Rio in partial fulfillment of the requirements for the degree of Mestre em Economia.

Advisor: Prof. Eduardo Zilberman

Rio de Janeiro
August 2022

Pontifícia Universidade Católica do Rio de Janeiro

Lucas Maneschy Costa Ferreira

Monetary Policy and Welfare Outcomes from Heterogeneity

Dissertation presented to the Programa de Pós–graduação em Economia of PUC-Rio in partial fulfillment of the requirements for the degree of Mestre em Economia. Approved by the Examination Committee.

Prof. Eduardo Zilberman
Advisor
Departamento de Economia – PUC-Rio

Prof. Yvan Pierre Becard
Departamento de Economia – PUC-Rio

Prof. Felipe Saraiva Iachan
Escola Brasileira de Economia e Finanças – FGV EPGE

Rio de Janeiro, August 25th, 2022

Lucas Maneschy Costa Ferreira

B.A., Economics, Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio), 2018

Bibliographic data

Maneschy Costa Ferreira,Lucas

Monetary Policy and Welfare Outcomes from Heterogeneity / Lucas Maneschy Costa Ferreira; advisor: Eduardo Zilberman. – Rio de janeiro: PUC-Rio , Departamento de Economia, 2022.

v., 119 f: il. color. ; 30 cm

Dissertação (mestrado) - Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Economia.

Inclui bibliografia

1. Economia – Teses. 2. Heterogeneidade. 3. HANK. 4. Política monetária. 5. Taylor rule. 6. Bem-estar. I. Zilberman, Eduardo. II. Pontifícia Universidade Católica do Rio de Janeiro. Departamento de Economia. III. Título.

CDD: 339

To my parents, for their support and encouragement. And to my brother who made me interested in economics.

Acknowledgments

To my adviser Professor Eduardo Zilberman for all his time, experience and mentorship. Thanks also to Professor Yvan Bécard for his valuable comments and for our discussions about economics.

I also thank the other professors and the staff of the Department of Economics at PUC-Rio.

Finally, I thank to CNPq and PUC-Rio, for the aids granted, without which this work does not could have been accomplished.

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

Abstract

Maneschy Costa Ferreira,Lucas; Zilberman, Eduardo (Advisor). **Monetary Policy and Welfare Outcomes from Heterogeneity**. Rio de Janeiro, 2022. 119p. Dissertação de Mestrado – Departamento de Economia, Pontifícia Universidade Católica do Rio de Janeiro.

We explore the relation between monetary policy and welfare in a heterogeneous agent New Keynesian (HANK) model by grouping households in wealth classes. Our goal is to analyze the principal channels through which monetary policy affects classes' income, savings and how it is related to their welfare after a demand and technology shocks. Our analysis covers different signs and magnitudes for these shocks, along with different Taylor rules and parameters' calibration. In the demand shock case, the wealthiest 10% and poorest 90% have irreconcilable policy preferences. We propose total income is central to explain classes' policy preferences. Bigger streams of income augment the number of consumption and leisure streams households can choose, improving welfare. In the technology shock case, after a negative shock, rules more reactive to output moderate the rise in interest rates and the recession. We propose it is relatively easier to cushion the shock under these rules by increasing borrowings. Consequently, households prefer them instead of rules more reactive to inflation and non reactive to output. However, after a positive shock, households prefer the Taylor rule which maximize total income, following the same logic from the demand shock case.

Keywords

Heterogeneity HANK Monetary policy Taylor rule Welfare

Resumo

Maneschy Costa Ferreira,Lucas; Zilberman, Eduardo. **Política Monetária e Consequências da Heterogeneidade para o Bem-Estar**. Rio de Janeiro, 2022. 119p. Dissertação de Mestrado – Departamento de Economia, Pontifícia Universidade Católica do Rio de Janeiro.

Investigamos a relação entre política monetária e bem-estar em um modelo de agentes heterogêneos Novo Keynesiano (HANK) agrupando as famílias em classes de riqueza. Nosso objetivo é analisar os principais canais pelos quais a política monetária afeta a renda e a poupança das classes e como isso se relaciona com seu bem-estar após choques de demanda e tecnológico. Nossa análise abrange diferentes sinais e magnitudes para os choques, juntamente com diferentes regras de Taylor e calibração de parâmetros. No caso do choque de demanda, os 10% mais ricos e os 90% mais pobres têm preferências políticas irreconciliáveis. Propomos que a renda total é central para explicar as preferências políticas das classes. Quão maior for a renda, maior o número de escolhas factíveis de consumo e lazer os quais as famílias podem escolher. Isso melhoraria o bem-estar delas. No caso do choque tecnológico, após um choque negativo, regras mais reativas ao hiato do produto moderam a elevação dos juros e a recessão. Propomos que é relativamente mais fácil amortecer o choque sob essas regras, tomaando mais empréstimos. Consequentemente, as famílias as preferem em vez de regras mais reativas à inflação e pouco reativas ao hiato do produto. Entretanto, após um choque positivo, as famílias preferem a regra de Taylor que maximiza a sua renda total, seguindo a mesma lógica do caso do choque de demanda.

Palavras-chave

Heterogeneidade   HANK   Política monetária   Taylor rule   Bem-estar

Table of contents

List of figures

List of tables

1
Introduction

In macroeconomics, a common hypothesis is that households can be described by a representative agent, unfortunately it precludes an assessment of what is the overall effect of monetary policy on different households. However, recent developments in modeling have made heterogeneous agent models easier to solve and simulate, allowing macroeconomists to conduct research on how monetary policy channels affect each household individually.

We seek to study households' preferences for different monetary policy rules, specifically Taylor rules. We build a one-asset Heterogeneous Agent New Keynesian (**HANK**) model. Households are exposed to idiosyncratic shocks on their labour productivity and may save or borrow in government bonds, the sole issuer of assets in this economy. We use Achdou *et al.* (2022) algorithm to compute the steady state of our model, and Ahn *et al.* (2018) linearization procedure to simulate the transition dynamics after MIT-Shocks.

We conduct three policy experiments. The first is our baseline model in which the calibration follows diverse sources in the literature. We compute the Impulse Response Functions (**IRF**s) after a one-time MIT-shock, for different Taylor rules. We simulate for one and two standard deviations, expansionary and contractionary, demand and technology shocks.

We group our households in different wealth classes and compute each class' life-time consumption equivalent under different rules relative to their steady-state. Then, we make a positive welfare analysis for each class.

In the demand shock case, the top 10% and bottom 90% of the wealth distribution have irreconcilable policy preferences. No matter the shock's sign or magnitude, the best policy for the top 10% is the worst for the bottom 90% and vice-versa. As each class have different wealth levels, they are differently exposed to movements in the interest rate, impacting the richest households more. Therefore, financial income is the most important income component for the wealthiest households. Consequently, they prefer policy rules which maximize financial and total income.

On the other hand, the poorer non-indebted households don't reap much benefits from interest rate hikes, nor they lose too much from falling interest rates. Also, the indebted households prefer rates to fall, so they can make lower interest payments. For these households, financial income has a smaller weigh in income and income dynamics, thus other components have a more prominent role.

After a demand shock, if wages increase, labour income follow suit, but profits fall because marginal costs increase. If it falls, labour income once again move with wages, profits rise, however, as marginal costs decrease. As a result, these components' impact on income have different signs and will almost annul one another. Therefore, labour income and profits play a small part in determining total income dynamics.

Interest rates and wages always move together after a discount factor shock. So, while the national debt service increases with interest rates, wages also rise, propping up labour tax revenue. In the same manner, if interest rates fall, the government debt service also decreases, but as wages also fall, labour tax revenue diminishes as well. Therefore, regardless of the shock's sign, transfers might increase or fall depending on the policy rule adopted, and how it affects wages and interest rates.

For the bottom 90%, households will prefer policies which maximize transfers, even if it means a smaller financial income. They prefer to live in a economy where the Taylor rule guarantees an increase in transfers because, in their case, it compensates for a smaller financial income. Therefore, they choose the policy delivering the highest income stream.

No matter the shock's sign or magnitude, after a demand shock, households always prefer the policy rule which maximizes their income. We argue the higher the income stream, the largest is the set of consumption and leisure streams the household can choose. Therefore, the Taylor rule that maximizes income will be the best policy.

In the technology shock case, all classes agree on the same policy preferences. Nonetheless, the determining component of income dynamics will vary with the Taylor rule adopted. Once again, as each class have different wealth levels, they are differently exposed to movements in the interest rate, impacting the richest households more. However, in all simulations, interest rates change moderately, thus financial income have a parsimonious effect on income dynamics.

The main driver of income change will be profits and labour income. After a negative shock, rules more reactive to output gap generate a smaller increase in the interest rates. Therefore, the recession is less accentuated, and wages fall less, reducing its impact on labour income. However, it also increases marginal costs, causing a huge fall in profits. Consequently, these rules decrease income the most.

Paradoxically, after a negative technology shock, households prefer rules more reactive to output, even though income drops the most under them. As inflation rises and output falls after a contractionary technology shock, the central bank, which weighs output gap in his decision, will choose a more dovish policy. A loose policy makes borrowing easier for households, which borrow more to cushion the shock. It improves welfare, making these policies the preferred ones.

Policy rules which react less to output, however, increase interest rates the most. It worsens the recession, leading to a bigger decrease in wages. Now, labour income has a more accentuated drop, while marginal costs rise moderately, and so profits' fall is more temperate. Nonetheless, the tighten monetary policy restricts borrowing, thus it is more difficult for households to cushion the shock.

However, after a positive technology, the same logic from the demand shock case follows. Rules more reactive to inflation and less reactive to output decrease interest rates more intensively, providing more stimulus to the economy. Under them, income increases the most led by rising wages and labour income. Households prefer these policies as they increase their choices over consumption and leisure streams.

The second calibration consists in increasing the economy's liquidity by augmenting the net supply of bonds. We call it the high liquidity model setting. As the net supply of bonds augment, households' wealth or debt increases, therefore their exposure to changes in the interest rates also rises. Additionally, as the national debt increases, interest rates' impact on transfers rise.

In the demand shock case, the new dynamics change policy preferences for the top $10-30\%$, which will now agree with the top 10%. As financial income has a stronger effect over its income dynamics, a policy which maximizes financial income is also maximizing total income, so households' preferences in this class change. In the technology shock case, although there is a change in income and savings dynamics, policy preferences won't be altered.

In the third, we enhance the risk of unemployment, i.e. getting a low labour productivity state. We call it the high unemployment setting. As the idiosyncratic risk increases, households will accumulate more wealth due to precautionary motives, or be more indebted. Therefore, their exposure to changes in the interest rates rises.

In the demand shock case, once again, the new dynamics change policy preferences for the top $10-30\%$, which will now agree with the top 10%. As in the high liquidity setting, financial income has a stronger effect over its income dynamics, so a policy which maximizes financial income is also maximizing total income, changing households' preferences in this class. In the technology shock case, although there is a change in income and savings dynamics, policy preferences won't be altered.

Relation to the Literature

Our work is based on the one-asset heterogeneous agent New Keynesian (HANK) model in continuous time. This new class of model generally presents households who insure themselves against idiosyncratic labour productivity shocks by trading risk-free bonds in an incomplete market, and are subject to a borrowing constraint, as in Huggett (1993) and Aiyagari (1994).

On the other hand, the firm side remains close to the traditional representative agent New Keynesian (**RANK**) models. A continuous of intermediary firms behave as in a monopolistic competitive market, and sell their products to final firms, which sell their final good in a perfectly competitive market. Prices are rigid à la Rotemberg (1982), although discrete time HANKs feature rigidity à la Calvo (1983) as well.

HANK was probably first introduced in Mckay *et al.* (2016) to explain how precautionary savings could reduce the power of forward guidance, thus solving the forward guidance puzzle. Afterwards, other research topics were explored using the new class of model. Auclert (2019) builds a model in discrete time to study the redistribution channel of monetary policy. Our model features his earnings heterogeneity channel. Monetary policy impacts labour and profits earnings, nonetheless, their gains or losses aren't evenly distributed, as some households are more favoured or hurt than others.

Kaplan *et al.* (2018) models a two asset HANK model in continuous time to discuss how HANK differs and improve RANK models and the two agents New Keynesian (**TANK**) models. E.g., with two assets, one liquid and the other illiquid, it is possible to match the model's wealth to output ratio with the data, while obtaining high marginal propensities to consume (**MPC**s), which isn't possible in a RANK or an one asset HANK model. It also matches other moments of the wealth distribution to those of the data. We make our calibration as close as possible to theirs. Also, we seek to match some of the same moments such as the fraction of indebted households in the population in our model's wealth distribution.

Nonetheless, we took our model from PHACT Toolbox example in Ahn (2017) which is similar to a continuous time version of the model in Mckay *et al.* (2016). Therefore, it features only one asset and can't match wealth to output ratio with the Survey of Consumer Finances (**SCF**) data, only the liquid wealth output ratio. Also, we are unable to match the fraction of hand-to-mouth households in the population, as we don't penalize borrowers by imposing a wedge between borrowing and lending rates. As a result, our MPCs won't match the empirical evidence from micro data (see, e.g., Broda & Parker (2014), Blundell *et al.* (2008) and Johnson *et al.* (2006)). Finally, we preferred to adopt a simple Poisson process to model our labour productivity idiosyncratic shock, instead of the more realistic jump-drift process.

In Achdou *et al.* (2022), they describe an algorithm with finite differences method to compute the model's steady state distribution. Ahn *et al.* (2018) describes a procedure to solve the system of linearized equilibrium equations around variables' steady state, and simulate the model's transition dynamics. We take our solution method from both articles.

In the literature, Gornemann *et al.* (2016) is closer to our work's objectives. The authors build a New Keynesian with matching frictions in the labour market and rich in heterogeneity. They separate households into classes and make a welfare analysis after a one-time shock and for systematic response from monetary policy, considering different Taylor rules.

We also separate households into classes and analyze the welfare implications of one-time shocks under different Taylor rules. We also discuss each class' policy preferences and why they prefer or despise a given policy. However, their results are normative, while we restrict ourselves to positive conclusions only. Also, their work considers technology and monetary shocks in an environment rich in heterogeneity and with matching frictions in the labour market. We consider discount factor shocks instead of monetary shocks in a much simpler model.

Additionally, in the demand shock case, we find the labour income and profits nearly annul each other. These findings relate to Broer *et al.* (2020) from the Tractable-HANK literature. The authors divide the population in two classes, the capitalists, who own all firms' profits, and the workers, who don't. They find a monetary loosening redistribute resources from the poorer to the richer. As flexible wages cause countercyclical profits, an expansionary monetary shock increases wages and decreases profits as in our model. Nonetheless, in our model profits are redistributed equally among the wealth classes. It exemplifies how profits' distribution have welfare consequences even when we have only one asset.

Although, for the past two years, a great variety of shocks have been studied in HANK, such as technology, demand and exchange rate shocks (see, e.g., Kaplan & Vioante (2018), Gornemann *et al.* (2016), Auclert *et al.* (2020), Auclert *et al.* (2021)), much of the earlier literature focused on monetary shocks only. Therefore, much of monetary policy's heterogeneous impact on households' labour and financial earnings, profits, transfers, total income and savings was studied mainly after a monetary shock. Besides, as the literature on normative analysis of welfare and optimal policy in HANK evolves, it may be enlightening to discuss if households disagree on their preferred policy *ex-post*, and why.

We contribute to the literature by analyzing the principal channels through which monetary policy affects classes' income, savings and how it is related to their welfare after a demand and technology shocks take place. Our analysis covers different signs and magnitudes for these shocks, along with different Taylor rules and parameters' calibration. Also, there aren't many previous works on positive welfare analysis with HANK, a gap we aim to fill.

Section 2 describe the model of our economy. Section 3 lays our quantitative results; explains our calibration, earnings process and the steady state of our economy. Presents the impulse response functions to our shocks and closes by drawing the positive welfare outcomes of our baseline model. In section 4, we briefly explain how our analysis change under the other two calibrations, previously described. Section 5 concludes.

2
Model

The model is in continuous-time. There is a continuum of households, of mass one. They have different labour productivity levels, that changes at each period following a two state Poisson process. They choose between consumption and leisure and can save through a real bond b_t, which pays one unit of consumption good c_t on the following instant. They receive (pay) the same amount of lump-sum transfers (taxes) from (to) the government, and get dividends from the firms accordingly to its level of productivity, $\pi(z_t)$. Each solves the following utility maximization problem:

Households:

$$\max_{\{c_t, l_t\}} \mathbb{E}_0 \int_0^\infty e^{-\rho_t t} u(c_t, l_t) dt$$

$$\dot{b}_t = (1 - \tau_t) w_t z_t l_t + \pi(z_t) + r_t b_t + T_t - c_t$$

$$b_t \geq -\underline{b}$$

$$z_t \sim \text{Two state Poisson process with intensity } \lambda(z, z^{'})$$

Where dividends are given by,

$$\pi(z_t) = \frac{z_t}{\bar{z}} \Pi_t$$

The resulting first-order conditions are given by:

$$c_t = u_c^{-1}(V_b(b_t, z_t, t)) \tag{2-1}$$

$$l_t = u_l^{-1}(-(1 - \tau_t) w_t z_t V_b(b_t, z_t, t)) \tag{2-2}$$

Firms

Firms' block is the same of the RANK model. There is a single **final goods** firm, behaving as in a perfectly competitive market. It buys goods j from a continuum of **intermediate goods firms**, of mass one, to produce a final good. Solving the following cost minimization problem, it obtains good j's demand schedule:

$$\min_{\{y_{j,t}\}} \int_0^1 p_{j,t} y_{j,t} dj$$
$$\text{s.t}$$
$$Y_t = \left(\int_0^1 y_{j,t}^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}$$

$$y_{j,t}(p_{j,t}) = \left(\frac{p_{j,t}}{P_t} \right)^{-\epsilon} Y_t \tag{2-3}$$

Where, the aggregate price level is given by:

$$P_t = \left(\int_0^1 p_{j,t}^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}}$$

Each **intermediate goods firm** produces a differentiated good and behaves as in a competitive monopolistic market. Intermediate goods firms' cost minimization problem is given by:

$$\min_{\{l_{j,t}\}} w_t n_{j,t}$$
$$\text{s.t}$$
$$y_{j,t} = \gamma_t n_{j,t}$$
$$y_{j,t}(p_{j,t}) = \left(\frac{p_{j,t}}{P_t} \right)^{-\epsilon} Y_t$$

Where, γ_t is the technology level at period t. Solving it we arrive at the optimal demand for effective labour and the marginal cost functions:

$$n_{j,t} = \frac{y_{j,t}}{\gamma_t} \tag{2-4}$$

$$m_t = \frac{w_t y_{j,t}}{\gamma_t} \tag{2-5}$$

They must maximize their discounted stream of profits, taking into account price adjustment costs as in Rotemberg (1982):

$$\max_{\{\pi_t\}} \int_0^{\infty} e^{\int_0^t r_s ds} \Big\{ \tilde{\Pi}_t - \theta \frac{\pi_t^2}{2} Y_t \Big\} dt$$

Where,

$$\tilde{\Pi}_t = \Big(p_t - \frac{w_t}{\gamma_t} \Big) y_t$$

Is the maximized profits at period t without adjustment costs. Firms' dynamic problem is given by:

$$r_t J(p_{j,t}, t) = \max_{\pi_{j,t}} \left(\frac{p_{j,t}}{P_t} - m_t \right) \left(\frac{p_{j,t}}{P_t} \right)^{-\epsilon} Y_t - \frac{\theta}{2} \pi_t^2 Y_t + J_p(p_{j,t}, t) p_{j,t} \pi_{j,t} + J_t(p_{j,t}, t)$$

Which solution delivers the Phillips Curve equation of the Economy:

$$\left(r_t - \frac{\dot{Y}_t}{Y_t} \right) \pi_t = \frac{\epsilon}{\theta} (m_t - m^*) + \dot{\pi}_t \tag{2-6}$$

Where, $m^* = \frac{\epsilon - 1}{\epsilon}$, is the steady state of the marginal cost. Aggregating Effective Labour between firms we get:

$$N_t = \frac{Y_t}{\gamma_t} \tag{2-7}$$

Profits after cost-adjustments are given by:

$$\Pi_t = \Big(1 - m_t \Big) Y_t - \frac{\theta}{2} (\pi_t)^2 Y_t \tag{2-8}$$

Government

The government taxes effective labour revenue, may tax each household lump-sum, and can issue debt, possibly deviating from steady state debt level, to finance its expenditure, lump-sum transfers, debt service and repayment. The government budget constraint must always be balanced:

$$\dot{B}_t^g + G_t + T_t = \tau_t w_t \sum_z \int z l(b,z,t) g(b,z,t) db + r_t B_t^g \tag{2-9}$$

Given shocks, government balances its budget by adjusting a single fiscal variable. Here, it is the lump-sum transfers, T_t, so government expenditure, total amount of debt and labour tax rate are kept at steady state levels, $\{\bar{B}^g, \bar{G}, \tau\}$.

Monetary Authority

The Central Bank follows a Taylor rule. The intercept is the steady state real interest rule and output gap from the steady state may matter, while inflation is always relevant for the rule, i.e. $\phi_\pi > 1$ and $\phi_y \geq 0$.

$$i_t = \bar{r} + \phi_\pi \pi_t + \phi_y y_t \tag{2-10}$$

$$r_t = i_t - \pi_t \tag{2-11}$$

Equilibrium

Equilibrium is defined by paths for individual household and firm decisions $\{b_t, c_t, d_t, l_t\}_{t\geq 0}$, input prices $\{w_t\}_{t\geq 0}$, returns on assets $\{r_t\}_{t\geq 0}$, the inflation rate $\{\pi_t\}_{t\geq 0}$, fiscal variables $\{\tau_t, T_t, G_t, B_t\}_{t\geq 0}$, measures $\{g(b,z,t)\}_{t\geq 0}$, and aggregate quantities such that at every period t: (i) households and firms maximize their objective functions taking as given equilibrium prices, taxes and transfers; (ii) the sequence of distributions satisfies aggregate consistency conditions; (iii) the government budget constraint holds; and (iv) all markets clear. There are 3 markets in our economy: the asset market, the labour market and goods market.

Asset Market - The asset market clears when the government (sole issuer of bonds) and households respectively offer and demand the same quantity of bonds:

$$\sum_z \int bg(b,z,t)db = B_t^h = B_t^g \tag{2-12}$$

Where B_t^g is the government total debt and household demand for liquid assets is given by B_t^h.

Labour Market - The Labour Market clears when the effective labour demand by firms equals the average effective labour supply, given by the Poisson process and the households' hours of leisure:

$$\int_0^1 n_{j,t}dj = N_t = \sum_z \int zl(b,z,t)g(b,z,t)db \tag{2-13}$$

Goods Market - Goods Market clears when final goods firm's supply equal households consumption, plus government expenditure and menu costs:

$$Y_t = C_t + G_t + \frac{\theta}{2}\pi_t^2 Y_t \tag{2-14}$$

This last market clearing condition won't be important, as we need only $n-1$ market equilibrium conditions of a total of n, by Walras' law.

Shocks

Later we'll hit the economy with technology and demand MIT-shocks, which is why we kept a time subscript in both the technology level and households' discount factor. Both variables follow a deterministic version of a Ornenstein-Uhlenbeck process after the unexpected shock hit them, i.e. both will mean-revert. The $\bar{\gamma}$ and ρ parameters give us the variables' values at steady-state, while the ρ_ρ and ρ_γ determine the speed of mean-reversion.

$$d\rho_t = \rho_\rho(\rho - \rho_t)dt \tag{2-15}$$

$$d\gamma_t = \rho_\gamma(\bar{\gamma} - \gamma_t)dt \tag{2-16}$$

3
Quantitative Results

The method to solve our model and run our HANK simulations are from Ahn *et al.* (2018). They compute the steady state of the model using the algorithm from Achdou *et al.* (2022) and then linearize the value and distribution functions, as well as aggregate equilibrium conditions around its value, and solve the linear system of stochastic differential equations. Both the method and the algorithm will be described at appendix A.4.

The linearization procedure Ahn *et al.* (2018) features certainty equivalence with respect to aggregate shocks, and sign and size independence. It means the algorithm computes households' responses as not considering the possibility of aggregate shocks hitting the Economy again. This is not a problem as we are considering MIT-shocks.

Also, shocks will be symmetric, i.e. if we consider a contractionary shock instead of a expansionary one, the IRFs only change their sign. The absolute magnitude and behavior of the responses don't change. In other words, considering contractionary shocks, households will flip their policy preferences symmetrically.

3.1
Earnings Process and Steady State

All variables are calibrated in quarterly values. Most of the parametrization comes from Kaplan *et al.* (2018) and the one-asset model from the PHACT Toolbox example in Ahn (2017). The earnings process is given by a two state Poisson process, which can be interpreted as unemployed and employed status. The arrival rates of the process, $\lambda_u = 0.0376$ and $\lambda_e = 0.5$, guarantees 7% of the population is unemployed. Productivity levels were re-scaled, so the mean productivity equals 3, which, with the calibrated disutility of labour, ψ, delivers a steady state aggregated hours worked of approximately 1/3, and steady state quarterly GDP of 1.

Given the earnings process, we calibrate the Government block parameters[1] and the steady-state discount factor in a manner the indebted population

[1] In Ahn *et al.* (2018), fiscal policy parameters are set such that a given percentage of the population receives positive net transfers from the government, i.e. labour tax < lump-sum transfers. In a model without capital this would mean an excessively high transfers to output

is approximately 26%[2], and the steady state quarterly real interest rate is 0.5%. We select four Taylor rules. The first comes from Taylor (1993), being one of the most common rules in the RANK literature. The rest of them come from Galí (2015), the second disregarding the reaction to output gaps, the third considers an extremely hawkish Central Bank on inflation only, and finally the fourth considers a monetary authority highly reactive to output gap.

As an inflation reaction parameter bellow 1.0 doesn't guarantee local uniqueness, we abstain from setting it bellow that mark. Our model's equilibrium is both existent and locally unique given any rule selected. The model calibration is as follows:

Table 3.1: Calibration

Preferences		
Discount Factor	ρ	0.0053
Risk Aversion	σ	1
Frisch Elasticity	ϕ	2
Disutility of Labour	ψ	20.25
Earnings Process		
Productivity of Employed	z_1	3.12
Productivity of Unemployed	z_2	1.402
Arrival rate	λ_1	0.5
Arrival rate	λ_2	0.0376
Mean Productivity of Labour	$\bar{z}$	3.0
Production		
Elasticity of Substitution	ϵ	10
Price Adjustment Cost	θ	100
Steady State Firm Productivity	$\bar{\gamma}$	1
Government		
Labour Tax rate	τ	0.2
Steady State Gov. Transfers as % GDP	$\bar{T}$	6%
Steady State Gov. Exp. as % GDP	$\bar{G}$	11.5%
Debt to GDP ratio	B^g/Y	1

ratio.

[2]In Kaplan *et al.* (2018), they calculate from the 2004 Survey of Consumer Finances data that 15% of households holds negative positions of liquid asset. But they also compute 20% of the population has zero-net liquid assets, holding positive illiquid assets, and 10% holding zero-net assets. Our model does not feature illiquid assets, and thus we aim a (indebted population)/(total population) ratio near 0.25.

Monetary Policy		
Steady State real interest rate	r	0.5%
Taylor 1993 rule	(ϕ_π, ϕ_y)	$(1.5, 0.125)$
Taylor rule #2	(ϕ_π, ϕ_y)	$(1.5, 0)$
Taylor rule #3	(ϕ_π, ϕ_y)	$(5.0, 0)$
Taylor rule #4	(ϕ_π, ϕ_y)	$(1.5, 1.0)$

The steady state distribution for employed and unemployed households[3] give us the following distribution by class and the wealth range as percentage of a one quarter GDP each class hold. The fraction of liquid assets to quarterly output is equal to the calculated with 2004 Survey of Consumers Finances data, as in Kaplan *et al.* (2018).

In order to achieve an indebted households to population ratio above 25%, we need to stretch the borrowing limit, achieving levels as high as 5 times the disposable average quarterly labour income, although, less than 5% of all households will be indebted above 2.5 times this measure. Even among the unemployed population, it will be less than 15%.

Table 3.2: Distribution Characteristic

Class	Frac. Pop.	Wealth Range	Wealth Avg.
Top 1%	0.9%	$[4.57, 6.00]$	4.87
Top 1-10%	8.1%	$[3.35, 4.57)$	3.68
Top 10-30%	21%	$[2.10, 3.35)$	2.55
Top 30-50%	18.6%	$[1.31, 2.10)$	1.59
Top 50-70%	21.4%	$[0.29, 1.31)$	0.68
Top 70%-Indebted	3.6%	$[0.08, 0.29)$	0.08
Indebted	26.3%	$[-4.00, 0.08)$	-1.14

The consumption and savings policy functions follow the expected behavior, observed throughout the literature. Consumption increases with wealth, and both savings and consumption are higher for employed than unemployed. The aggregate value of savings is 0 as in steady state government total debt doesn't change.

[3]Figures A.3 and A.3 at Appendix A.

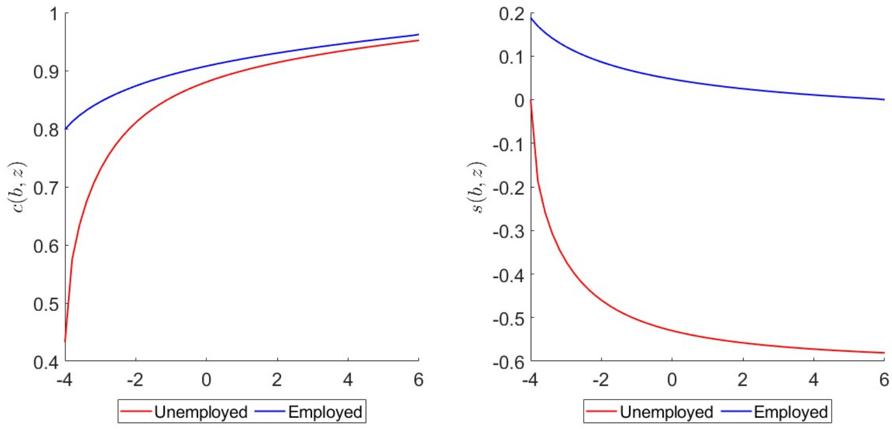

Figure 3.1: *Left:* Consumption Policy functions. *Right:* Savings Policy functions.

3.2 Impulse Response Shocks

Now we analyze the dynamics of consumption and hours for each class, the main aggregate variables and prices after a one-time MIT shock. We consider expansionary and contractionary demand and technology shocks with two different magnitudes, one and two standard deviations. We also consider their behavior under each Taylor rule calibration on Table 3.1. As mentioned in section 2, both the technology level and discount factor follow a deterministic version of a Ornenstein-Uhlenbeck process. The ρ_ρ and ρ_γ determine the speed of mean-reversion.

$$d\rho_t = \rho_\rho(\rho - \rho_t)dt$$
$$d\gamma_t = \rho_\gamma(\bar{\gamma} - \gamma_t)dt$$

We'll discuss the demand or discount factor shock first, and the technology shock case will follow. For each case, we describe a general picture of how the shock affects the relevant variables in our model, independent of it being aggregate or specific to a class. Afterwards, in the demand shock case, we take a closer look in transfers, considering how their dynamics changes under different Taylor rules. In the technology shock case, however, we will analyze profits' dynamics and how it changes under different policies.

Demand shock - We set $\rho_\rho = 0.5$, and simulate a quarterly increase (decrease) of 0.25% and 0.5% of the nominal interest rate. It would be equivalent to consider, respectively, one and two standard deviations shocks of a stochastic Ornenstein-Uhlenbeck process with $\sigma_\rho = 0.0025$. In either case, the shock will be completely dissipated by the sixth quarter. Our calibration mimics the discount factor shock process in Galí (2015).

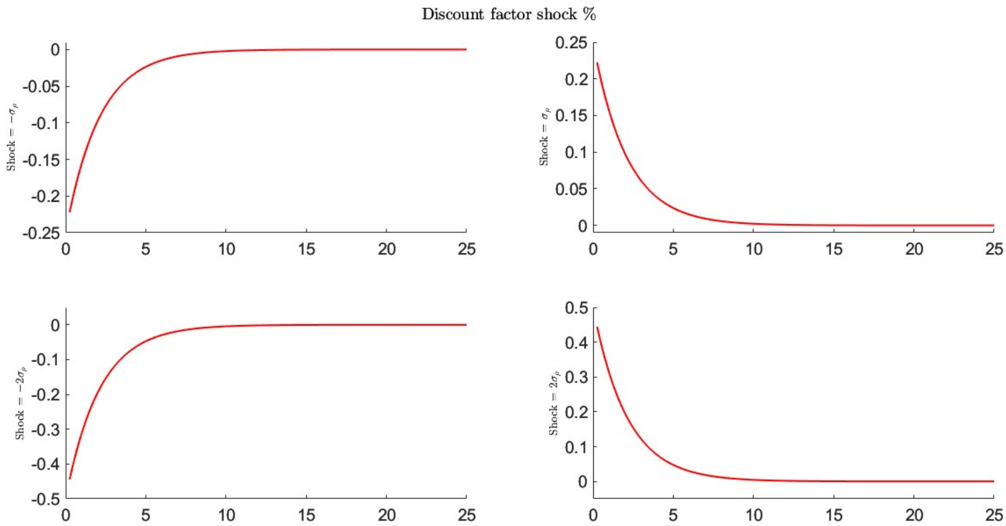

Figure 3.2: Discount factor shocks

If positive, the shock increases the discount factor ρ, making households more impatient. As a result, they wish to take more leisure time and consume more in the present. Nonetheless, in order to meet the demand, firms increase output, thus pushing wages up so households choose to increase labour supply, as seen in Figures 3.3 and 3.6. Indeed, as we can see in Figures 3.4 and 3.5, for the positive shocks, both consumption and hours worked increase relative to their steady-state values regardless of class or Taylor rule.

In turn, higher wages raise the marginal cost and, ultimately, inflation. Higher output and inflation generate menu costs à la Rotemberg, and although output increases, higher marginal and menu costs diminish profits. The Taylor rule can be re-written in a manner real rates are given by:

$$r_t = (\phi_\pi - 1)\pi_t + \phi_y y_t$$

As $\phi_\pi > 1$, an inflation and positive output gap increase real rates, implying a larger government debt service. Still, the increase in wages and hours worked enlarge the tax revenue which might generate bigger transfers to households. As we will see later, the dynamics of transfers will depend on the Taylor rule adopted and the government's total debt. Finally, a higher real interest rate also implies a higher payment burden for indebted households.

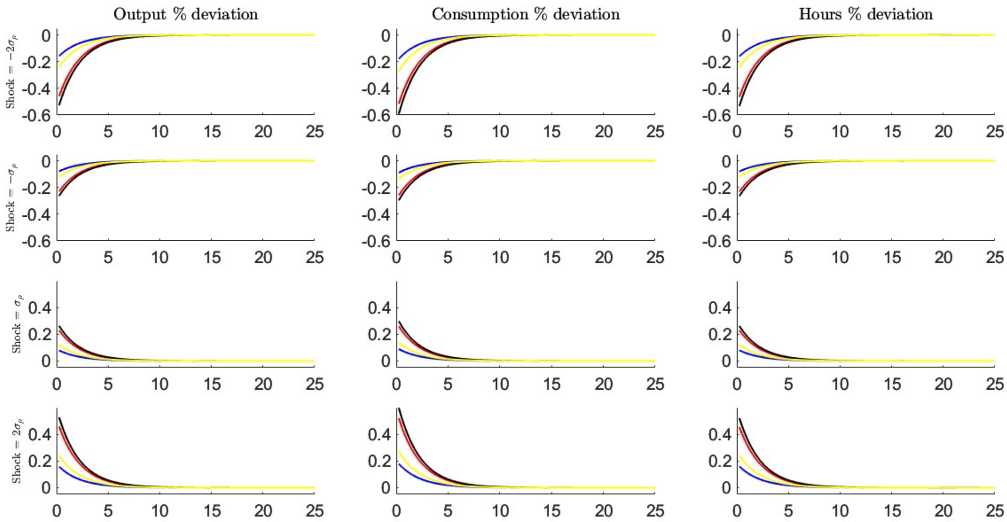

Figure 3.3: Output, consumption and hours deviation after a one-time discount factor shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

If negative, the shock decreases the discount factor ρ, making households more impatient. As a result, they wish to postpone more leisure time and consumption to the future. Therefore, the shock contracts demand, firms decrease output, cutting wages and laying-off workers. Indeed, looking at the negative shock cases in Figures 3.4 and 3.5, we can observe consumption and hours worked decreasing relative to their steady-state values regardless of class or the Taylor rule adopted.

Wage cuts decrease the marginal cost and the economy experience deflation. Although, menu costs rise due to the deflation, smaller marginal costs prop-up firms' profits. Symmetrically to the expansionary shocks, deflation and negative output gap decrease the real interest rate, diminishing government's debt service. Nonetheless, tax revenue from labour goes down as consequence of wages and hours worked decrease, so, as before, the total impact on transfers will depend on the Taylor rule adopted. Finally, smaller real interest rates push-down the payment burden for indebted households.

Taking a closer look on Figures 3.4, 3.5 and 3.6, it is easy to notice a rather expected result: the more hawkish the Taylor rule (e.g. lines in blue and yellow) the more moderate the fluctuations in both expansionary and contractionary shocks. In case of an expansionary shock, the larger the reaction to inflation and output growth is, the larger the real rate increase. It encourages households to substitute consumption intertemporally into the future which cools the economy. On the other hand, in case of a negative demand shock, the more reactive policy rule will provide more stimuli to the economy during a recession.

On the first case, consumption will have a weaker boom, output won't increase as much, and consequently, wages, hours worked and inflation will have a moderate increase. Consequently, profits will have a less accentuated decrease. On the latter case, however, consumption will face a softer blow, output won't decrease as much leading to a moderate decrease of wages, hours worked and inflation. Also, profits have a modest rise.

Now, we discuss how consumption, hours worked, income and savings dynamics depend on the shock. It plays two effects; a direct one, impacting households' patience, and an indirect one impacting their intratemporal leisure-consumption choices and income.

Let's consider the direct effect first. If the shock is positive (negative) households get more impatient (patient) and wish to increase present (future) consumption and leisure by diminishing (increasing) savings. However, it has an indirect effect through the rise (fall) of wages, which incentive households to work more (less) in case of a positive (negative) shock. Furthermore, it causes an income effect which, as will see later, can be either positive or negative depending on the household. If positive, the income effect makes it possible to increase consumption without decreasing savings, and if negative, decrease income and increase borrowing, so the household can smooth consumption.

For example, after a contractionary demand shock, if we kept their income constant, as households wish to push more leisure and consumption into the future, we'd observe an increase in their savings. Nonetheless, we observe a slowdown of the economy. In one hand, wages and interest earned decrease. On the other, profits increase, interest payments decrease for indebted households, and transfers might go up, depending on the Taylor rule. Thus, household's income may drop or rise, depending on where it is in the distribution and the monetary rule adopted. If total income drops enough, despite their increased patience, households might choose to borrow more, so it can cushion the income effect on consumption and leisure. However, if it drops moderately, or even rises, households will be able to cut consumption and increase savings.

In turn, if we consider a positive shock the opposite happens. Under a constant income level, households wish to anticipate future consumption and leisure and decrease their savings. The shock affects income, though. Even with falling profits and (possibly) transfers, as wages and interest rates rise, some households' income may increase. If their income rises, it may be possible to increase present consumption and savings. However, if it increases moderately, or even falls, households will need to decrease their savings to increase consumption.

As we'll see afterwards, the overall impact of each of those factors will vary with the class and Taylor rule. Now, we analyze transfers' dynamics.

Transfers: Taking the government's budget constraint, we can see the government's transfers depend only on labour tax revenue and its debt service:

$$\bar{G} + T_t = \tau w_t \sum_z \int zl(b, z, t)g(b, z, t)db + r_t \bar{B}^g \tag{3-1}$$

In other words, it depends on wages, effective aggregate labour supply, real interest rate and government's stock on debt. Transfers move with the first two, i.e, when aggregate labour income increases, so will transfers. However, everything else equal, supposing the government is a net borrower from society, transfers and real interest rates are negatively related. Its impact over transfers will depend on the government debt stock. The higher the debt stock, the higher the total debt service. The national debt level won't be important now, as we discuss how transfers dynamics change only with the Taylor rule. Later, we'll run another exercise where the government debt stock is multiplied by 6.

Looking at Figure 3.6, notice that under the traditional Taylor (1993) calibration and Taylor rule #2 (lines in red and black), transfers fall after a contractionary discount factor shock. For our more hawkish rules, however, it increases. The reason is simple: under more reactive rules, after a negative shock, real interest rates' drop is accentuated. Therefore, a hawkish rule decreases the debt service more than a dovish one, and in our simulation, even though wages and hours decrease, the smaller interest payments produce enough fiscal space for the government to increase transfers. Nonetheless, under more dovish rules, the reverse occurs.

After a positive shock the reverse happens. Under hawkish rules, the interest rate rises the most, which increases the debt service, surpassing the extra tax revenue from the increase of wages and hours. Nonetheless, under more dovish rules, labour tax revenue is bigger than the increased interest payments and so, transfers go up.

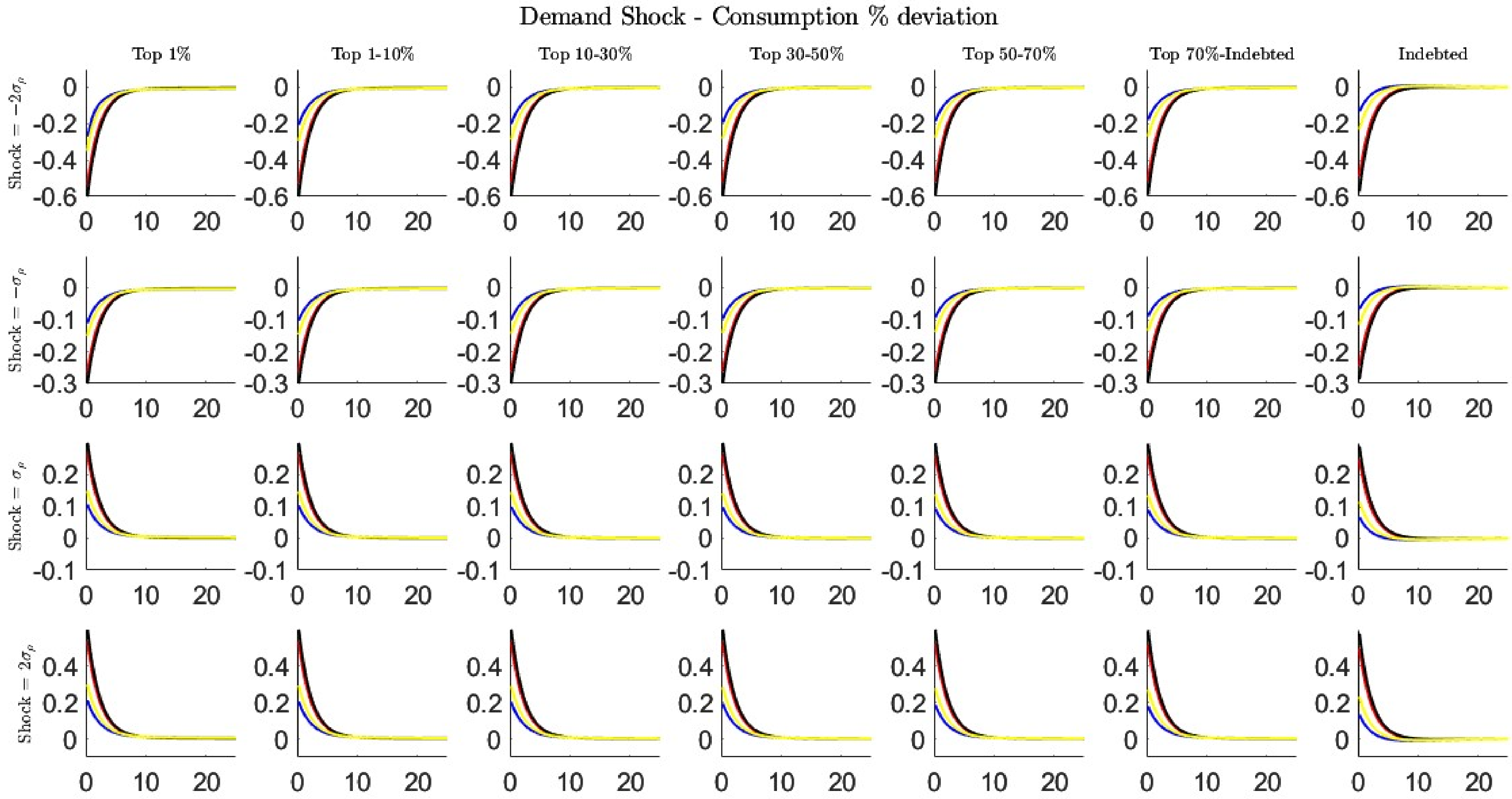

Figure 3.4: Consumption deviation after a one-time discount factor shock. In red we have the consumption dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

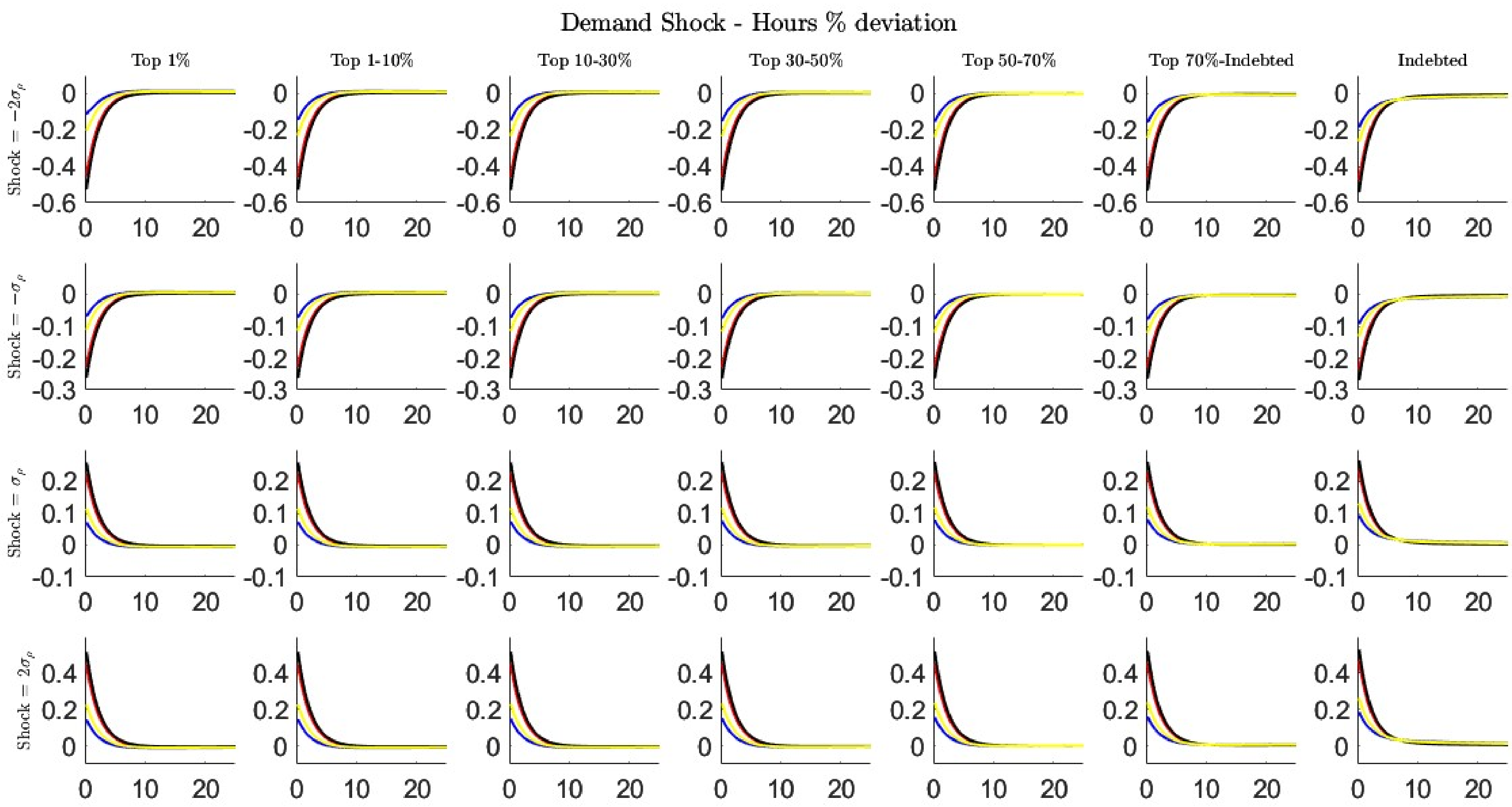

Figure 3.5: Hours deviation after a one-time discount factor shock. In red we have the hours worked dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

Technology Shock - We set $\rho_\gamma = 0.05$ and simulate a quarterly increase (decrease) of 0.7% and 1.4% of the technology productivity. It would be equivalent to consider, respectively, one and two standard deviations shocks of a stochastic Ornenstein-Uhlenbeck process with $\sigma_\gamma = 0.007$. In either case, the shock will be completely dissipated by the 135th quarter. We took the calibration for the technology shock from Cooley & Prescott (1995).

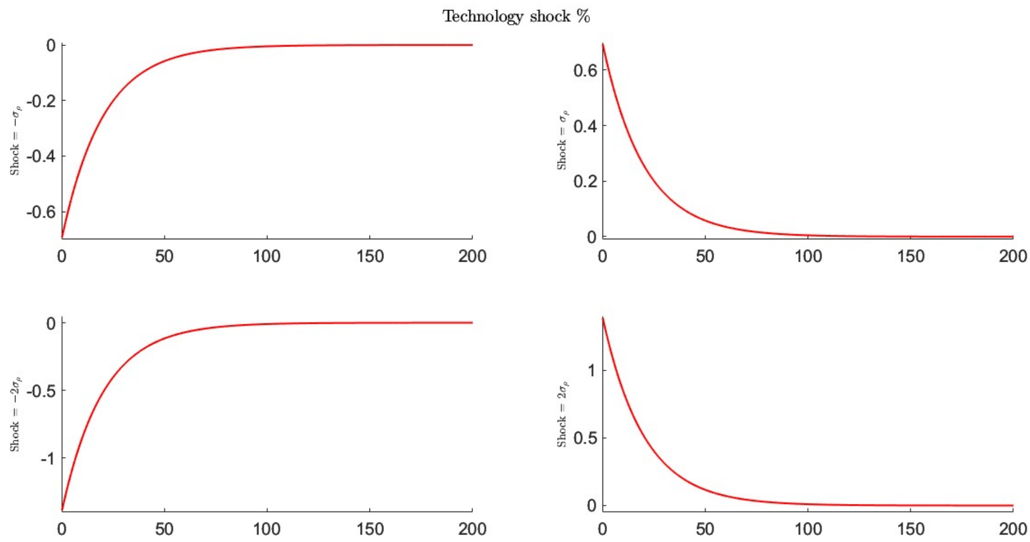

Figure 3.7: Technology shocks

If positive, the shock increases the technology productivity, boosting the marginal productivity of labour, which pushes wages up, as seen in figure 3.8. The movement of wages has both an income and substitution effect on hours worked. As we can check in figure 3.9, the latter prevails, and total hours worked decreases. Although households take more leisure, productivity increases enough to boost firms' production, while wages raise demand. Thus, output and consumption augment, as in figure 3.9.

The increase in consumption and leisure time will be common among all classes. Taking figures 3.10 and 3.11, we can see after, a positive shock, all classes prefer to take advantage from the higher wage to work less, and from the increased income to consume more.

Wages increase in a proportion less than one-to-one in relation to the shock. This means marginal cost decreases, resulting in a deflation. In one hand, smaller marginal costs and a bigger output should lead to higher profits. On the other, deflation increases menu costs for the firms. As we will see, the latter effect is mostly secondary, and a decrease in marginal cost is followed by an increase in profits. Nonetheless, depending on the Taylor rule, menu costs can be so high, they diminish profits for a while, before they surge again.

The Taylor rule ca be re-written in a manner real rates are given by:

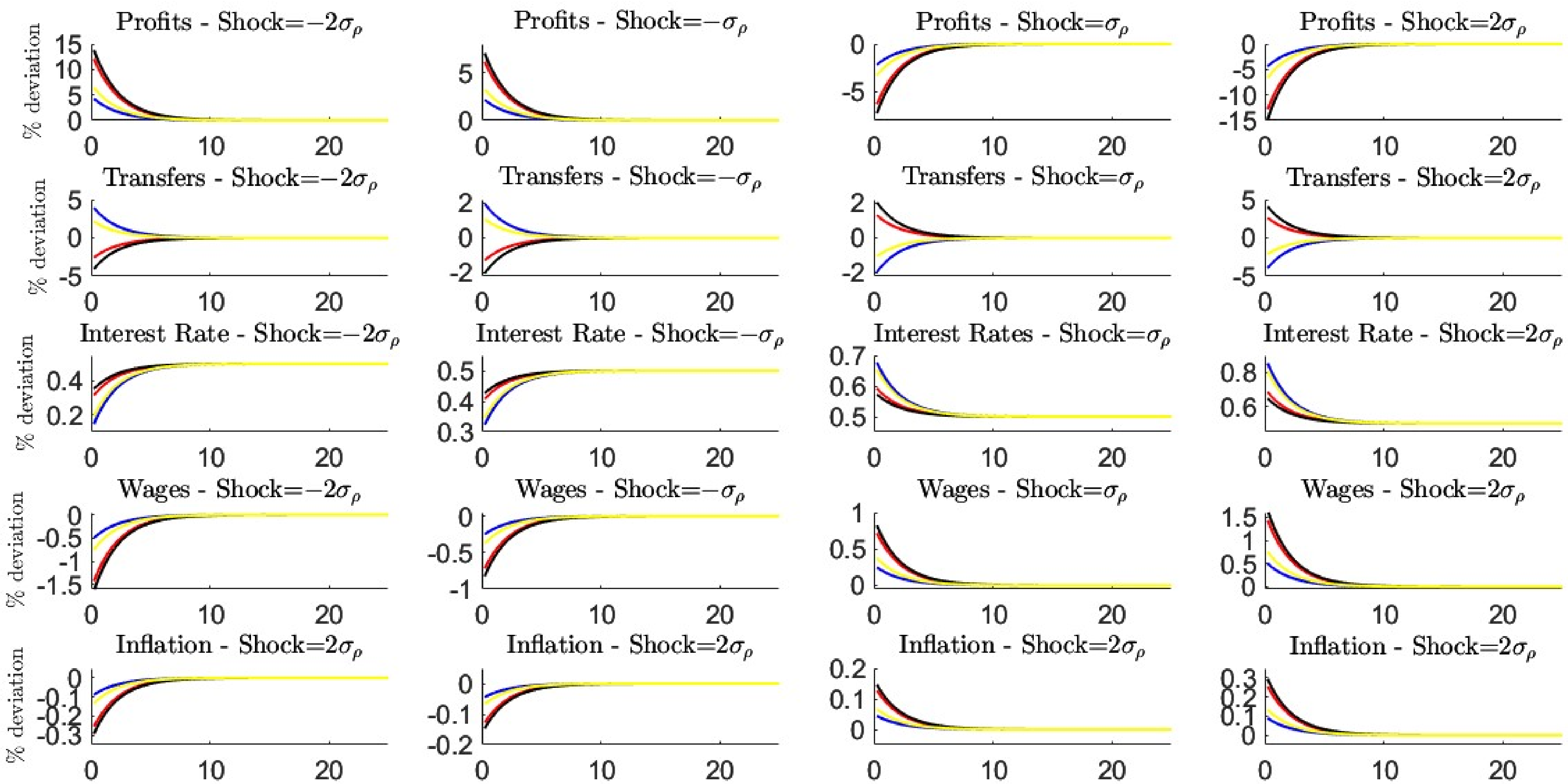

Figure 3.6: Aggregate variables deviation after a one-time discount factor shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

$$r_t = (\phi_\pi - 1)\pi_t + \phi_y y_t$$

As $\phi_\pi > 1$, a deflation has a negative impact on real rates, even though the positive output gap has a positive one. The first effect overcomes the second, implying a smaller government debt service. It also relieves the interest payment burden on indebted households and incentive all households to bring future consumption to the present. As wages grow, even with households taking more leisure time, labour tax revenue increases. Together with the smaller government debt service, it generates higher transfers to households, further boosting demand.

If negative, the shock decreases the technology productivity, diminishing the marginal productivity of labour, which pushes wages down, as seen in figure 3.8. The movement of wages has both an income and substitution effect on hours worked. As we can check in figure 3.9, the latter prevails, and total hours worked increases. Although households take less leisure, productivity decreases enough to depress firms' production, while wages reduce demand. Thus, output and consumption fall, as in figure 3.9.

The decrease in consumption and leisure time will be common among all classes. Taking figures 3.10 and 3.11, we can see after, a negative shock, all classes prefer to work more, despite the reduced wage, and to consume less because of the smaller income.

Wages decrease in a proportion less than one-to-one in relation to the shock. This means marginal cost increases, resulting in an inflation and smaller profits. Once more, Taylor rule ca be re-written in a manner real rates are given by:

$$r_t = (\phi_\pi - 1)\pi_t + \phi_y y_t$$

As $\phi_\pi > 1$, an inflation has a positive impact on real rates, even though the negative output gap has a negative one. The first effect overcomes the second, implying a larger government debt service. It also increases the interest payment burden on indebted households and incentive all households to substitute consumption intertemporaly to the future. As wages contract, even with households taking less leisure time, labour tax revenue decreases. Together with the bigger government debt service, it generates smaller transfers to households, further depressing demand.

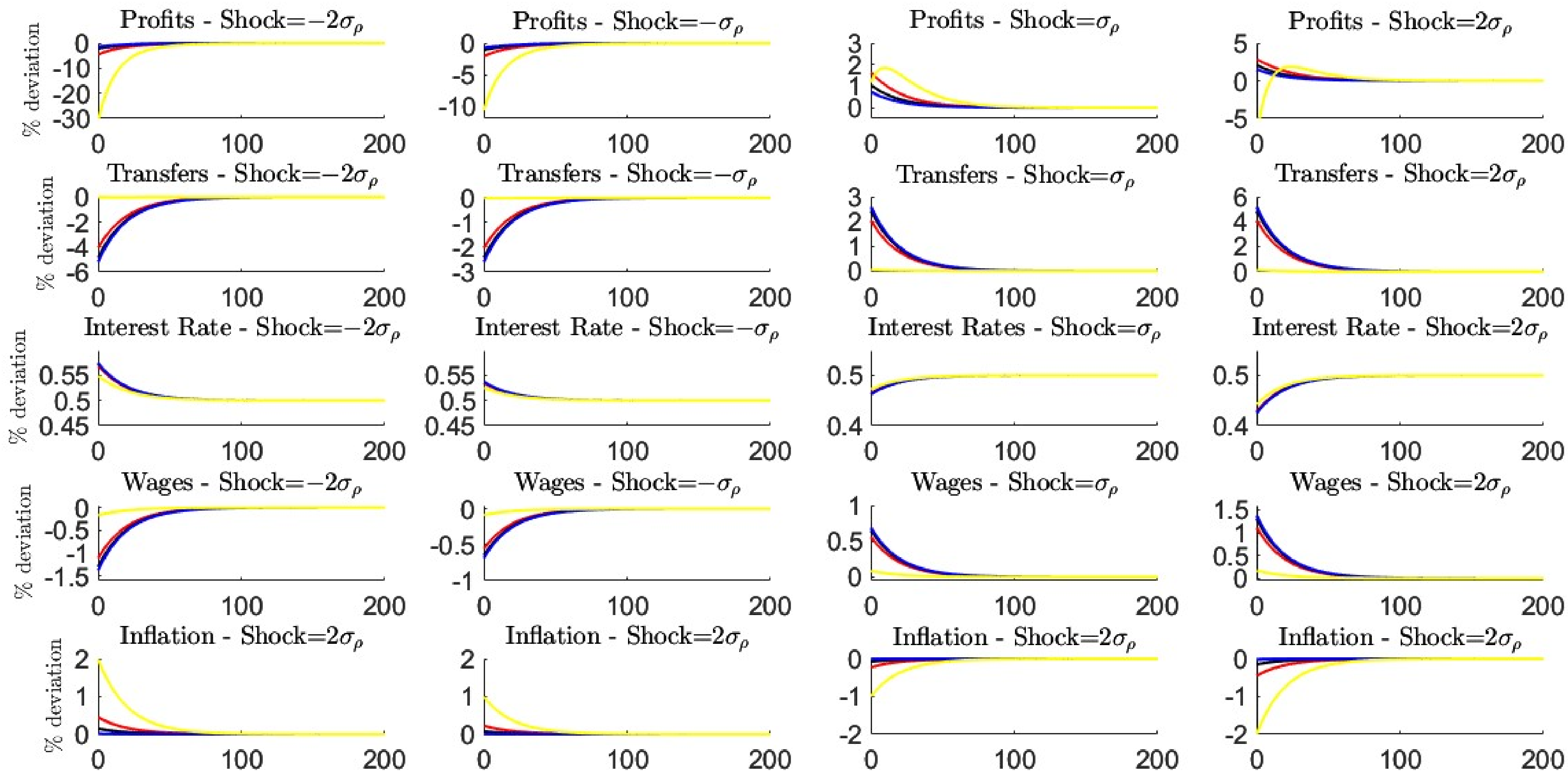

Figure 3.8: Aggregate variables deviation after a one-time technology shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

Now, we discuss how consumption, hours worked, income and savings dynamics depend on the shock. For most policies, income decreases (increases) after a contractionary (expansionary) technology shock, except for Taylor rule #4 which makes income decrease momentarily, after an expansionary shock. With a lower (higher) income, households should decrease (increase) both savings and consumption. However, after a negative (positive) shock, interest rates rise (fall), creating an incentive for households to save (borrow) more. Therefore, the shock has two opposing effects.

For example, after a contractionary shock, the technology level falls, marginal productivity of labour decreases, pushing wages down. At the same time, households decide to work more to compensate the loss of income. Still, output falls. Marginal costs rise, as the cut in wages doesn't compensate the effect of the shock on the technology level. As a consequence, inflation rises, and profits decrease.

Despite the fall in output, real interest rates increase because of inflation. Therefore, interest payments to households rises, together with the government debt service. Even though hours worked augment, the falling wages lead to a decrease in labour tax revenue. Together with the increase of the national debt service, it generates a fall in transfers.

In sum, profits and transfers take a blow from the shock, while financial income rises for the non-indebted households and falls for the indebted ones. Labour income might rise, if the increase in hours worked compensate the fall of wages, but it only happens under rule #4. We discuss this further afterwards.

As we will see, after taking all those components into account, income will always fall after a negative shock. Households should cut its consumption and borrow more to cushion the shock. However, interest rates rise, encouraging households to substitute their consumption intertemporally into the future. Which effect will prevail will depend on the Taylor rule and class.

In turn, after an expansionary shock, the technology level rises, marginal productivity of labour increases, pushing wages up. At the same time, households decide to work less, taking advantage of the wage increase. Even though, output still rises. Marginal costs fall, as the increase in wages doesn't undo the effect of the shock on the technology level. Consequently, we have deflation. Profits' behavior will depend on the Taylor rule, as we will see later.

Despite the rise in output, real interest rates decrease because of deflation. Therefore, interest payments to households falls, together with the government debt service. Even though leisure time augment, the rising wages lead to an increase in labour tax revenue. Together with the decrease of the national debt service, it generates a rise in transfers.

In sum, transfers are propped up by the shock, while financial income falls for the non-indebted households and increases for the indebted ones. Labour income might fall, if the decrease in hours worked compensate the rise in wages, but it only happens under rule #4. Profits may rise or momentarily fall, it will depend on the policy rule, as we discuss bellow. After taking all those components into account, income mostly rise after a positive shock. Only when profits fall aggressively, it will make income decrease.

Therefore, if income rises above steady-state, households can increase its consumption and savings. However, interest rates fall, encouraging households to substitute their consumption intertemporally to the present. Which effect will prevail will depend on the Taylor rule and class.

Profits: Taking the equation for profits, we can see it depends on output, marginal cost and the inflation rate:

$$\Pi_t = \Big(1 - m_t\Big)Y_t - \frac{\theta}{2}(\pi_t)^2 Y_t \tag{3-2}$$

Profits will rise with output and decrease with marginal costs and menu costs. As mentioned, generally menu costs won't be relevant to determine the dynamics of profits. If we look at figure 3.8. after a contractionary shock, for all Taylor rules, wages fall because of the technology shock, although marginal costs still increase. Finally, as output drops, profits follow suit.

Although interest rates increase in response to inflation after a negative shock, policy rules reactive to output gap raise the real rate less than those non-reactive to output. Therefore, under these policies, households are less encouraged to postpone consumption and to save. The result is a less severe recession, with a higher inflation rate.

As the economy contracts less intensively under Taylor rule #4 and Taylor (1993) calibration, wages suffer a softer blow. In one hand, this benefits households because their labour income falls less, as in Taylor's original calibration, and even rises, as under Taylor rule #4. On the other hand, falling wages soften the shock's impact on marginal costs and profits. Under them, profits have an accentuated fall. Especially for Taylor rule #4, inflation will increase the most, raising menu costs. As wages remain almost unaltered, marginal costs will also rise. Consequently, profits take a massive fall.

After an expansionary shock the opposite takes place. For most rules, wages increase because of the technology shock, although marginal costs still decrease. Finally, as output rises, profits follow suit. Once again, although interest rates decrease in response to deflation after a positive shock, policy rules reactive to output gap decrease the real rate less than those non-reactive to output. Therefore, under these policies, households are less encouraged to anticipate consumption and to borrow. The result is a moderate boom, with a higher deflation rate, under Taylor (1993) calibration. However, the case of Taylor rule #4 is unique.

Taking a close look at figure 3.8, only under Taylor rule #4, we observe profits falling below its steady-state, after an expansionary shocks. Nonetheless, it surges, surpassing the steady-state level and converging back to it afterwards.

Taylor rule #4 is the most reactive policy to output gap. After the positive shock, interest rates drop because of deflation, however, under rule #4, the decrease in real rates is moderated by output's rise. As interest rates decrease the least under this rule, households have less incentive to increase consumption today. In other words, rule #4 doesn't stimulate the economy as much as the other policies. The result is a smaller output increase and an immense deflation. In turn, it will increase menu costs, which will be so high, profits will decrease bellow steady-state, before rising again when prices start stabilizing.

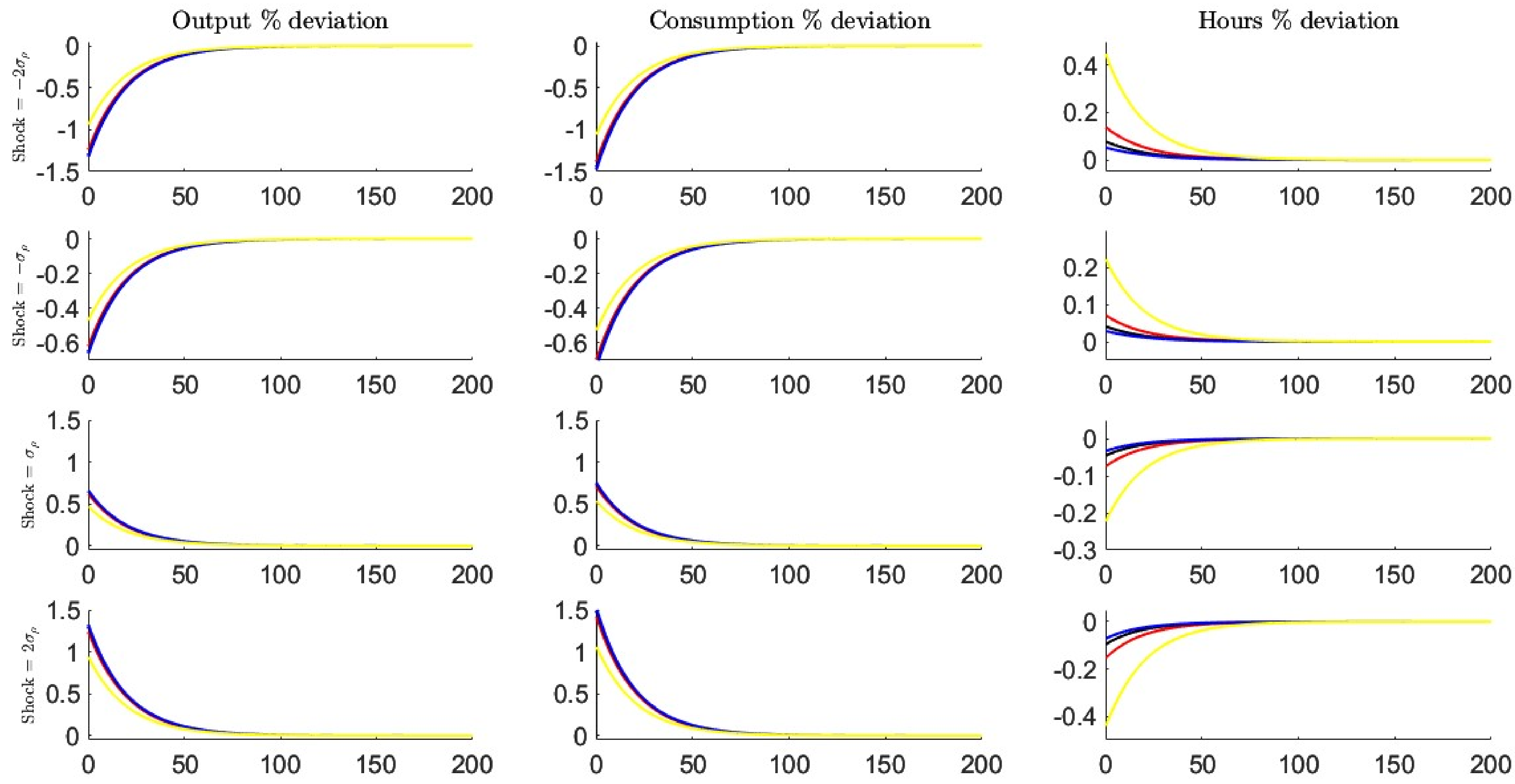

Figure 3.9: Output, consumption and hours deviation after a one-time technology shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

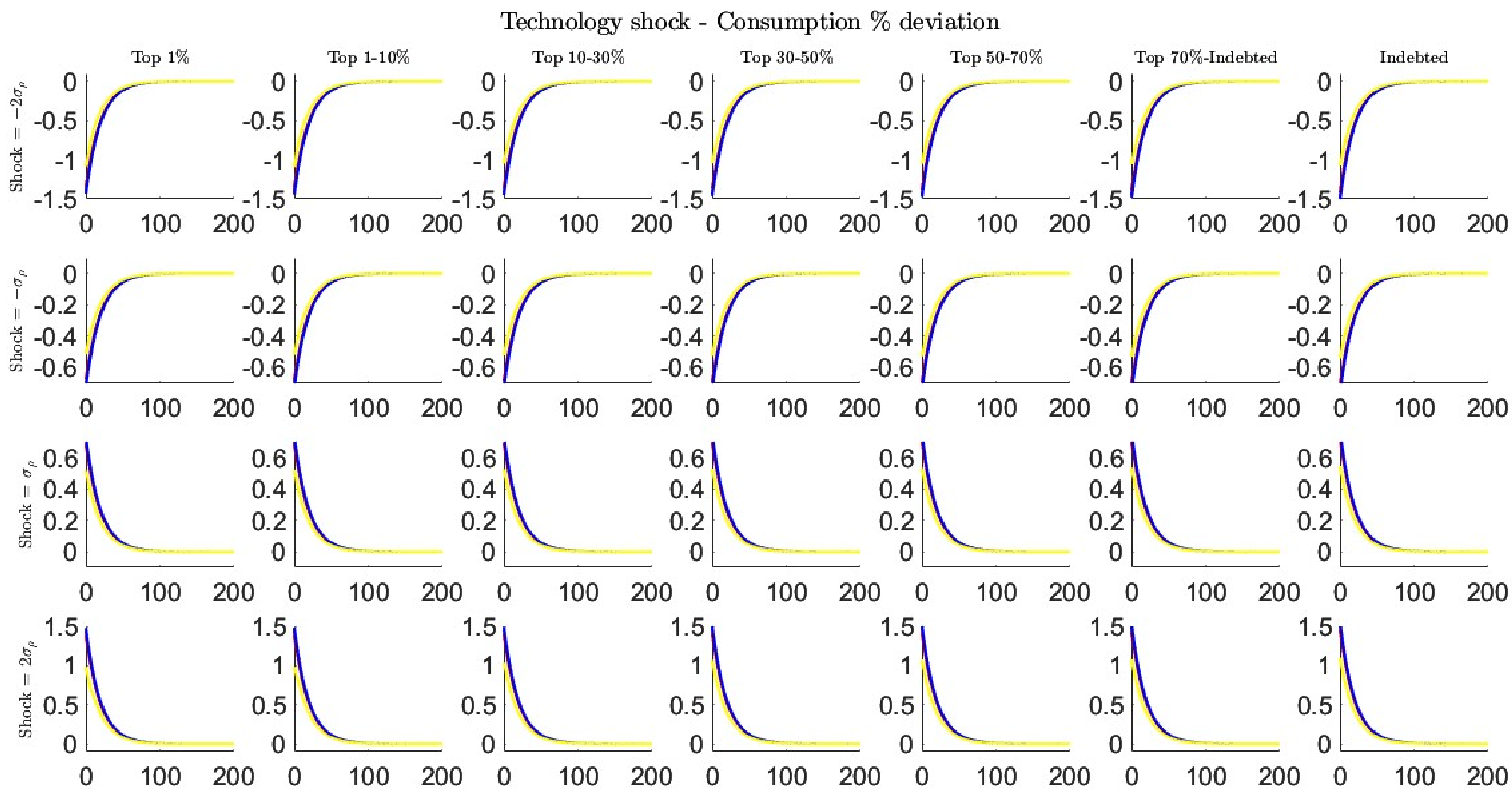

Figure 3.10: Consumption deviation after a one-time technology shock. In red we have the consumption dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

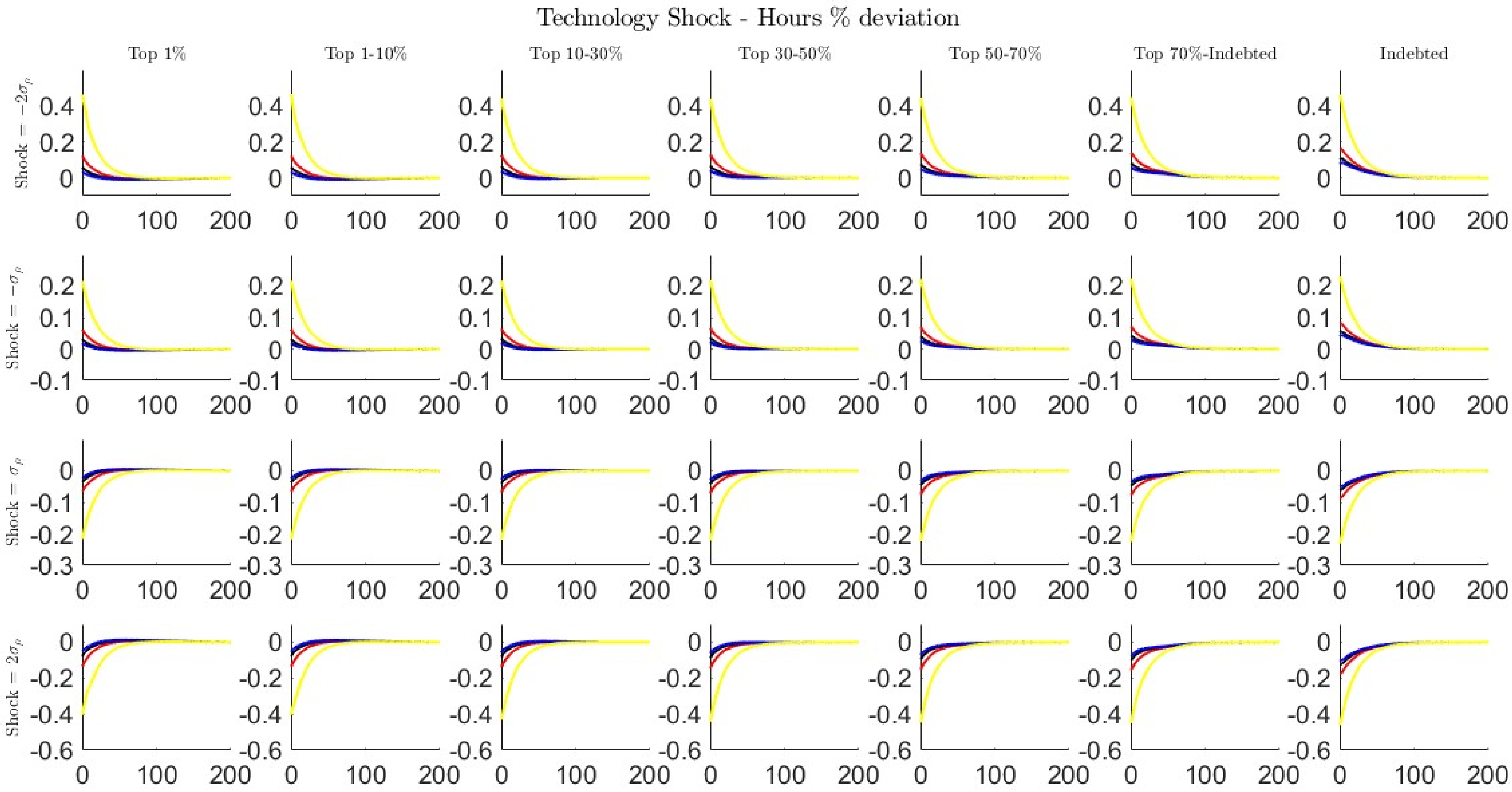

Figure 3.11: Hours deviation after a one-time technology shock. In red we have the hours worked dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

3.3
Welfare Effects of One-Time Shocks: a positive analysis

We analyze the *ex-post* welfare loss or gain for different wealth groups after an MIT shock under the selected Taylor rules, compared to their steady-state welfare levels. The shocks are the same from the subsection 3.2, i.e. demand and technology shocks. We keep the calibration from subsection 3.1 and adopt $u(c_t, l_t) = \log(c_t) - \psi \frac{l_t^{1+\frac{1}{\phi}}}{1+\frac{1}{\phi}}$ as the instantaneous utility function. Our welfare loss measure is given by the life-time consumption equivalent. The welfare of a given class p is given by:

$$\Omega(p) = \frac{\sum_z \int_0^\infty \int_{B(p)} e^{-\rho t} u(c(b,z,t), l(b,z,t)) g(b,z,t) dbdt}{\sum_z \int_{B(p)} g(b,z,t) db}$$

Where $B(p)$ is the subset of assets belonging to class p in the steady state. We re-scale welfare by the mass of agents in that class, so, our welfare measure represents the percentage of consumption you must give or take at each period to the average household in class p to be indifferent between never leaving the steady-state or experiencing the shock.

We define those classes as percentiles of wealth accordingly to the steady-state distribution[4]. The classes selected are those presented in Table 3.2. Already taking into account the instantaneous utility function, the life-time consumption equivalent of class p, for policy (ϕ_π, ϕ_y), is given by:

$$\frac{\log(1+\Delta)}{\rho} = \bar{\Omega}(p) - \Omega(p; \phi_\pi, \phi_y)$$
$$\Delta = e^{\rho\{\bar{\Omega}(p) - \Omega(p;\phi_\pi,\phi_y)\}} - 1$$

Where $\bar{\Omega}(p)$ is the steady-state welfare level and Δ is the life-time consumption equivalent, i.e. negative values mean individuals would choose to experience the shock, while positive values mean they would prefer the shock never happened.

[4]As the distribution changes, some states composing a given class at $t = 0$ might not be in this wealth group at $t = T > 0$. Thus, we could have reassigned the states belonging to each class at each period. We didn't do it for two reasons; we didn't want to account for the effect of given states entering and leaving classes, what would make the analysis less clear. In addition, the distribution doesn't move much with the shocks in any case.

3.3.1 Demand Shock

If the demand shock is positive (negative), it will increase (decrease) both consumption and hours worked from its steady-state level. While an increase in consumption boosts welfare, less leisure time diminishes it. Therefore, we can't affirm *a priori* whether households will prefer to live through the shock or not. A household will benefit from it if the utility gained by an increase in consumption or leisure is bigger than its loss due to an increase in hours worked or decrease in consumption.

Nonetheless, after analyzing table 3.3, it is clear all classes benefit from a positive discount factor shock, and are made worse if they live through a negative one. In sum, table 3.3 summarizes an unsurprising result: all households wish to live an expansionary shock, and prefer to avoid a contractionary one.

A closer look on the life-time consumption equivalent measures, however, show an unclear result. In case of a contractionary shock, no matter its magnitude, the top 10% prefer Taylor rule #2, i.e., the most dovish Taylor rule with parameters $\phi_\pi = 1.5$ and $\phi_y = 0$, while all the remaining households will favor Taylor rule #3, that is, the most hawkish Taylor rule with parameters $\phi_\pi = 5$ and $\phi_y = 0$. At the same time, the worst policy rule for the top 10% and bottom 90% is Taylor rule #3 and #2, respectively.

However, when we consider an expansionary shock, no matter its magnitude, policy preferences are switched. The top 10% will favor Taylor rule #3 and despise Taylor rule #2, while the bottom 90% will prefer Taylor rule #2 and loose the most under Taylor rule #3. In other words, society is divided in two irreconcilable positions: one group's best scenario is the other's worst, no matter the shock sign or magnitude.

Remembering our discussion from subsection 3.2, the shock have opposing effects on households. In one hand, after a positive (negative) demand shock, households want to anticipate (postpone) future (present) consumption and leisure. On the other hand, wages increase (decrease) creating incentives for them to work more (less), while income may fall or rise depending on the household, making it possible to both increase (decrease) consumption and savings.

Table 3.3: Demand Shock - Life-time Consumption Equivalent

	$(\phi_\pi, \phi_y) = (1.5, 0.125)$	$(\phi_\pi, \phi_y) = (1.5, 0)$	$(\phi_\pi, \phi_y) = (5.0, 0)$	$(\phi_\pi, \phi_y) = (1.5, 1.0)$
Contractionary shock: $-2\sigma_\gamma$				
Top 1%	0.0700	0.0692	0.0746	0.0732
Top 1-10%	0.0698	0.0695	0.0709	0.0706
Top 10-30%	0.0701	0.0702	0.0697	0.0698

Top 30-50%	0.0707	0.0710	0.0691	0.0695
Top 50-70%	0.0715	0.0721	0.0686	0.0694
Top 70%-Indebted	0.0708	0.0719	0.0662	0.0708
Indebted	0.0704	0.0728	0.0596	0.0626
Contractionary shock: $-\sigma_\gamma$				
Top 1%	0.0349	0.0345	0.0364	0.0360
Top 1-10%	0.0348	0.0347	0.0354	0.0352
Top 10-30%	0.0350	0.0351	0.0348	0.0348
Top 30-50%	0.0353	0.0355	0.0345	0.0347
Top 50-70%	0.0357	0.0360	0.0342	0.0346
Top 70%-Indebted	0.0353	0.0359	0.0330	0.0336
Indebted	0.0351	0.0363	0.0298	0.0312
Expansionary shock: σ_γ				
Top 1%	-0.0347	-0.0344	-0.0360	-0.0357
Top 1-10%	-0.0347	-0.0346	-0.0352	-0.0351
Top 10-30%	-0.0349	-0.0350	-0.0347	-0.0347
Top 30-50%	-0.0352	-0.0354	-0.0344	-0.0346
Top 50-70%	-0.0356	-0.0359	-0.0341	-0.0345
Top 70%-Indebted	-0.0352	-0.0358	-0.0329	-0.0335
Indebted	-0.0350	-0.0362	-0.0297	-0.0311
Expansionary shock: $2\sigma_\gamma$				
Top 1%	-0.0693	-0.0687	-0.0717	-0.0710
Top 1-10%	-0.0693	-0.0691	-0.0703	-0.0700
Top 10-30%	-0.0697	-0.0698	-0.0692	-0.0693
Top 30-50%	-0.0702	-0.0706	-0.0686	-0.0690
Top 50-70%	-0.0710	-0.0717	-0.0680	-0.0688
Top 70%-Indebted	-0.0703	-0.0714	-0.0656	-0.0669
Indebted	-0.0669	-0.0723	-0.0592	-0.0622

In order to understand the results from table 3.3, first, we describe the dynamics of total income and savings for each class, shock and Taylor rule. We also discuss how each income component contributes to total income change for each class, considering the Taylor rule adopted and the sign of the shock. Finally, we close by offering an explanation on why classes disagree on policy preferences.

Forestalling our results, considering a single class, whenever the contractionary shock has a strong negative impact on households' income, they decrease consumption and borrow more to cushion the shock. Consequently, their class' consumption and savings decrease. However, when the contractionary shock has a weak negative, or a positive impact on income, as households are more patient, they manage to decrease consumption but also increase savings, wishing to prop up resources in the future. As a result, their class' consumption decrease, but its savings increase.

In case an expansionary shock has a strong positive impact on a class' average income, its households can increase both savings and consumption. Consequently, their class' consumption and savings increase. But after an expansionary shock, if a class' income is mildly increased, or negatively affected, the impatient households borrow more to increase their consumption in the present. Therefore, their class' consumption increase, but its savings decrease.

Before we proceed to the analysis of total income and savings dynamics, lets explain the variables shown in figures 3.12 and 3.13. Figure 3.12 gives us the graphs of total income percentage deviation from steady state for each class, shock and Taylor rule. Figure 3.13 presents the change in savings relative to its steady-state, as percentage of steady-state income. To make it clearer, see the formula for the series in figure 3.13 bellow:

$$\theta(p,t) = \frac{s(p,t) - \bar{s}(p)}{\bar{I}(p)}$$

$\bar{I}(p)$ and $\bar{s}(p)$ are the steady-state average income and savings for class p, while $s(p,t)$ is the average savings for class p at period t. We use this measure to track the dynamics of savings for two reasons, first, the steady-state savings level of class p can be negative, which make it difficult to use savings percentage deviation from its steady-state. Second, using this measure, it is easier to compare both series and analyze the contribution of change in savings and income to change in consumption. For example, if income deviation and $\theta(p,1)$ equals -0.5%, consumption will be at steady-state level, i.e., in average households in class p fully compensate the drop in income with a drop in savings.

Top 1%: Looking at the graphs relative to the top 1% in figures 3.12 and 3.13 a pattern is clear. The more hawkish the Taylor rule is, the bigger the income drop, and the borrowing increase are after a negative shock, but the larger the income and savings increase are, after the positive shock. In figure 3.14, we divide the total income deviation by its components[5].

As wages and hours decrease after the negative demand shock, the labour income component (in black) falls, thus negatively impacting total income. For the positive shocks, the reverse takes place. Wages and hours increase, boosting labour income's contribution to income. After a contractionary shock, firms' profits rise affecting positively its contribution to income (in blue). After a positive shock, however, profits fall, having a negative effect on profits' share of income. Considering different monetary policies, as discussed in subsection 3.2, the more hawkish rules, i.e. Taylor rules #3 and #4, moderate the rise or fall of wages and hours worked compared to Taylor rule #2 and the Taylor

[5] That is, summing each component we get the total income deviation from steady-state.

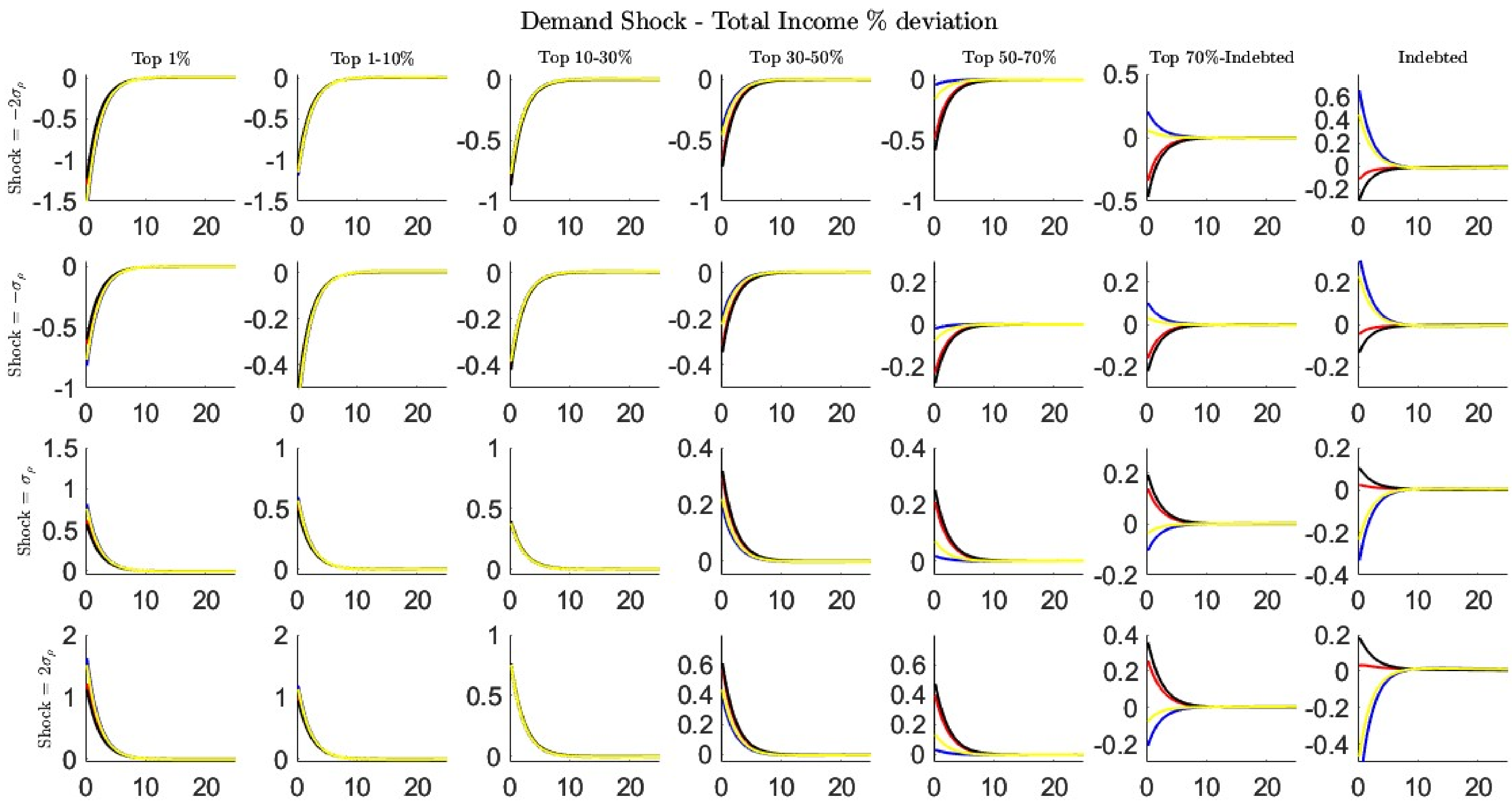

Figure 3.12: Total income deviation after a one-time discount factor shock. In red we have the income dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

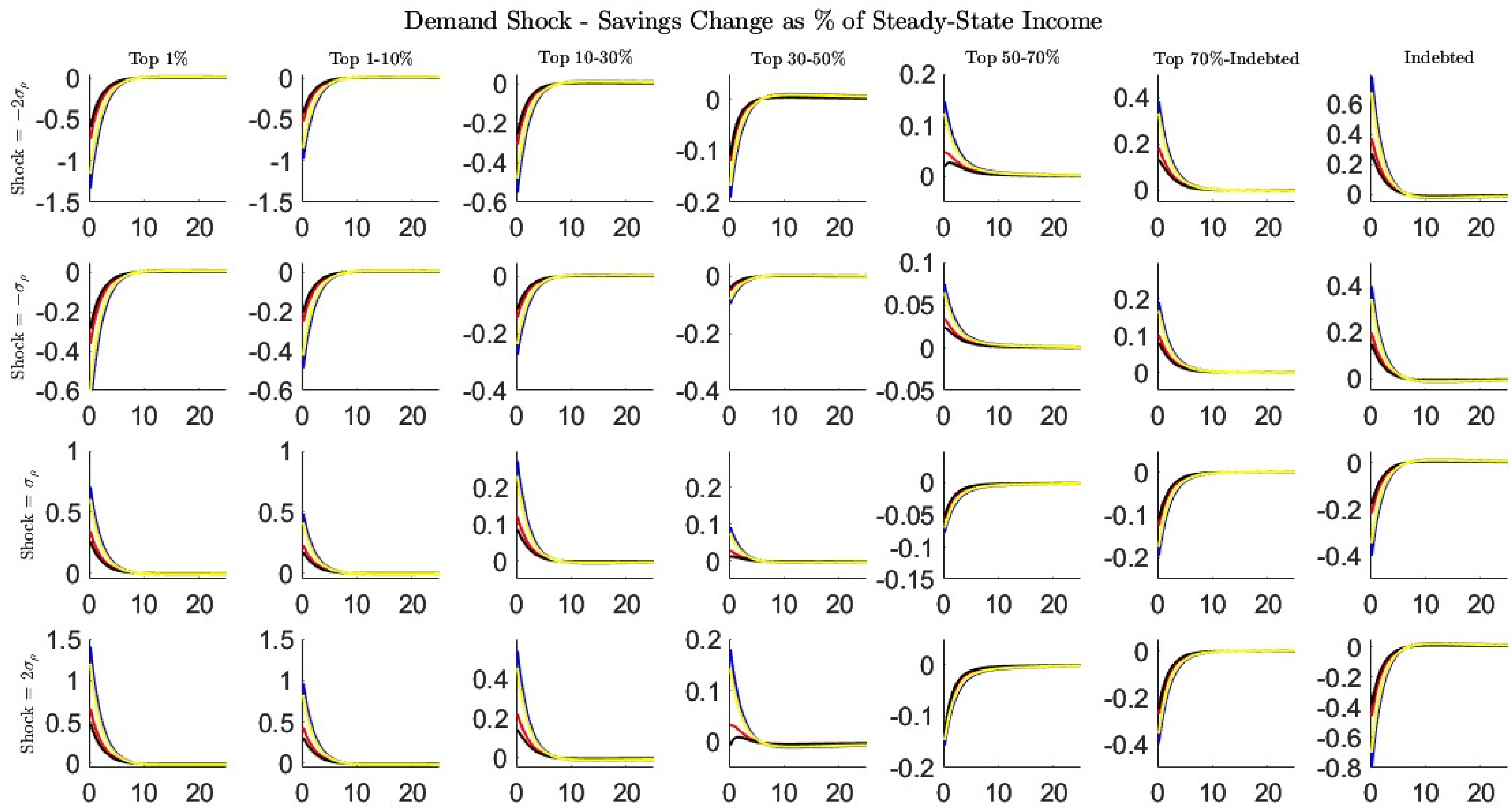

Figure 3.13: Savings change as percentage of total income at the steady-state after a one-time discount factor shock. In red we have the dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

(1993) calibration, which are more dovish. Consequently, they also moderate their contribution to total income deviation from steady-state.

Remembering the relation between transfers and Taylor rules discussed in subsection 3.2, its contribution to income (in yellow) may rise or fall depending on the monetary policy. For the hawkish rules, after a contractionary shock, the real interest rate drop compensates the labour tax revenue decrease. However, for positive shocks, the more reactive monetary policy accentuates the rate rise, surpassing the tax revenue increase.

Considering Taylor (1993) calibration and Taylor rule #2, real rates drop with less intensity after a negative shock, so the decrease of tax revenue isn't compensated by smaller interest payments. For the expansionary shock case, it's the opposite. The increase in interest payments is less intense and labour tax revenue surpass it, boosting transfers.

The financial income component (in green) consist in the interest payment received by asset holders. For this component, the hawkish Taylor rules don't moderate its contribution to income deviation, on the contrary. After a negative shock, real rates decline. The most hawkish rules exacerbate the interest rate decrease; therefore, financial income contract the most under them. In turn, after a positive shock, real rates rise, and more reactive rules increase financial income the most.

Under less reactive policy rules, however, financial income's contribution will be moderate. After a negative shock, under Taylor's calibration and Taylor rule #2, the interest rates and financial income will fall less intensively. On the other hand, after a positive shock, they will also rise less intensively.

In sum, after a negative shock, under Taylor #2, total income will drop by the least. Analyzing figure 3.14, we can check each component's contribution to total income deviation. Labour income's contribution (in black) drops the most under the Taylor rule #2. As the central bank react less to deflation and the output gap, interest rates decrease moderately compared to more hawkish rules. The economy is less stimulated; therefore, wages and hours fall the most.

On the other hand, under this rule, marginal profits will fall the most, rendering the biggest profit (in blue) increase among all rules. Those two components almost cancel each other. Because hours worked decrease, labour income diminish further, while output's fall curbs profits' rise. Therefore, in absolute terms, the drop in labour income contributes slightly more to income deviation than profits' increase. Meanwhile, transfers will drop the most under Taylor rule #2, as interest rate don't decrease as much, and tax revenue diminishes.

Even though labour income and transfers drop the most under this policy rule, financial income will drop the least. Profits almost cancel out the impact from the labour income component, while, regardless of the shock and rule analyzed, for the top 1%, transfers' contribution is too small when compared to the financial component's contribution, making the latter central in determining which policy renders the largest income. Therefore, the other rules' more accentuated decrease of the financial component is sufficient to make the drop in total income (in red) under Taylor rule #2 the smallest.

Looking now at the worst policy for the top 1%, Taylor rule #3, while profits' rise and labour income's fall are more moderate, the blow in financial income is the strongest[6]. As a consequence, total income will decrease the most under this rule, after a contractionary shock.

No matter the policy rule, the shock has a strong negative impact on the income of households at the top 1%, thus they cut consumption but also increase borrowing to smooth the impact of the contractionary shock, decreasing savings. Nonetheless, under Taylor rule #2, total income will drop the least, so consumption can have a moderate decrease, making less borrowing needed. In turn, under the most hawkish policy, Taylor rule #3, income drops the most, consumption suffer a harsher blow, and households will borrow more to soften the shock.

However, as mentioned, in the expansionary shock case, policy preferences are switched. Under Taylor #2, total income will rise by the least. As wages and hours increase, labour income's contribution grows. In turn, the larger marginal cost depresses profits, decreasing its share in total income. The government transfers component increases, as labour tax revenue increases more than interest payments on sovereign debt. As in the negative shock case, for the top 1% class, transfers' contribution to income deviation is too small compared to financial income's contribution, while profits and labour income almost cancel each other's impact.

As before, the main component to determine income change is financial income. Because of a less reactive policy rule, interest rates rise moderately, resulting in a modest increase of the financial and total income. In turn, under Taylor rule #3, real rates have the highest jump, propping up financial income to its highest levels. Thus, under the hawkish rule, income rise the most after the positive shock. As a result, consumption and savings rise the most under the hawkish rule and the least under the dovish one.

Top $1 - 10\%$: Once again, as in the graphs for the top 1% in figures 3.12

[6]Transfers also rise, but its contribution to total income deviation is too small.

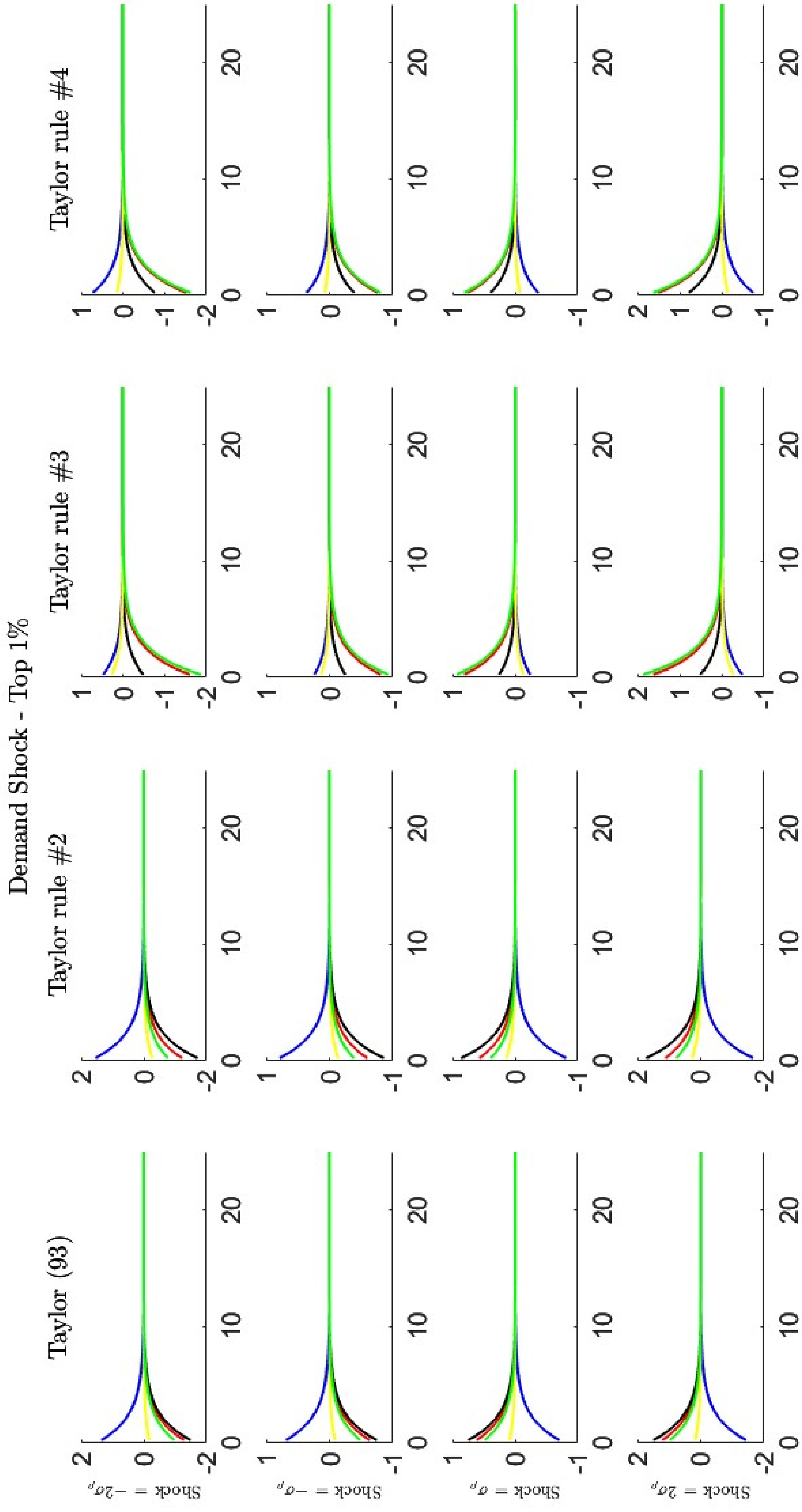

Figure 3.14: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to total income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

and 3.13, we can observe the hawkish rules deliver the higher drop in income and increase in borrowing after a negative shock. Nonetheless, after a positive shock, this is inverted, and income and savings have their strongest boost under more reactive policy rules. Analyzing each income component contribution in figure 3.15, we conclude the story here is similar to the one told for the top 1%.

Labour income and profits almost annul each other's impact, transfers contribute very little to total income deviation when compared to financial income's contribution, which is still the main component to determine which policy delivers the biggest change in the class' average income. Therefore, in case of a negative shock, Taylor rule #2 delivers the smallest income decrease, while Taylor rule #3, the largest. Consumption and savings will decrease by the least in the former, and the most in the latter, just like in the previous class. After a positive shock, policy preferences switch, a more hawkish rule boosts financial and total income the most, but a dovish rule renders a moderate increase in income. Both consumption and savings increase the most in the former, and the least in the latter.

In sum, the top $1 - 10\%$ agree in policy preferences for the same reason. Nonetheless, contrary to the top 1%, the life-time consumption equivalent for Taylor rule #3 is closer to those of Taylor rule #2, for the same shock sign and magnitude. That is, the difference in welfare level between each rule is smaller for this wealth class.

The motive is simple, as households at the top $1 - 10\%$ have a smaller average wealth than those at the top 1%, their financial income will change less after a swing of the interest rate. Therefore, the financial income contribution is less dominant, and income will be more dependent on labour income, profits and transfers. Those are components whose contribution to income deviation doesn't change much among the classes. Now, as we turn to less wealthy classes, the financial income component will no longer be predominant. When we analyze the indebted, however, it will have a dominant impact on income once again.

Top $10 - 30\%$: Inspecting figure 3.12, it is not easy to set each income series apart, but checking their vectors, after a negative shock, we can observe the biggest drop in income happens under Taylor rule #2 and the smallest under Taylor rule #3. Here, the shock's negative effect on total income is still strong enough to incentive households to borrow.

Income is less affected if the central bank chooses a hawkish policy, therefore, households would need to borrow less to smooth consumption after

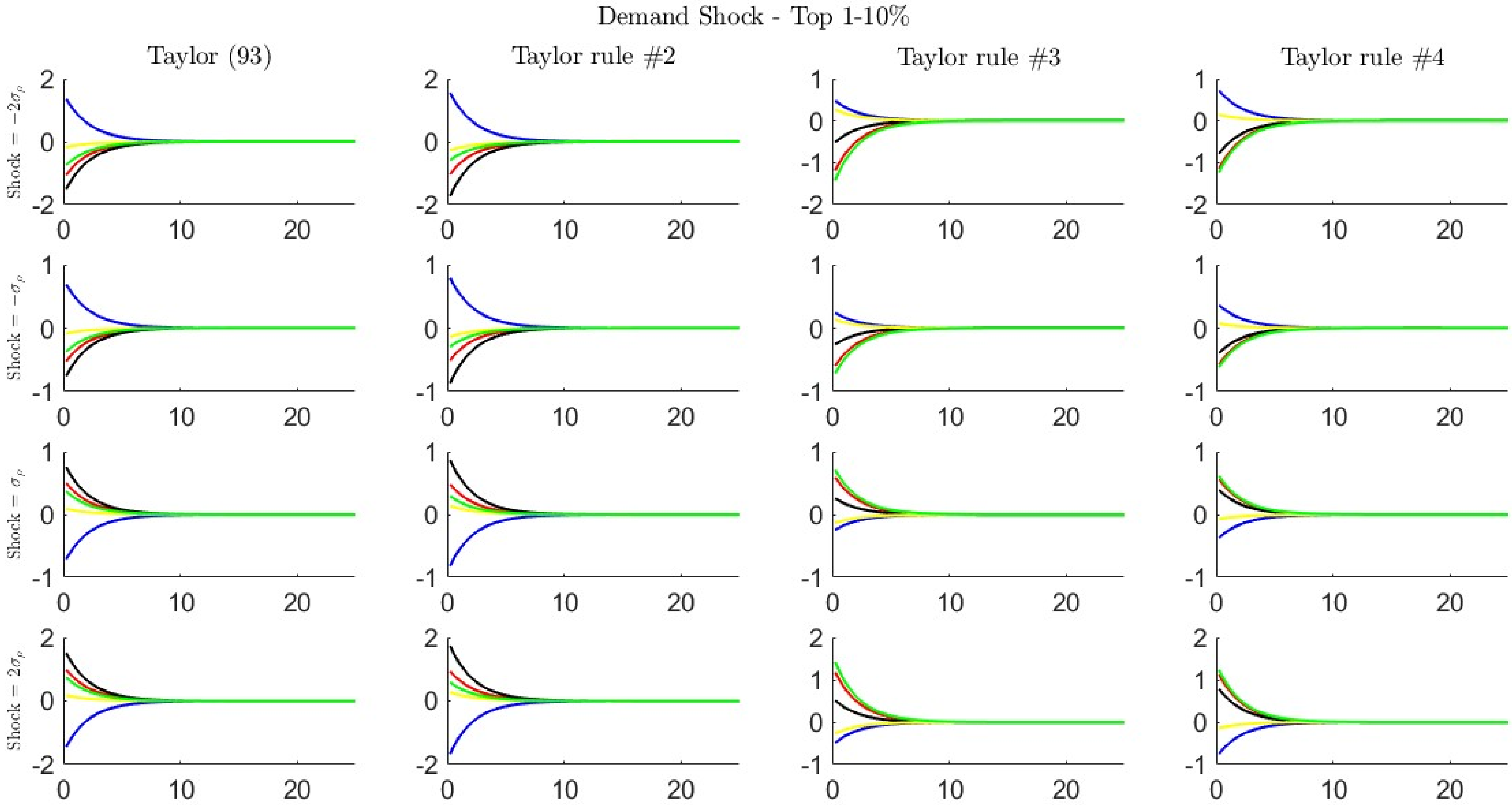

Figure 3.15: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

the shock. Nonetheless, the interest rates have its largest cut under this rule, which incentives borrowing. So, as for the last two classes, we can check in figure 3.13 that savings drop the most under Taylor rule #3 and the least under Taylor rule #2.

After a positive shock, Taylor rule #2 increase total income the most, while Taylor rule #3, the least. The shock's effect on income leads to a rise in savings as well as in consumption. However, as hawkish rules increase real rates more than dovish rules, savings increase more under Taylor rule #3, even though income increases more moderately.

Turning to figure 3.16, we can analyze each income component and their contribution to income deviation. First, we need to highlight, although financial income (in green) still have a prominent role in income change, it no longer determines which monetary policy has the biggest impact on total income (in red). Indeed, after a negative shock, the Taylor rule decreasing financial income the most, is Taylor rule #3, which is the policy that delivers the smallest drop in income. On the other hand, after a positive shock, the Taylor rule increasing financial income the least, delivers the highest income increase.

Additionally, the more reactive rules moderate the changes in labour income (in black) and profits (in blue), as discussed in subsection 3.2. It means the joined contribution of these two components, which is small and negative after a contractionary shock, and small and positive after an expansionary one, is closer to zero under those rules. Meanwhile, as financial income has a less prominent role, government transfers plays a more important part in determining which policy rule impacts income the most.

Under Taylor rule #3, after a negative shock, transfers increase the most, as labour income decreases the least and interest rates drops the most. After a positive shock, however, transfers increase the most under Taylor rule #2, as labour income increases the most and interest rates rise the least, under this policy. As financial income has a smaller impact on total income deviation, transfers' contribution become the tip in the scale, and end-up determining which rule impacts income the most.

Overall, the top $10-30\%$ disagree with the top 10%. While the former favours Taylor rule #3 after a negative shock, the latter prefers Taylor rule #2. In the positive shock case, those stances switch. The reason is simple. The average wealth of the top 10% magnifies the changes in financial income, making it the most important component of total income deviation.

For the top $10-30\%$, and as we'll see for all other classes except for the indebted, financial income won't have such a prominent role, allowing for transfers to become the tip in the scale to determine which rule delivers the highest levels of income. After the negative shock, under Taylor rule #3, transfers rise the most, softening the negative impact of financial income on total income. After the positive shock, Taylor rule #2 delivers the highest increase in transfers, compensating for any lost in financial gain due to smaller interest rates.

Top $30-50\%$: Looking at figures 3.12, 3.13 and 3.17, we observe the same patterns of the households in the top $10-30\%$. The shock's impact on income is strong enough to increase households' borrowing after they get more patient and increase savings after they get more impatient. After a contractionary shock, they will borrow more under hawkish rules, which drop the interest rates more than the less reactive policies. After an expansionary shock, they will save more under hawkish rules, which increase the interest rates more than the less reactive policies.

Meanwhile, as the average wealth decrease from class to class, financial income loses its importance and makes space for transfers to determine which rule delivers the largest income levels after a shock. After a contractionary shock, under Taylor rule #3, transfers increase the most, compensating the bigger drop in financial income due to smaller interest rates. After an expansionary shock, under Taylor rule #2, transfers increase the most, compensating the loss from not receiving higher interest payments, in case monetary policy were more hawkish.

Top $50-70\%$: As in the top $30-50\%$ case, the behavior of all variables will be similar to those for the top $10-30\%$. However, there will be one exception. The average wealth of the top $50-70\%$ is small, therefore income's financial component will have its impact soften. The income effect will be moderate. Depending on the rule analyzed, the financial component's impact is almost canceled by transfers' increase. On those cases, income will remain almost unaltered.

Remembering the discussion made in subsection 3.2, the shock have opposing direct and indirect effects on households. When strong and negative, the income effect pushed households to consume and save less, and when positive, to consume and save more. Nonetheless, when contractionary, the shock makes households more patient, willing to postpone consumption and to increase savings. When expansionary, it makes them less patient and willing to increase present consumption and diminish savings.

Now, as the income effect is moderate in both positive and negative shocks, the direct effect of the shock will be dominant. Therefore, after

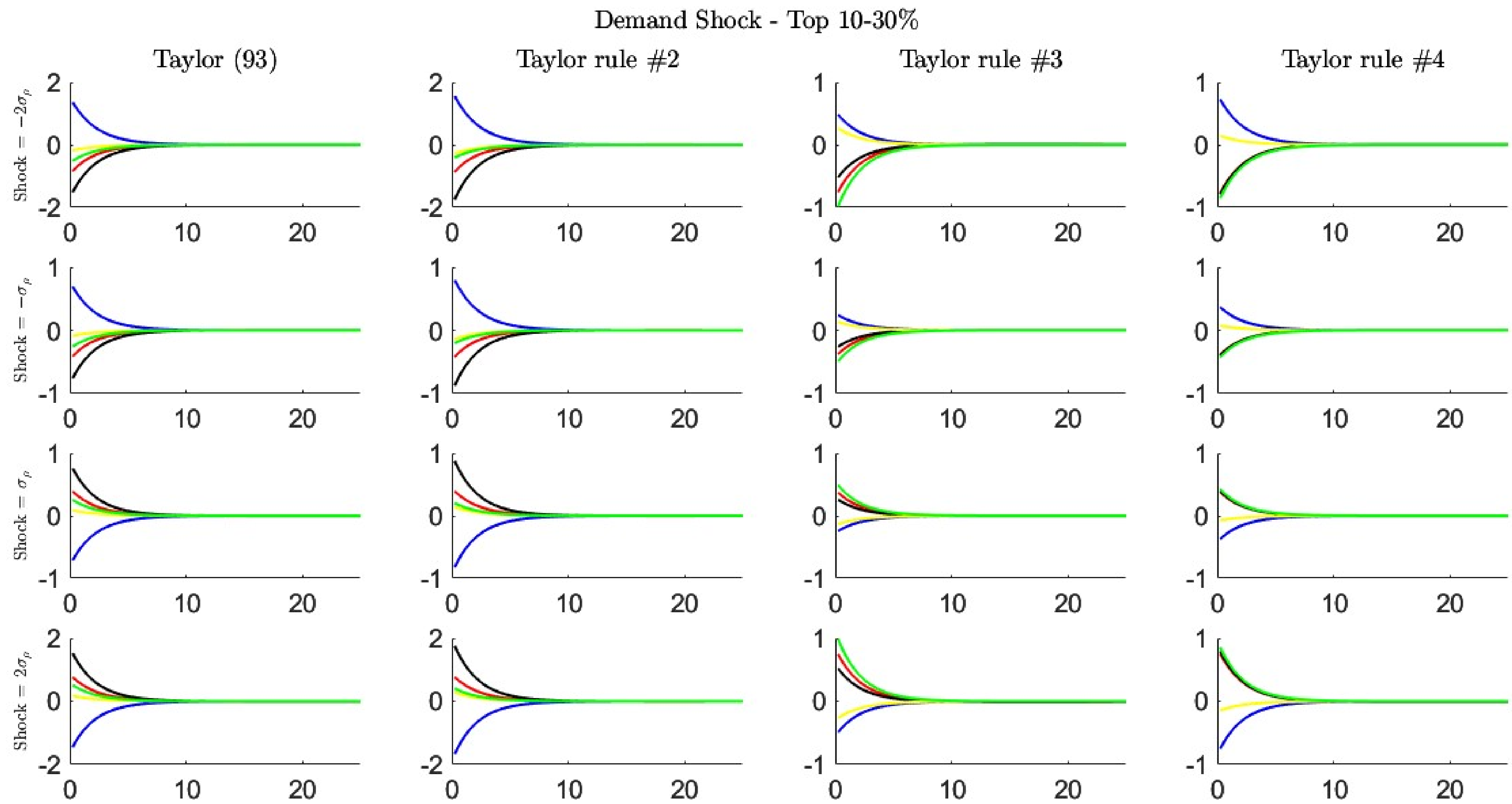

Figure 3.16: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

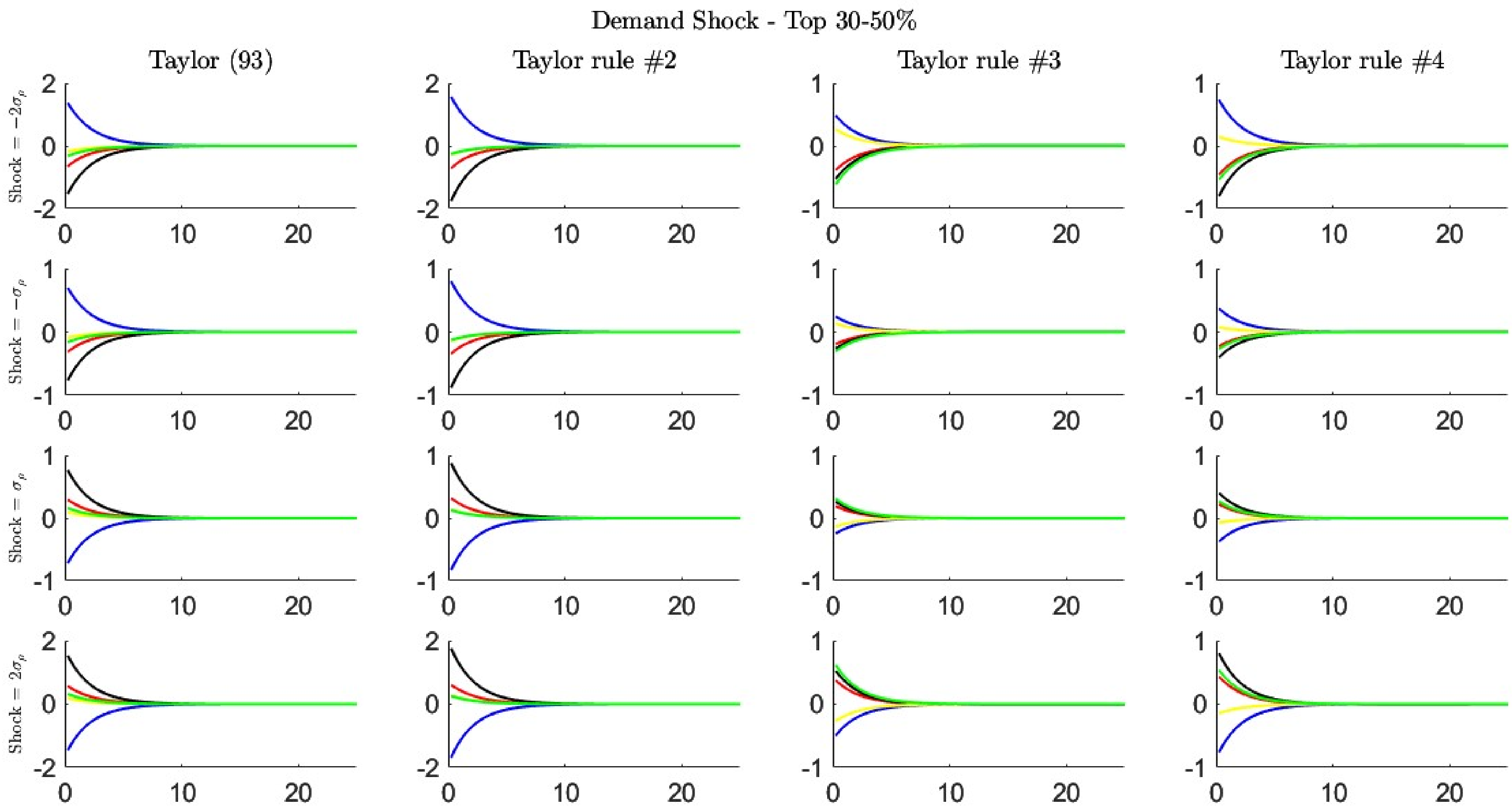

Figure 3.17: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

a negative shock, the income effect is weak, and households prefer to cut consumption but increase savings, bringing income into the future. After a positive shock, they prefer to increase consumption but decrease savings, as they are more impatient.

After the contractionary shock, under Taylor rule #3, the transfers component increases the most and total income remain almost unaltered. Households will save more under this policy than any other. For the expansionary shock case, under Taylor rule #2, income rise the most, the income effect is stronger under this rule, and so, savings fall by the least.

Looking at figures 3.12 and 3.13, we can see clearly the dynamic explained in the last paragraphs. Take figure 3.18, and once again, after a negative shock, we observe income fall the least under Taylor rule #3 because transfers (in yellow) almost compensate the drop in financial income (in green), while the joined contribution of labour income (in black) and profits (in blue) is almost null. After a positive shock, income will rise the most under Taylor rule #2, as transfers increase the most.

Top $70\%-Indebted$: Taking a close look at figure 3.19, we notice financial income (in green) doesn't contribute much for income deviation (in red) from the top 70%-Indebted, actually it barely change at all, no matter the shock's sign or magnitude. As labour income (in black) and profits (in blue) almost annul each other, transfers (in yellow) are the deciding factor to determine which rule delivers the highest income.

More than that, transfers determine if income will be above or below steady-state after the shock. After a negative shock, transfers rise under hawkish monetary rules. As the sum of all other components' contribution is too close to zero, income rises as well. The same happens under dovish Taylor rules, after a positive shock.

Looking at figures 3.12 and 3.13 we can check that, as in the top $50-70\%$ case, the income effect will be small. Contrary to the previous class, sometimes it will be small and positive. As the income effect has little impact, after a negative shock, the more patient households increase their savings, and after a positive shock, the more impatient households will decrease their savings.

In the contractionary shock case, transfers and total income rise the most under Taylor rule #3. As a result, the patient households will use this extra income to save more and cut consumption by the least amount, among all rules. After an expansionary shock, Taylor rule #2 will rise transfers and income the most. Consequently, the impatient households will consume and borrow more.

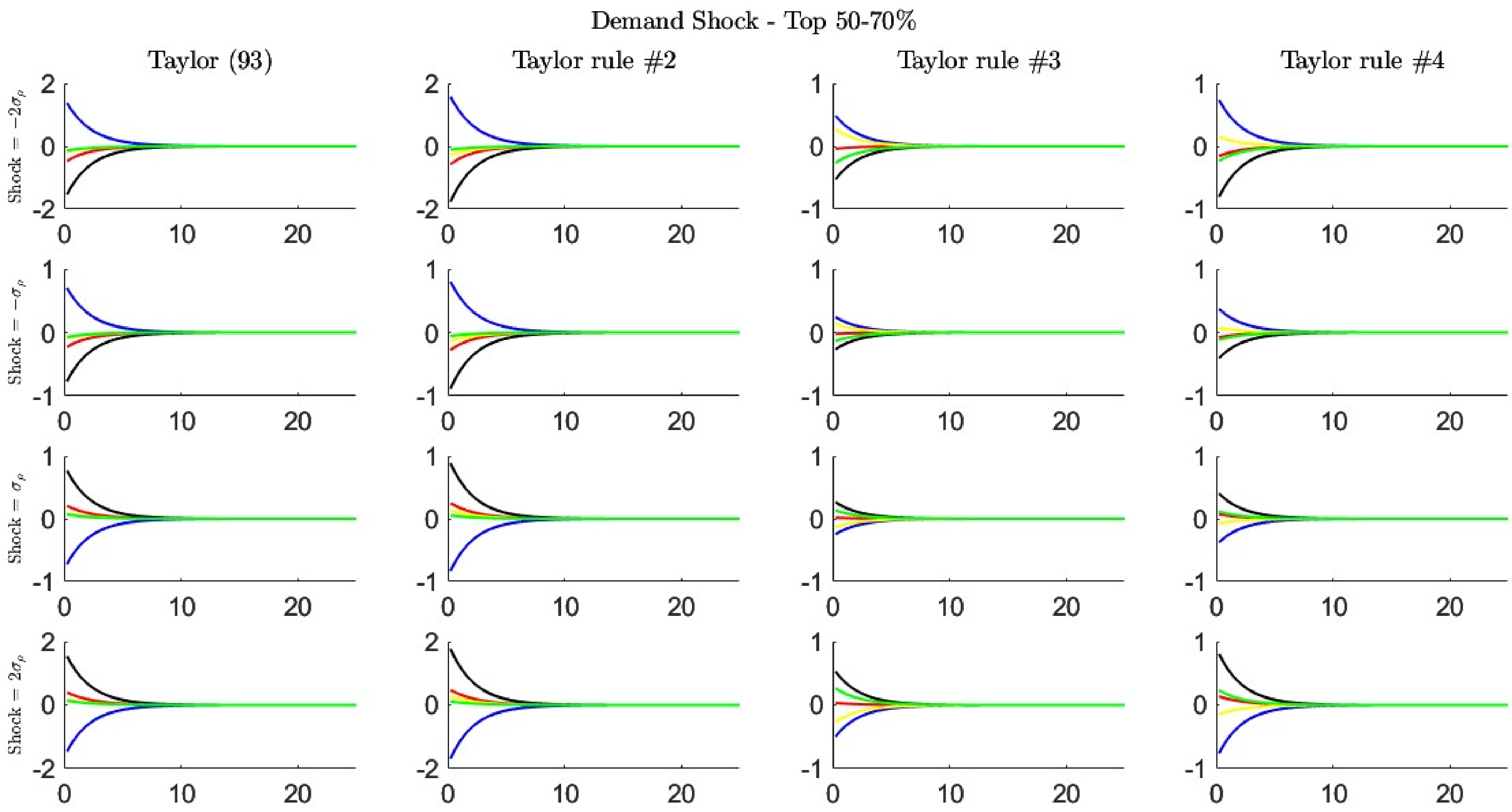

Figure 3.18: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

Indebted: The class of the indebted has a difference from the others. As they own assets to other households, when interest rates fall, their payments follow suit, increasing their income. Financial income (in green) will play an important role once again, but now, households will prefer policies that rise real rates the least or drop them the most.

After a negative demand shock, we can check in figure 3.20, financial income's contribution to income deviation is always positive. The shock diminishes output and leads to deflation, so, under any rule, real interest rates fall, together with interest payments. Although the financial component will always impact income positively, transfers fall under dovish rules, and rise under hawkish rules. Considering both components, income falls under dovish rules, dropping the most under Taylor rule #2, and increases under hawkish rules, rising the most under Taylor rule #3. As happened before with the top 70%-Indebted, savings will increase, as income rise. As Taylor rule #3 delivers the largest positive income deviation, the more patient households increase their savings the most under this rule, and the least under rule Taylor rule #2, when income drops.

However, we can't affirm transfers are the main determinant of income behavior. When it rises the most, under Taylor rule #3, the positive impact of financial income is greater than transfers' contribution to total income deviation. Nonetheless, when transfers drop the most, under Taylor rule #2, its impact exceeds financial income's contribution, decreasing total income.

After a positive shock, financial income's contribution is always negative. The shock increases output and inflation, so, under any rule, real rates rise together with interest payments. Still, transfers fall under hawkish rules, and rise under dovish rules. Considering both components' joined impact, income falls under hawkish rules, dropping the most under Taylor rule #3, and increases under dovish rules, rising the most under Taylor rule #2. As Taylor rule #2 delivers the largest positive income deviation, the income effect is stronger, and the more impatient households decrease their savings the least under this rule. Under rule Taylor rule #3, however, they borrow more, as income drops.

Once again, we can't affirm transfers are the main determinant of income behavior. When it rises the most, under Taylor rule #2, the negative impact of financial income is smaller than transfers' contribution, thus total income increases. Still, when transfers drop the most, under Taylor rule #3, its negative impact is smaller than the also negative contribution of financial income, decreasing total income. We conclude income is dependent on both transfers and financial income, no matter the shock.

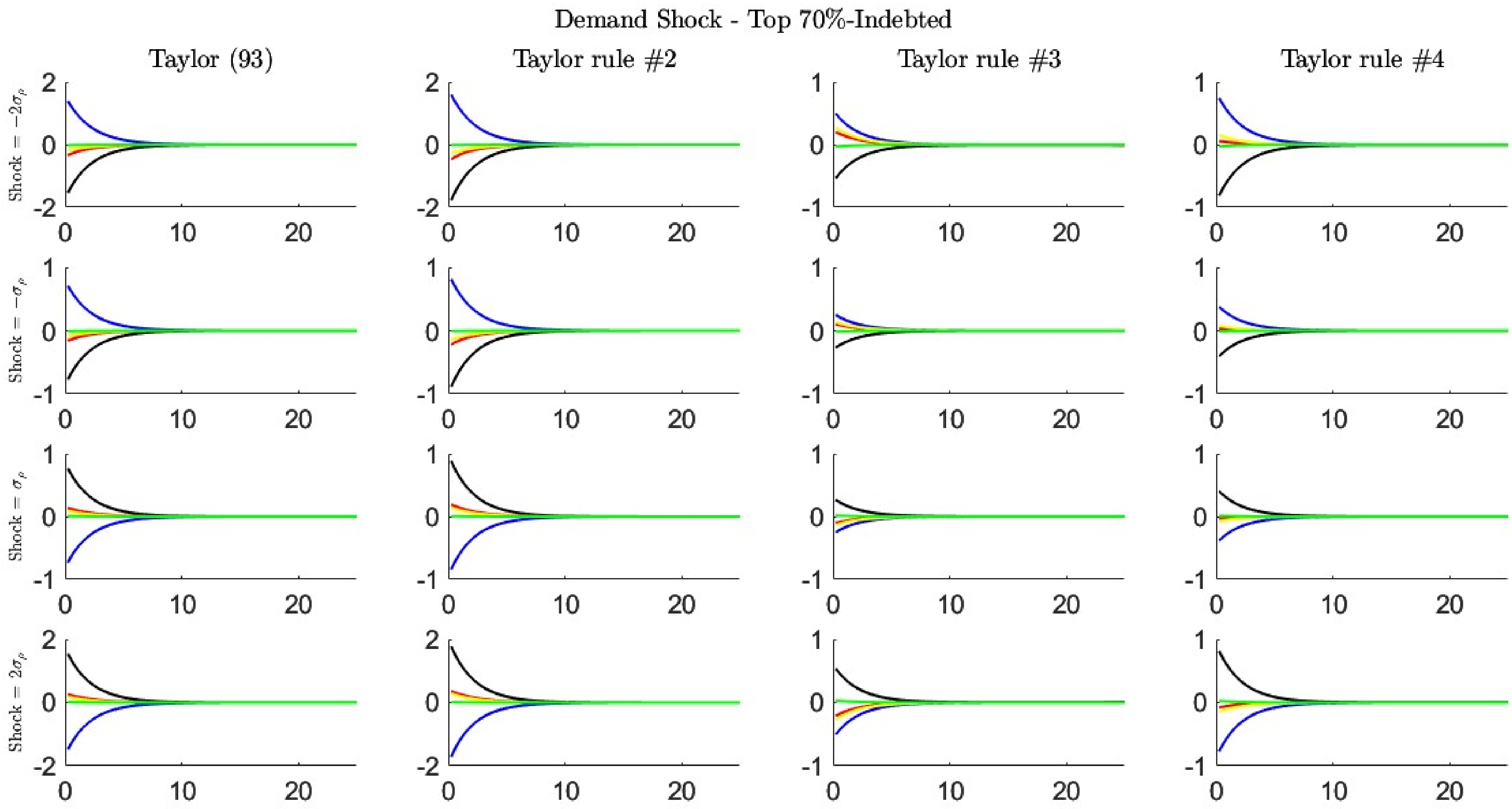

Figure 3.19: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

Why monetary policy preferences follow income behavior? — As it should be clear by now, given a shock's sign and magnitude, the monetary rules that maximize the income stream are the same that delivers the best welfare outcomes. This is no coincidence, the set of available streams of consumption and leisure time for a given income stream remain unaltered or increase if that income stream increases for every period. This is exactly what happens here. Households prefer policies that maximize their income because it also increases their number of consumption-leisure streams they can choose.

3.3.2 Technology Shock

If the technology shock is positive (negative), it will increase (decrease) consumption and decrease (increase) hours worked from its steady-state level. Therefore, households will (won't) prefer to live through the expansionary (contractionary) shock. Analyzing table 3.4, this becomes clear.

A closer look on the life-time consumption equivalent measures, however, show a not so obvious result. In case of a contractionary shock, no matter its magnitude, all classes prefer Taylor rule #4, with parameters $\phi_\pi = 1.5$ and $\phi_y = 1$. At the same time, the worst policy rule for all classes is Taylor rule #3, with parameters $\phi_\pi = 5$ and $\phi_y = 0$.

When we consider an expansionary shock, no matter its magnitude, policy preferences are switched. All classes prefer Taylor rule #3, with parameters $\phi_\pi = 5$ and $\phi_y = 0$. Meanwhile, the worst policy rule for all classes is Taylor rule #4, with parameters $\phi_\pi = 1.5$ and $\phi_y = 1$.

Remembering our discussion from subsection 3.2, the shock have opposing effects on households. In one hand, if after a positive (negative) technology shock, households' income increase (decrease), they will wish to consume and save more (less). On the other hand, real interest rates fall (rise) creating incentives for them to anticipate (postpone) consumption and decrease (increase) savings.

Table 3.4: Technology Shock - Life-time Consumption Equivalent

	$(\phi_\pi, \phi_y) = (1.5, 0.125)$	$(\phi_\pi, \phi_y) = (1.5, 0)$	$(\phi_\pi, \phi_y) = (5.0, 0)$	$(\phi_\pi, \phi_y) = (1.5, 1.0)$
Contractionary shock: -2σ_γ				
Top 1%	0.1315	0.1325	0.1329	0.1295
Top 1-10%	0.1356	0.1368	0.1373	0.1308
Top 10-30%	0.1395	0.1409	0.1414	0.1327
Top 30-50%	0.1422	0.1437	0.1443	0.1345
Top 50-70%	0.1453	0.1469	0.1476	0.1370

Top 70%-Indebted	0.1476	0.1495	0.1503	0.1379
Indebted	0.1535	0.1557	0.1566	0.1429
Contractionary shock: $-\sigma_\gamma$				
Top 1%	0.0659	0.0664	0.0666	0.0632
Top 1-10%	0.0680	0.0686	0.0689	0.0649
Top 10-30%	0.0700	0.0707	0.0710	0.0664
Top 30-50%	0.0713	0.0721	0.0724	0.0673
Top 50-70%	0.0729	0.0737	0.0741	0.0686
Top 70%-Indebted	0.0740	0.0750	0.0754	0.0690
Indebted	0.0770	0.0781	0.0785	0.0714
Expansionary shock: σ_γ				
Top 1%	-0.0658	-0.0664	-0.0666	-0.0630
Top 1-10%	-0.0682	-0.0689	-0.0691	-0.0648
Top 10-30%	-0.0702	-0.0709	-0.0713	-0.0663
Top 30-50%	-0.0715	-0.0724	-0.0727	-0.0673
Top 50-70%	-0.0731	-0.0740	-0.0744	-0.0686
Top 70%-Indebted	-0.0742	-0.0753	-0.0757	-0.0690
Indebted	-0.0772	-0.0784	-0.0789	-0.0712
Expansionary shock: $2\sigma_\gamma$				
Top 1%	-0.1319	-0.1330	-0.1335	-0.1221
Top 1-10%	-0.1368	-0.1382	-0.1388	-0.1280
Top 10-30%	-0.1408	-0.1423	-0.1430	-0.1327
Top 30-50%	-0.1435	-0.1452	-0.1459	-0.1348
Top 50-70%	-0.1466	-0.1484	-0.1492	-0.1373
Top 70%-Indebted	-0.1489	-0.1510	-0.1519	-0.1382
Indebted	-0.1549	-0.1573	-0.1583	-0.1425

In order to understand the results from table 3.4, first, we describe the dynamics of total income and savings for each class, shock and Taylor rule. We also discuss how each income component contributes to total income change for each class, considering the Taylor rule adopted, and the sign of the shock. Finally, we close by offering an explanation on why classes agree on policy preferences.

Forestalling our results, considering a single class, whenever the contractionary shock has a strong negative impact on households' income they decrease consumption and borrow more to cushion the shock. Consequently, their class' consumption and savings decrease. However, when the contractionary shock has a weak negative impact on income, as interest rates rises, the class' households prefer to postpone consumption, and to save. As a result, their class' consumption decrease, but its savings increase.

In case an expansionary shock has a strong positive impact on a class' average income, its households can increase both savings and consumption. Consequently, their class' consumption and savings increase. But, if a class' income is mildly increased, or negatively affected, as interest rates falls, households prefer to anticipate consumption, and to borrow. As a result, their class' consumption increase, but its savings decrease.

Finally, we must highlight figures 3.21 and 3.22 present the same vari-

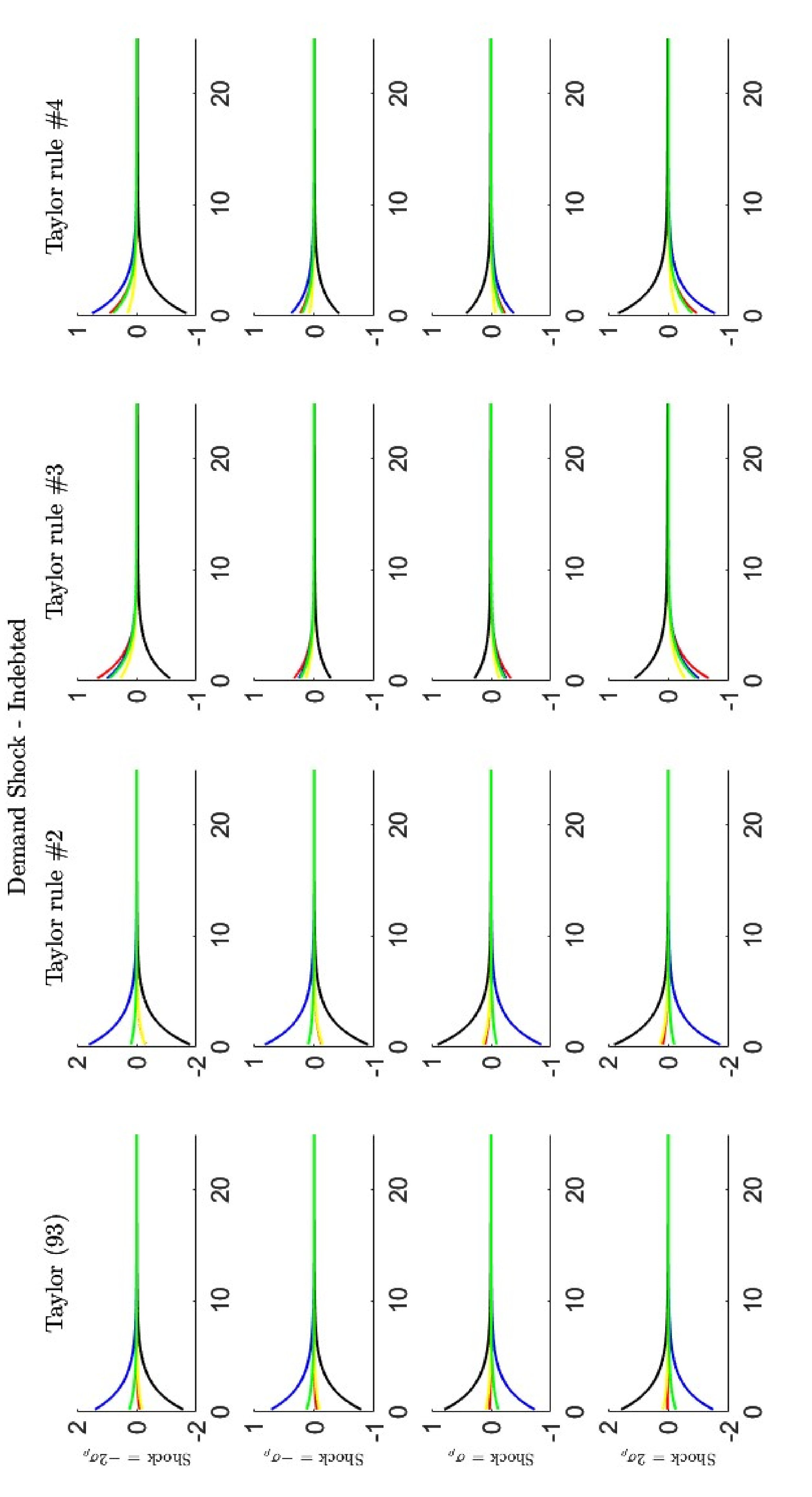

Figure 3.20: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

ables in figures 3.12 and 3.13, respectively.

Top 1%: Looking at the graphs of the top 1% in figures 3.21 and 3.22, we can observe that Taylor rule #4 produce the biggest income and savings decrease after a negative shock. Although it is clear income drops and savings rise for all other rules, it isn't easy to recognize their series in the figures' graphs.

However, in figure 3.23, we divide the total income deviation by its components. In it, we can see the rules reactive to output gap have the strongest impact on total income (in red) after a negative shock. Taking the savings' vector, we can verify that the bigger the drop-in income, the smaller is the increase in savings. Under Taylor rule #4, income falls so much, households in the top 1% choose to decrease their savings.

Figures 3.21 and 3.22 show income increase and savings decrease, after a positive shock, under all rules except for Taylor rule #4. Once again, a look at figure 3.23 reveals that rules non-reactive to output gap, such as Taylor rules #2 and #3, deliver a higher income than Taylor rule #4 and Taylor's original calibration. Indeed, under Taylor rule #4, despite the expansionary shock, total income falls momentarily, before rising above steady-state and then converging to it once again. Now let's analyze each income component.

Although wages decrease after a contractionary shock, hours worked increase, therefore, labour income (in black) could increase or fall. Nonetheless, for most rules the rise in hours worked doesn't compensate the wages' slump, apart from Taylor rule #4. Consequently, for most policies, labour income's contribution will decrease after a negative shock. Under Taylor rule #4, however, the wages fall so little, the increase in hours worked props labour income up.

Symmetrically, after an expansionary shock, hours worked decrease, while wages increase. Thus, labour income could increase or fall. Except for Taylor rule #4, wages increase labour income's contribution, despite households taking more leisure time. Nonetheless, under Taylor rule #4, wages rise so little, the decrease in hours worked diminish labour income.

After a negative shock, firms' profits (in blue) fall, impacting negatively its contribution to total income. In turn, after a positive shock, profits rise for most policy rules, impacting positively total income deviation. Only under rule #4, profits will decrease momentarily, decreasing its contribution to income deviation.

Consider now each Taylor rule. As the Taylor (1993) original calibration and Taylor rule #4 react to output gap, after a contractionary shock, real

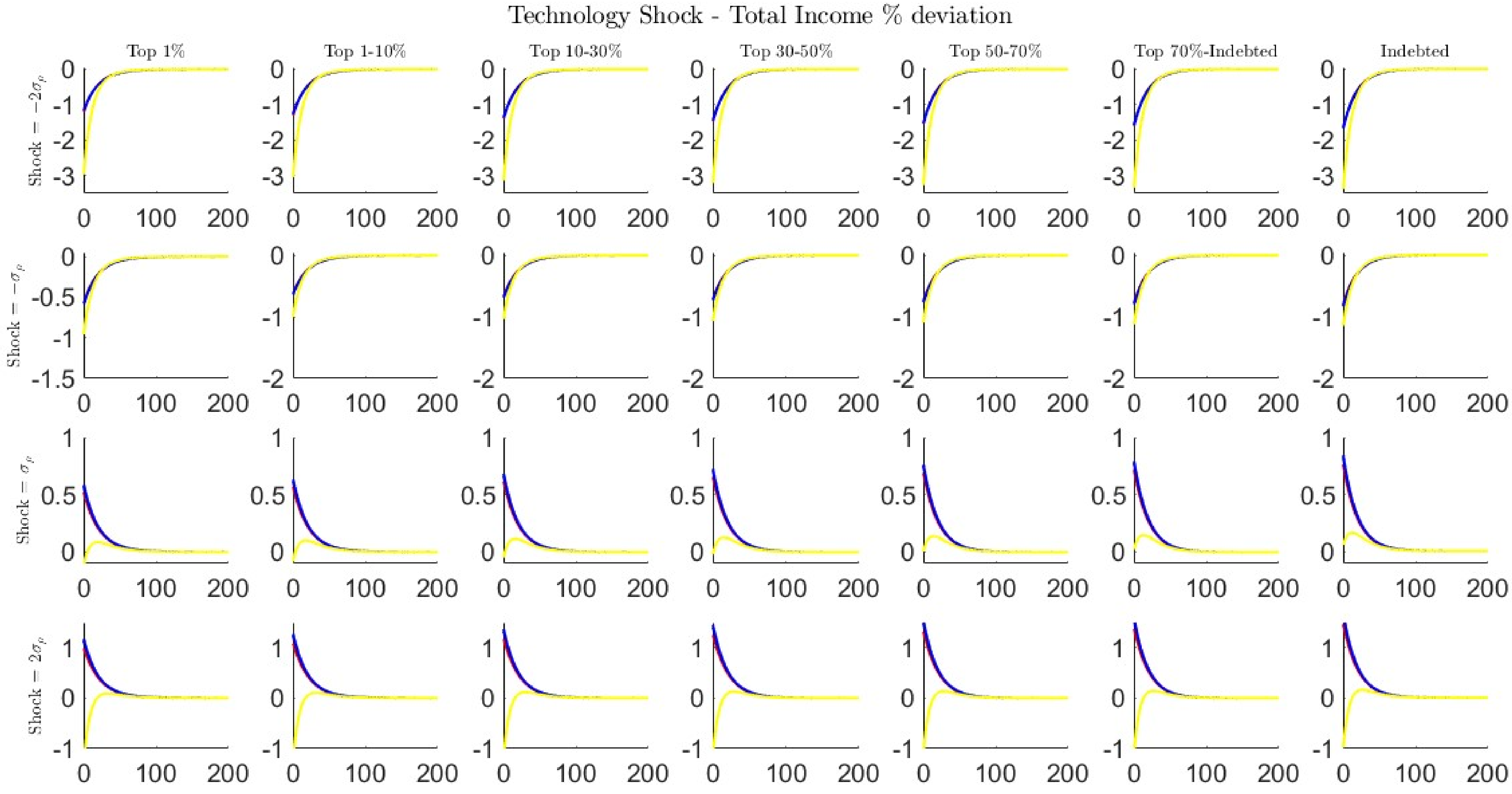

Figure 3.21: Total income deviation after a one-time technology shock. In red we have the income dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

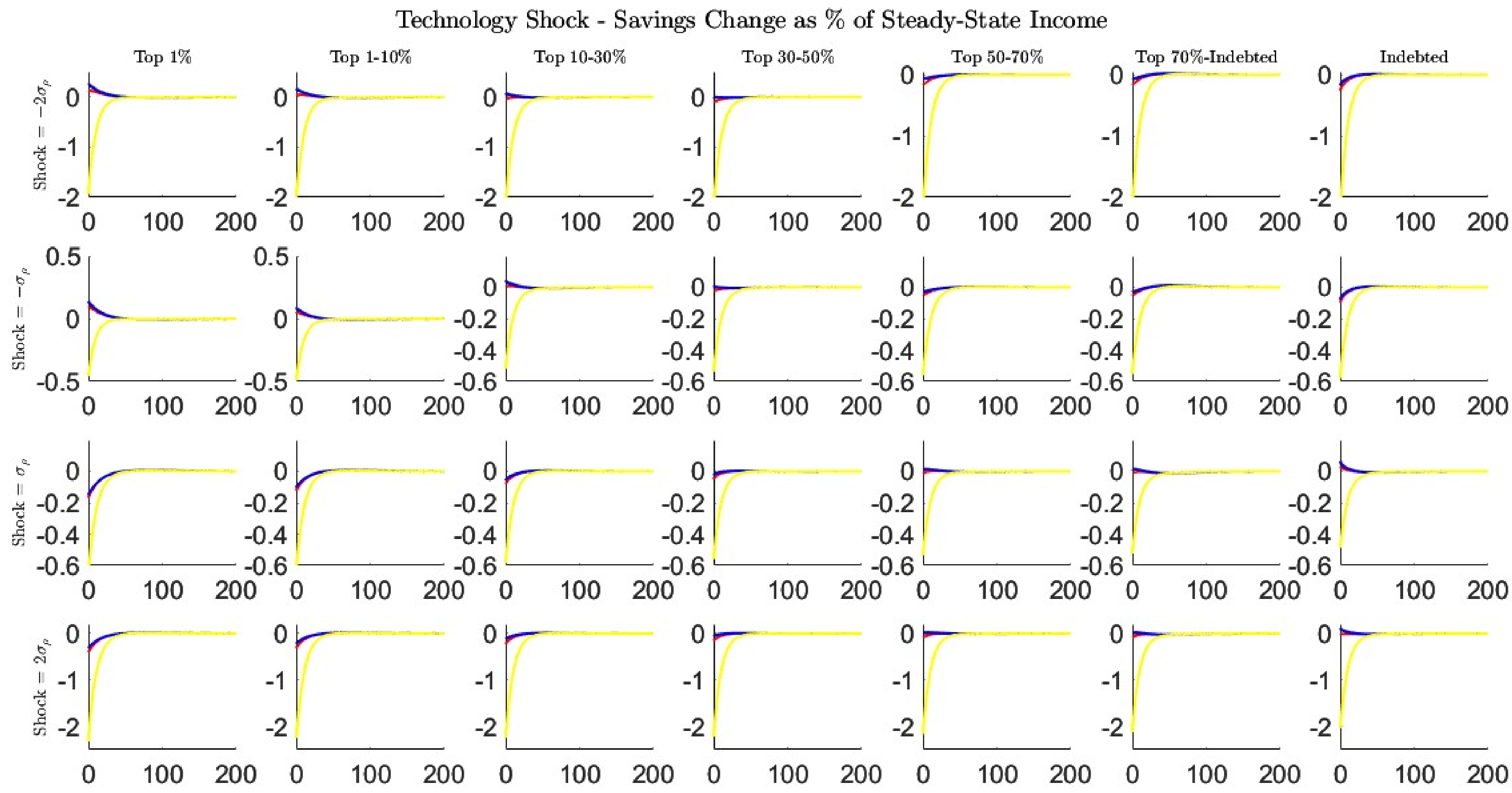

Figure 3.22: Savings change as percentage of total income at the steady-state after a one-time technology shock. In red we have the dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

rates will increase less than under Taylor rules #2 and #3. As monetary policy considers the fall of output, the recession will be less accentuated. Although wages still decrease, as the economy contracts less, the fall in wages will be soften as well. Also, with a less restrictive monetary policy, inflation will be higher.

Overall, rules reacting to output will moderate labour income's fall, and depending on how reactive the policy is, it may even increase the component's contribution. However, they will also depress profits more than rules #2 and #3 by softening the shock's impact on wages and increasing menu costs.

Now, taking once again the Taylor (1993) original calibration and Taylor rule #4, after an expansionary shock, real rates will decrease less than under Taylor rules #2 and #3. As monetary policy considers the increase of output, the boom will be less accentuated. Although wages still increase, as the economy expand less, the rise in wages will be moderate. Also, with a more restrictive monetary policy, deflation will be more intense.

Overall, rules reacting to output will moderate labour income's increase, and depending on how reactive the policy is, it may even decrease the component's contribution. However, they will also temperate profits' rise when compared to rules #2 and #3. In the case of Taylor rule #4, high menu costs will lead to a fall in profits. While deflation converges back to the steady state, menu costs shrink, and as marginal costs and output are respectively bellow and above steady-state, profits rise, surpass its steady-state level, and then falls again.

For most rules, after a contractionary shock, labour income falls, and so does labour tax revenue. At the same time, interest rates rise, increasing the national debt service. Consequently, transfers (in yellow) decrease. However, under Taylor rule #4, as labour income rises, so will labour tax revenue. Even though interest rates increase the debt service, the increase in revenue keeps transfers constant. In any case, transfers won't change much under any rule. Its role will be limited in our analysis.

No matter the policy rule, the financial component (in green) will rise with interest rates after a negative shock. It will rise the most under Taylor rules #2 and #3, which don't react to the recession caused by the shock, only to inflation. As for the other rules, interest rates increase parsimoniously under them, financial income's contribution still increase, but moderately.

After a positive shock, real rates fall the most under Taylor rules #2 and #3, and so will financial income. Under Taylor's original calibration and rule #4, however, the Central Bank considers the boom of the economy and moderate the rates' cut. Financial income still falls, but less than under the other rules.

In sum, after a negative shock, under Taylor rule #4, total income will drop by the most. As rule #4 is the most reactive to the output gap, it produces the smallest rise in real rates, generating the least severe recession. As a result, wages fall moderately, and inflation rises more than under any other rule. Hours worked increase, so households can compensate the smaller wages. Meanwhile the shock increases marginal and menu costs, as wages have the smallest fall and inflation increases.

Analyzing each component's contribution to total income deviation in figure 3.23, we can check labour income and transfers will rise. Under any other rule, the fall in wages isn't compensated by the increase in hours. For rule #4, this is not case, however. Therefore, labour income increases, together with labour tax revenue. The increased revenue surpasses the increased government debt service. Although both components rise, it is not by much. Transfers for example remain almost constant after the shock. Financial income also rises, but, as interest rates increase the least under Taylor rule #4, the financial component will have its smallest increase under this policy.

Labour income, transfers and financial income increase after a negative shock, under Taylor rule #4, even if only moderately. However, profits take its biggest blow under this rule. As wages remain practically unchanged, marginal costs and inflation rise, leading to the biggest drop in profits among all rules. As a result, under Taylor rule #4, total income falls the most led by profits.

If we consider the least preferred policy, Taylor rule #3, each components' contribution is different. Labour income and transfers fall, so they contribute negatively to total income deviation. Financial income increases more than under rule #4, as interest rates also rise more. Profits have a parsimonious fall due to wages' more intense decrease, so labour income's decrease will be the most relevant component in determining total income deviation. Finally, we can observe total income falls the least under this rule.

Nonetheless, no matter the rule, the shock has a negative impact in income, consequently, households will reduce their consumption. However, only under Taylor rule #4, total income falls so much that households choose to borrow and cushion the shock, despite the rise in interest rates. For all other rules, income drops only moderately, so they take advantage of the higher interest rates to increase savings.

After a positive shock, Taylor rule #3, total income rises the most. As rule #3 is the most reactive to inflation and the least reactive to output, it produces the higher drop in interest rates, generating the most accentuated boom. As a result, wages increase the most, households take advantage of it to take more leisure time, and hours worked decrease. Meanwhile, the shock decreases marginal costs, but as wages rise the most under this policy, deflation is moderate. As marginal costs decrease, profits are propped up.

Analyzing each component's contribution to total income deviation in figure 3.23, we can check labour income, transfers and profits will rise the most under Taylor rule #3. Although hours worked falls, as wages rises the most, labour income also increases the most, together with labour tax revenue. With falling rates, the national debt service decreases, resulting in transfers rising.

Also, as wages rise the most under this policy, the shock still reduces marginal costs, but moderately. Therefore, profits rise parsimoniously. For last, financial income falls the most because interest rates fall the most under this policy. Taking all components into account, we notice the same pattern observed in the contractionary shock case, for Taylor rule #3. The financial component, profits and transfers play a small part determining total income deviation. The most important component is labour income.

Considering the worst policy for households, Taylor rule 4, wages remain almost unaltered, and hours worked drop the most, so labour income decrease, contrary to what happens under every other rule. Labour tax revenue also decreases, so transfers remain practically unaltered despite the national debt service's decrease. Financial income falls moderately, as interest rates have a smaller cut.

As wages remain almost unaltered, the shock's effect on marginal costs will be much stronger, leading to a higher deflation and menu costs. The latter is so high, it manages to drop profits bellow its steady-state level, despite the increase in output and decrease of marginal costs. However, as deflation fades, the marginal costs' fall and output' rise overcome menu costs' impact, thus, profits rise above steady-state before returning to it. Taking all components into account, we notice the same pattern observed in the contractionary shock case, for Taylor rule #4. The financial component, labour income and transfers play a small part determining total income deviation. The most important component still is profits.

For most rules, the shock has a positive impact in income, only under Taylor rule #4, total income falls momentarily because of profits. Nonetheless, under all rules, consumption will rise. Under rule #4, households will borrow knowing their income will rise in the future, so they manage to increase consumption despite their income's fall. For all other rules, especially policy rule #3, income rises, therefore, households consume more. Although their income increases, as interest rates fall, households wish to take advantage of them and borrow, thus boosting consumption even more. The intertemporal substitution channel is stronger than the income channel, and so savings will decrease.

Top $1-10\%$: Inspecting figures 3.21, 3.22 and 3.24, we notice households in the top $1-10\%$ behave similarly to those in the top 1%. After a negative shock, total income drops under any rule, and households cut consumption down.

Under Taylor rule #4, income drops so much, they prefer to borrow more to cushion the shock. On the other hand, for any other rule, income's fall is not enough to overcome the intertemporal substitution channel, and so households prefer take advantage of higher interest rates to increase savings.

Decomposing among the components, we can check profits still is the main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income under rule #4, much more than labour income under any other rule. As a result, policy rule #4 contracts income the most, while rule #3, the least.

After a positive shock, total income rises under any policy rule, except for Taylor rule #4. As in the previous class, profits take a blow after an expansionary shock, decreasing income. Nonetheless, as profits will increase later, income will also follow suit, so households decide to borrow enough to increase their consumption, compensating for the income fall.

For any other policy, as total income increases, households will choose to consume more. Although income rises, its impact isn't strong enough to overcome the effect of the falling interest rates. Therefore, households decrease their savings to boost consumption.

Decomposing among the components, we can check profits still is the main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income temporarily, under rule #4, while labour income boosts total income under any other rule. As a result, policy rule #4 contracts income, while rule #3, boosts it the most.

However, there is one difference worth mentioning between both classes' cases. As the top $1-10\%$ have less assets on average than the top 1%, thus the financial component will rise and drop less in the contractionary and expansionary shock cases, respectively. It means the top $1-10\%$ income will decrease and increase more than the top 1%, after negative and positive

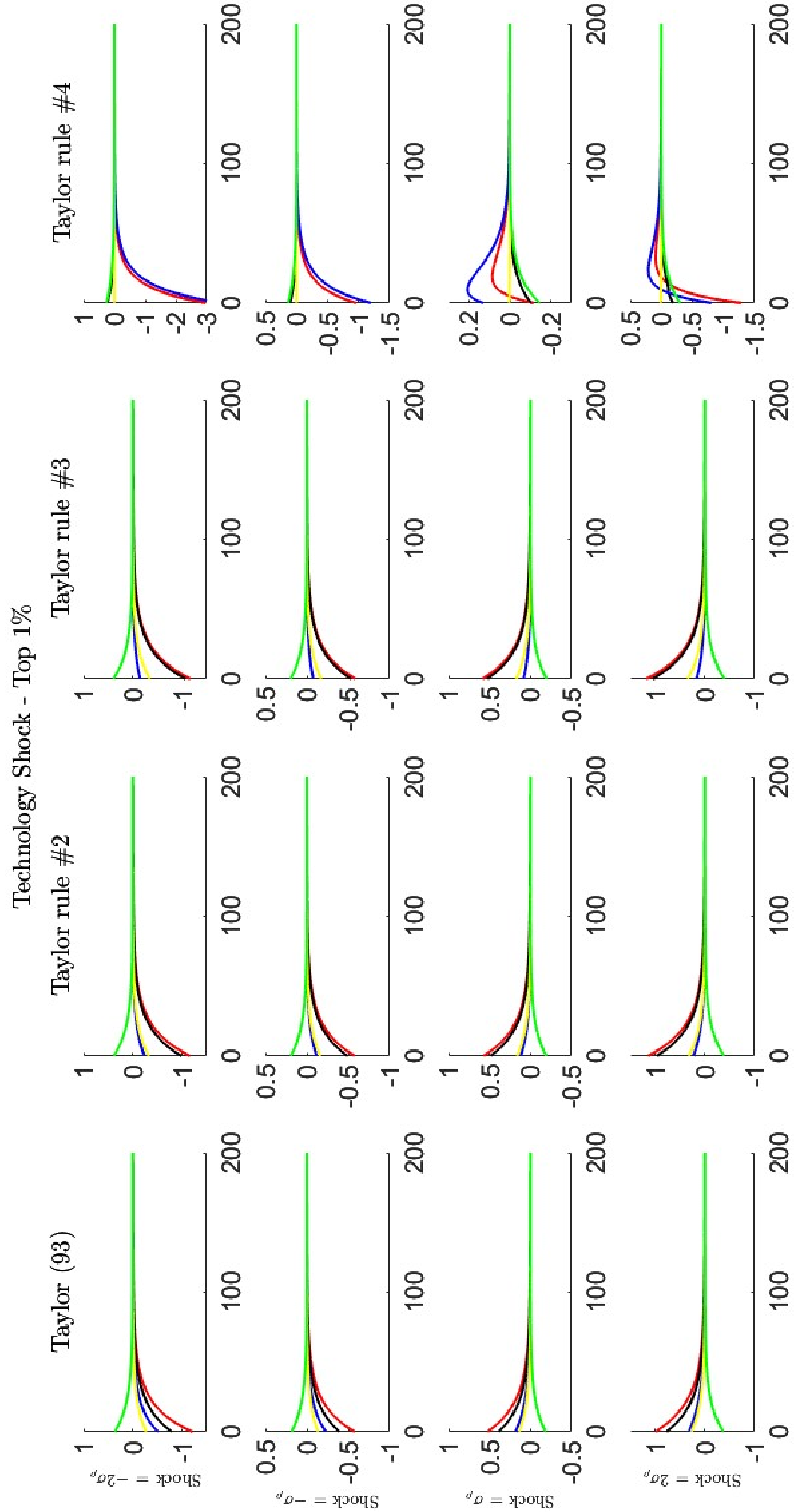

Figure 3.23: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to total income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

shocks respectively. We will see this same pattern repeat itself. It will have consequences for the behavior of each class' savings.

Top $10-30\%$: Inspecting figures 3.21, 3.22 and 3.25, once again, we observe similar dynamics to those in the top 10%. After a negative shock, total income drops under any rule, and households cut consumption down.

Under Taylor rule #4, income drops so much, they prefer to borrow more to cushion the shock. On the other hand, for any other rule, income's fall is still not enough to overcome the intertemporal substitution channel, and so households prefer take advantage of higher interest rates to increase savings.

Decomposing among the components, we can check profits still is the main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income under rule #4, much more than labour income under any other rule. As a result, policy rule #4 contracts income the most, while rule #3, the least.

After a positive shock, total income rises under any policy rule, except for Taylor rule #4. As in the previous class, profits take a blow after an expansionary shock, decreasing income. Nonetheless, as profits will increase later, income will also follow suit, so households decide to borrow enough to increase their consumption, compensating for the income fall.

For any other policy, as total income increases, households will choose to consume more. Although income rises, its impact still isn't strong enough to overcome the effect of the falling interest rates. Therefore, households decrease their savings to boost consumption.

Decomposing among the components, we can check profits still is the main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income temporarily, under rule #4, while labour income boosts total income under any other rule. As a result, policy rule #4 contracts income, while rule #3, boosts it the most.

As the top $10-30\%$ have less assets on average than the top 10%, thus the financial component will rise and drop less in the contractionary and expansionary shock cases, respectively. It means the top $10-30\%$'s income will decrease and increase more than the top 10%, after negative and positive shocks respectively.

Top $30-50\%$: Looking at figures 3.21, 3.22 and 3.26, once again we observe similar dynamics to those seen in the previous classes. As the top

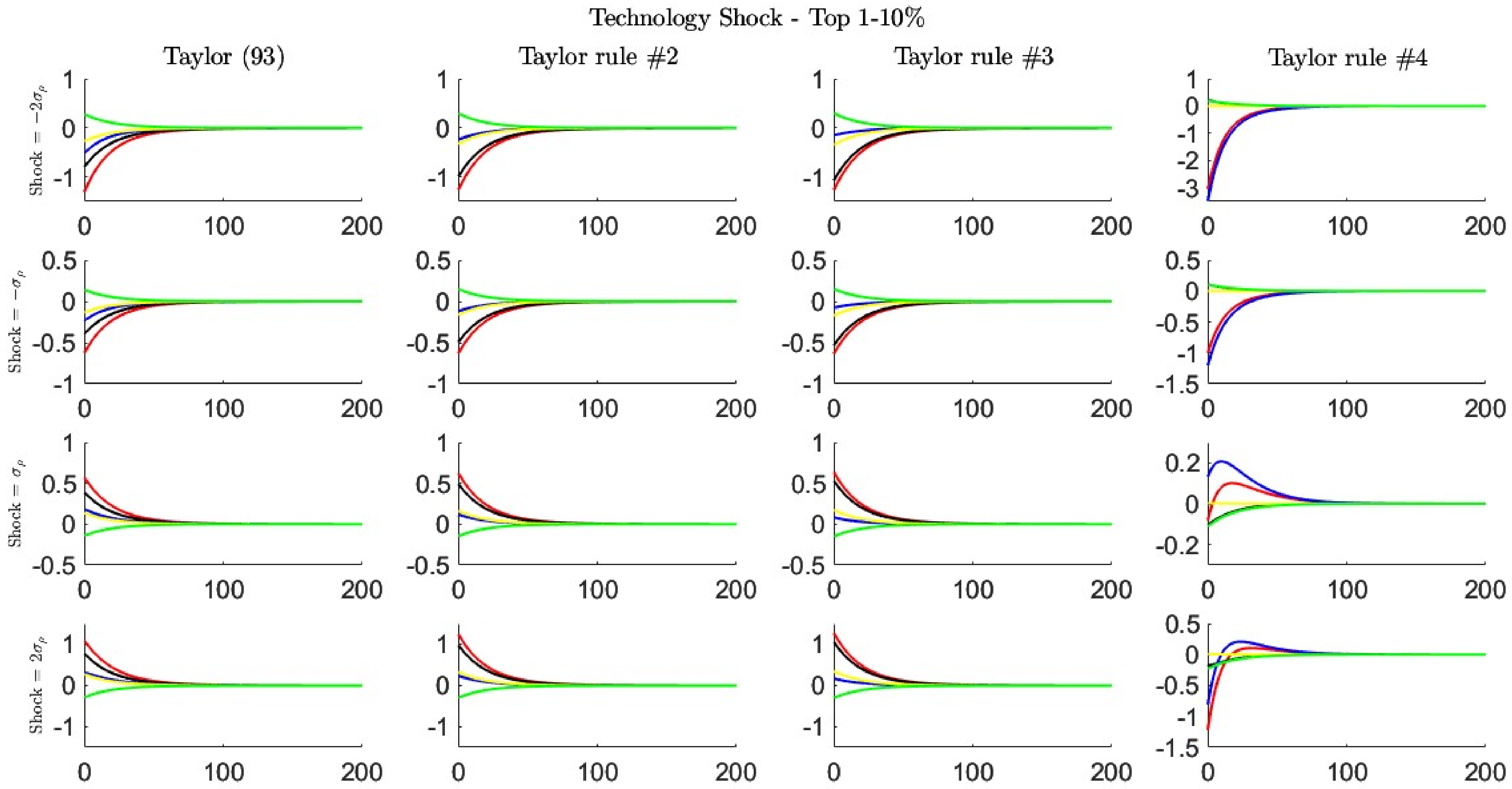

Figure 3.24: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to total income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

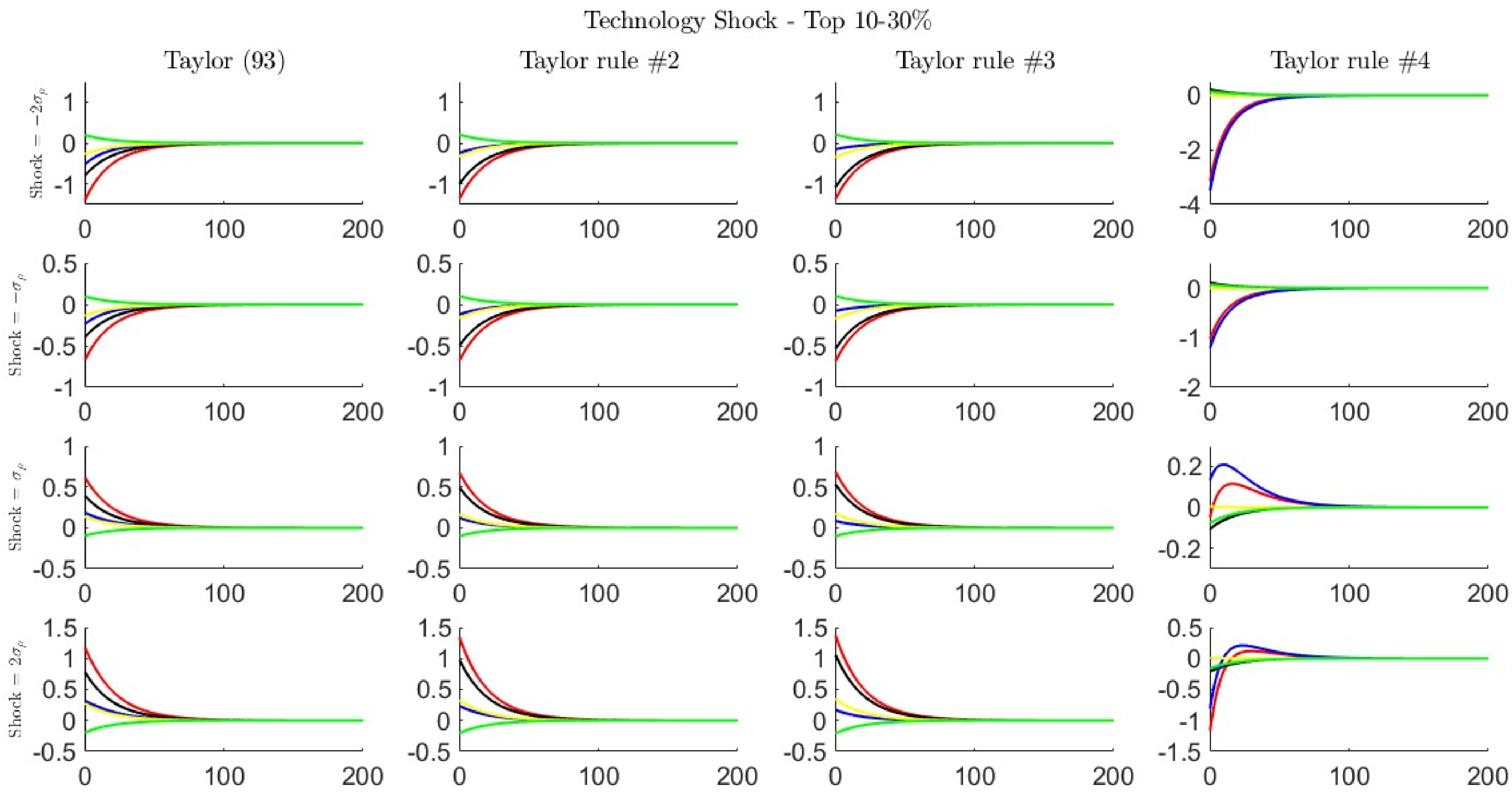

Figure 3.25: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to total income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

$30-50\%$ have less assets on average, the financial component will rise and drop less in the contractionary and expansionary shock cases, respectively. Therefore, as for top $1-30\%$, income will decrease and increase more than in the top 30%, after negative and positive shocks respectively.

After a negative shock, total income drops under any rule, and households cut consumption down. Under Taylor rule #4, income drops so much, they prefer to borrow more to cushion the shock. However, now, under Taylor's original calibration, income's fall is great enough to overcome the impact of the intertemporal substitution channel. Consequently, households prefer to decrease savings to soften the blow on consumption. Under Taylor rules #2 and #3, the intertemporal substitution effect is still stronger.

Decomposing among the components, we can check profits still is the main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income under rule #4, much more than labour income under any other rule. As a result, policy rule #4 contracts income the most, while rule #3, the least.

After a positive shock, total income rises under any policy rule, except for Taylor rule #4. As in the previous class, profits take a blow after an expansionary shock, decreasing income. Nonetheless, as profits will increase later, income will also follow suit, so households decide to borrow enough to increase their consumption, compensating for the income fall.

For any other policy, as total income increases, households will choose to consume more. Now, under Taylor rules #2 and #3, income rises enough to overcome the effect of the falling interest rates. Therefore, households increase their savings and consumption. Under Taylor's original calibration, the intertemporal substitution effect is still stronger.

Decomposing among the components, we can check profits still is the main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income temporarily, under rule #4, while labour income boosts total income under any other rule. As a result, policy rule #4 contracts income, while rule #3, boosts it the most.

Top $50-70\%$: Looking at figures 3.21, 3.22 and 3.27, once again we observe similar dynamics to those seen before. As the top $50-70\%$ have less assets on average, the financial component will rise and drop less in the contractionary and expansionary shock cases, respectively. Therefore, income will decrease and increase more than in the previous classes, after negative and

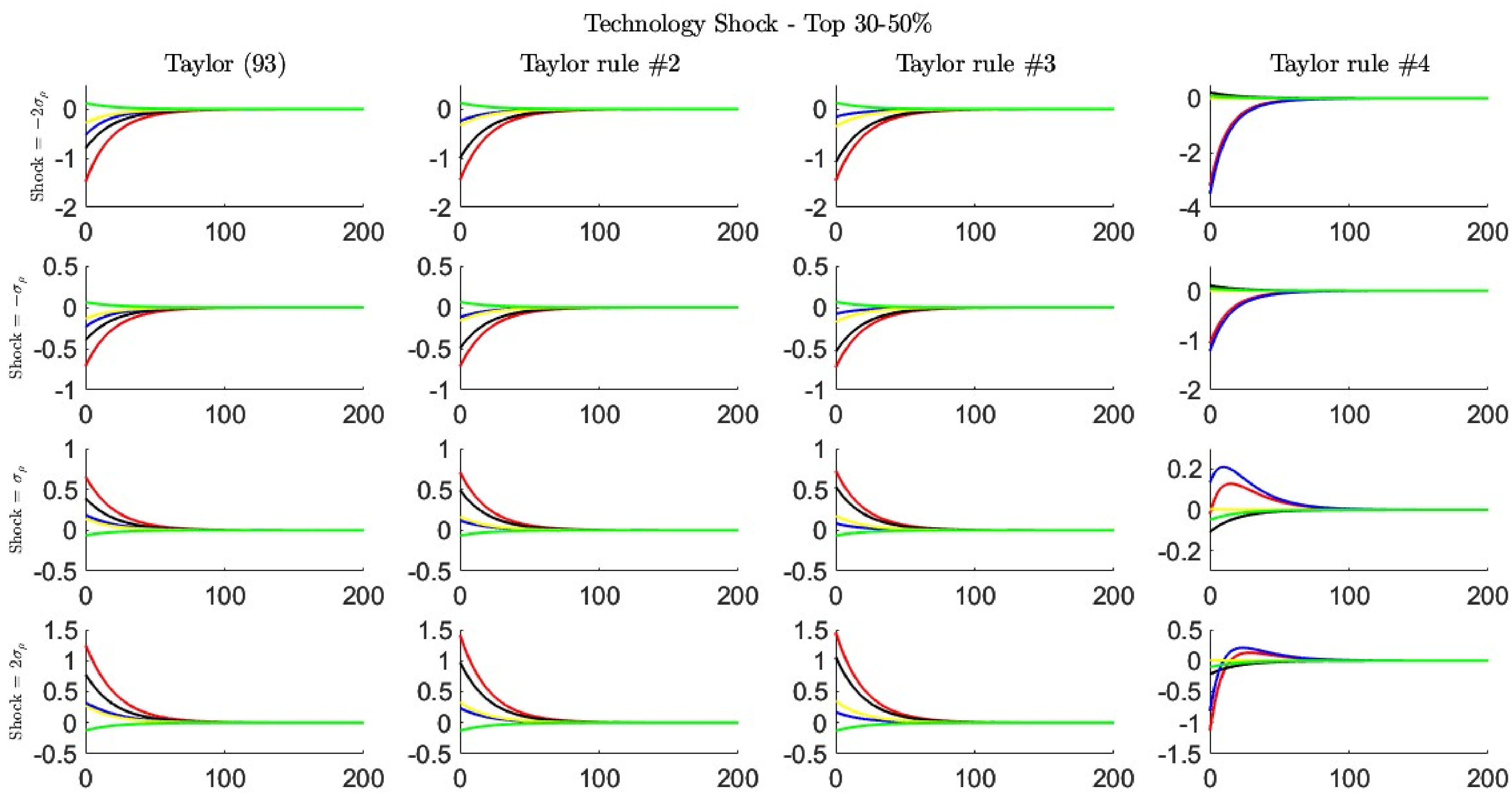

Figure 3.26: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to total income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

positive shocks respectively.

After a negative shock, total income drops under any rule, and households cut consumption down. Under Taylor rule #4, income drops so much, they prefer to borrow more to cushion the shock. However, now, under any other rule, income's fall is great enough to overcome the impact of the intertemporal substitution channel. Consequently, households also prefer to decrease savings to soften the blow on consumption.

Decomposing among the components, we can check profits still is the main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income under rule #4, much more than labour income under any other rule. As a result, policy rule #4 contracts income the most, while rule #3, the least.

After a positive shock, total income rises under any policy rule, except for Taylor rule #4. As in the previous class, profits take a blow after an expansionary shock, decreasing income. Nonetheless, as profits will increase later, income will also follow suit, so households decide to borrow enough to increase their consumption, compensating for the income fall.

For any other policy, as total income increases, households will choose to consume more. As income rises, its impact is strong enough to overcome the effect of the falling interest rates. Therefore, households increase their savings and consumption.

Decomposing among the components, we can check profits still is the main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income temporarily, under rule #4, while labour income boosts total income under any other rule. As a result, policy rule #4 contracts income, while rule #3, boosts it the most.

Top 70%-*Indebted*: Looking at figures 3.21, 3.22 and 3.28, once again we observe similar dynamics to those seen before. The households in the top $70\%-Indebted$ class have almost no asset, consequently financial income remains practically unaltered. Therefore, income will decrease and increase more than in the previous classes, after negative and positive shocks respectively.

After a negative shock, total income drops under any rule, and households cut consumption down. Under any Taylor rule, income drops so much, they prefer to borrow more to cushion the shock. Consequently, households also prefer to decrease savings to soften the blow on consumption.

Decomposing among the components, we can check profits still is the

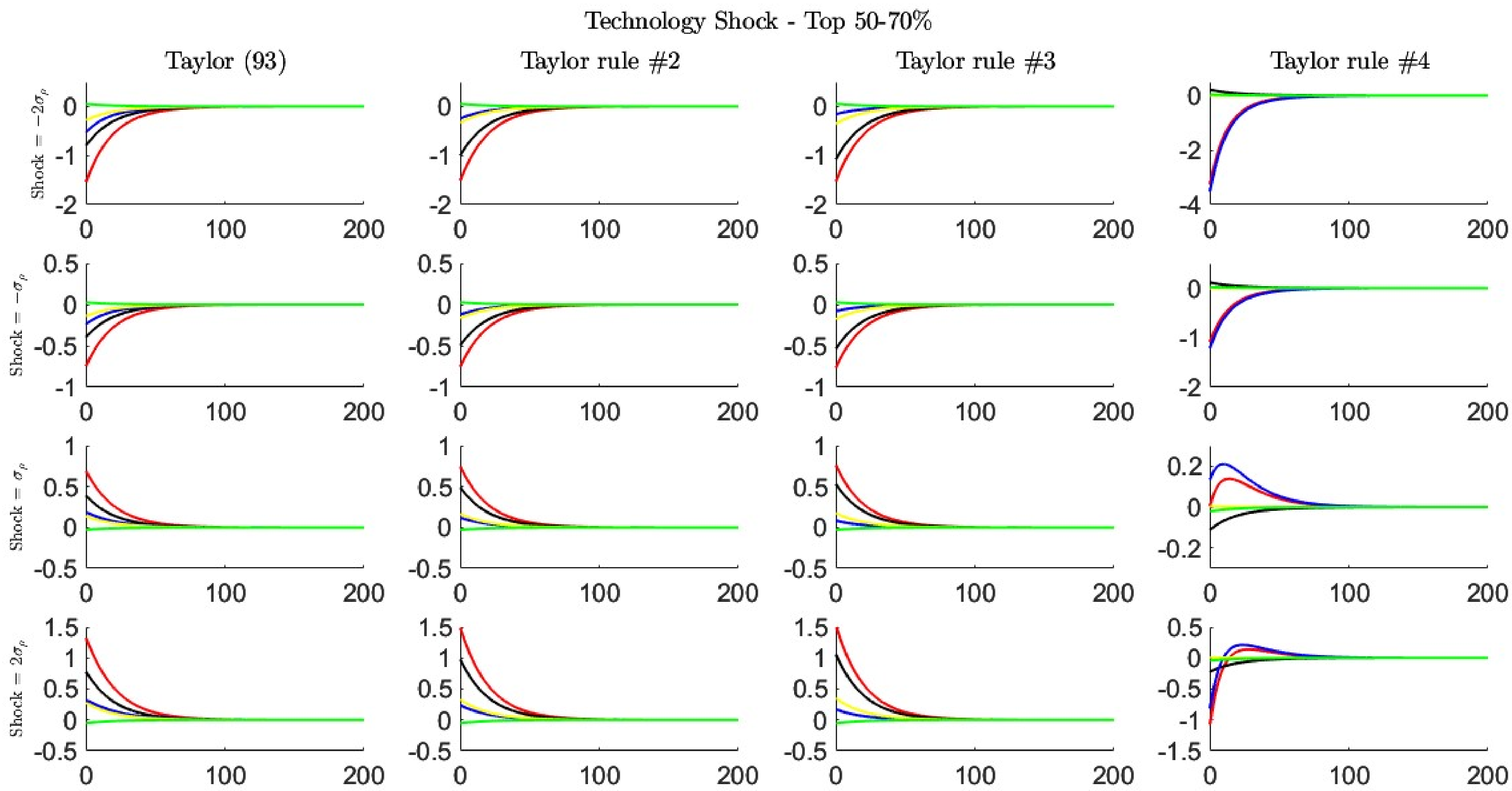

Figure 3.27: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to total income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income under rule #4, much more than labour income under any other rule. As a result, policy rule #4 contracts income the most, while rule #3, the least.

After a positive shock, total income rises under any policy rule, except for Taylor rule #4. As in the previous class, profits take a blow after an expansionary shock, decreasing income. Nonetheless, as profits will increase later, income will also follow suit, so households decide to borrow enough to increase their consumption, compensating for the income fall. For any other policy, as total income increases, households will choose to consume more. As income rises, its impact is strong enough to overcome the effect of the falling interest rates. Therefore, households increase their savings and consumption.

Decomposing among the components, we can check profits still is the main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income temporarily, under rule #4, while labour income boosts total income under any other rule. As a result, policy rule #4 contracts income, while rule #3, boosts it the most.

Indebted: Looking at figures 3.21, 3.22 and 3.29, once again we observe similar dynamics to those seen before. The households in the Indebted class have negative wealth, consequently financial income contribution decreases after a negative shock, and increases after a positive one. Therefore, income will decrease and increase more than in the previous classes, after a contractionary and expansionary shocks respectively.

After a negative shock, total income drops under any rule, and households cut consumption down. Under any Taylor rule, income drops so much, they prefer to borrow more to cushion the shock. Consequently, households also prefer to decrease savings to soften the blow on consumption.

Decomposing among the components, we can check profits still is the main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income under rule #4, much more than labour income under any other rule. As a result, policy rule #4 contracts income the most, while rule #3, the least.

After a positive shock, total income rises under any policy rule, except for Taylor rule #4. As in the previous class, profits take a blow after an expansionary shock, decreasing income. Nonetheless, as profits will increase

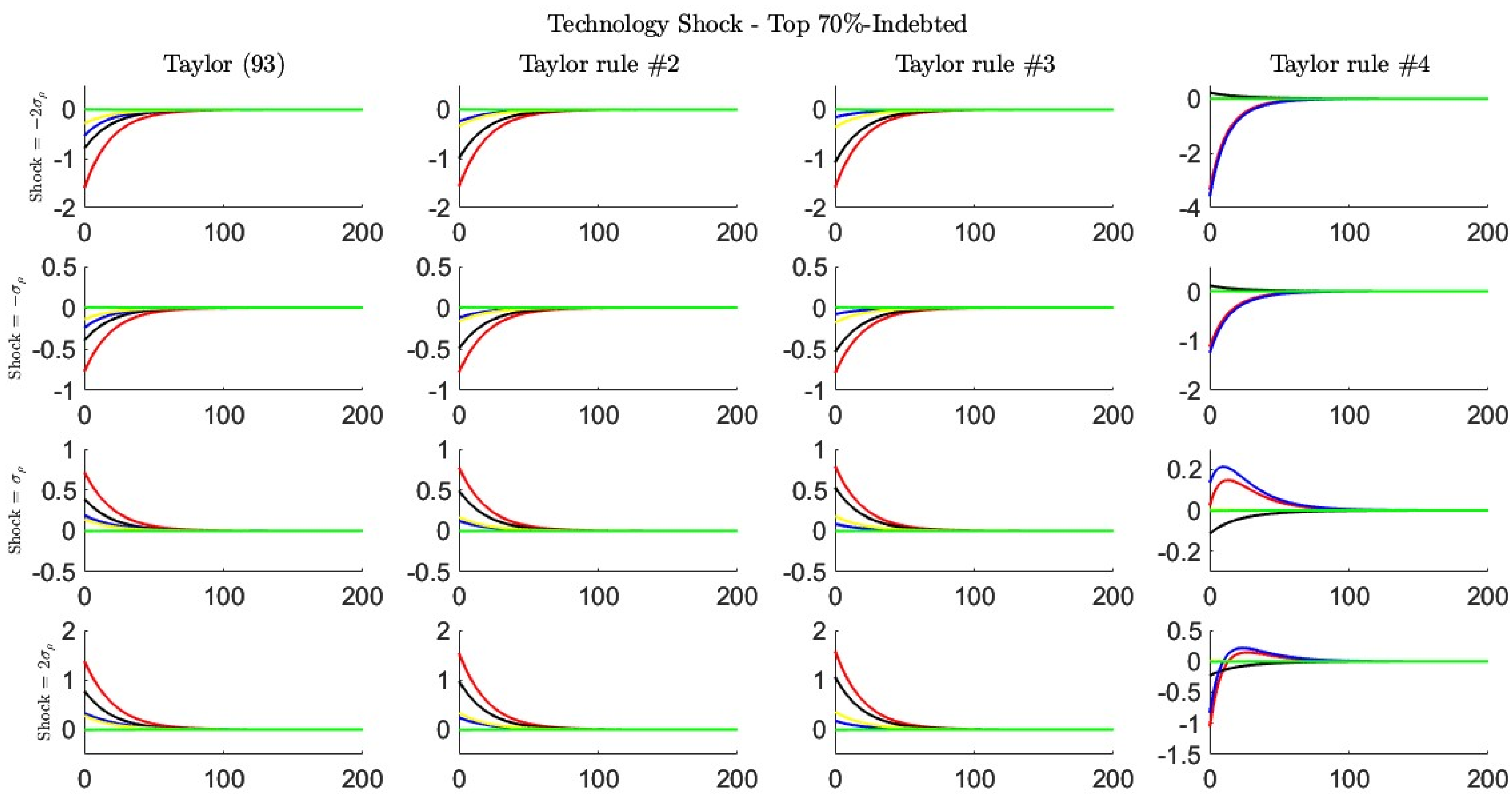

Figure 3.28: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to total income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

later, income will also follow suit, so households decide to borrow enough to increase their consumption, compensating for the income fall. For any other policy, as total income increases, households will choose to consume more. As income rises, its impact is strong enough to overcome the effect of the falling interest rates. Therefore, households increase their savings and consumption.

Decomposing among the components, we can check profits still is the main determinant of total income deviation, under Taylor rule #4, while labour income is the main determinant, under any other rule. Nonetheless, profits' impact depress income temporarily, under rule #4, while labour income boosts total income under any other rule. As a result, policy rule #4 contracts income, while rule #3, boosts it the most.

Why all classes have the same policy preferences? — After a positive shock, the policies that increases income the most and the least are the same for all classes. The same logic from the demand shock case follows: households prefer policies that enhance their income because it increases their options of consumption and leisure time streams.

To answer the question for the contractionary shock cases is more difficult, though. Households all agree the policy that delivers the smallest income stream is the best, while the rule delivering the highest income is the worst. Nonetheless, Taylor rule #4 offers the best environment for households to borrow. As interest rates increase the least under this policy, it is easier for households to borrow.

Therefore, the most reactive monetary policy to output gap create an environment where it is easier to borrow and to cushion the shock. Even if income drops more than under any other rule, as households can better protect themselves against the shock, they prefer policy #4.

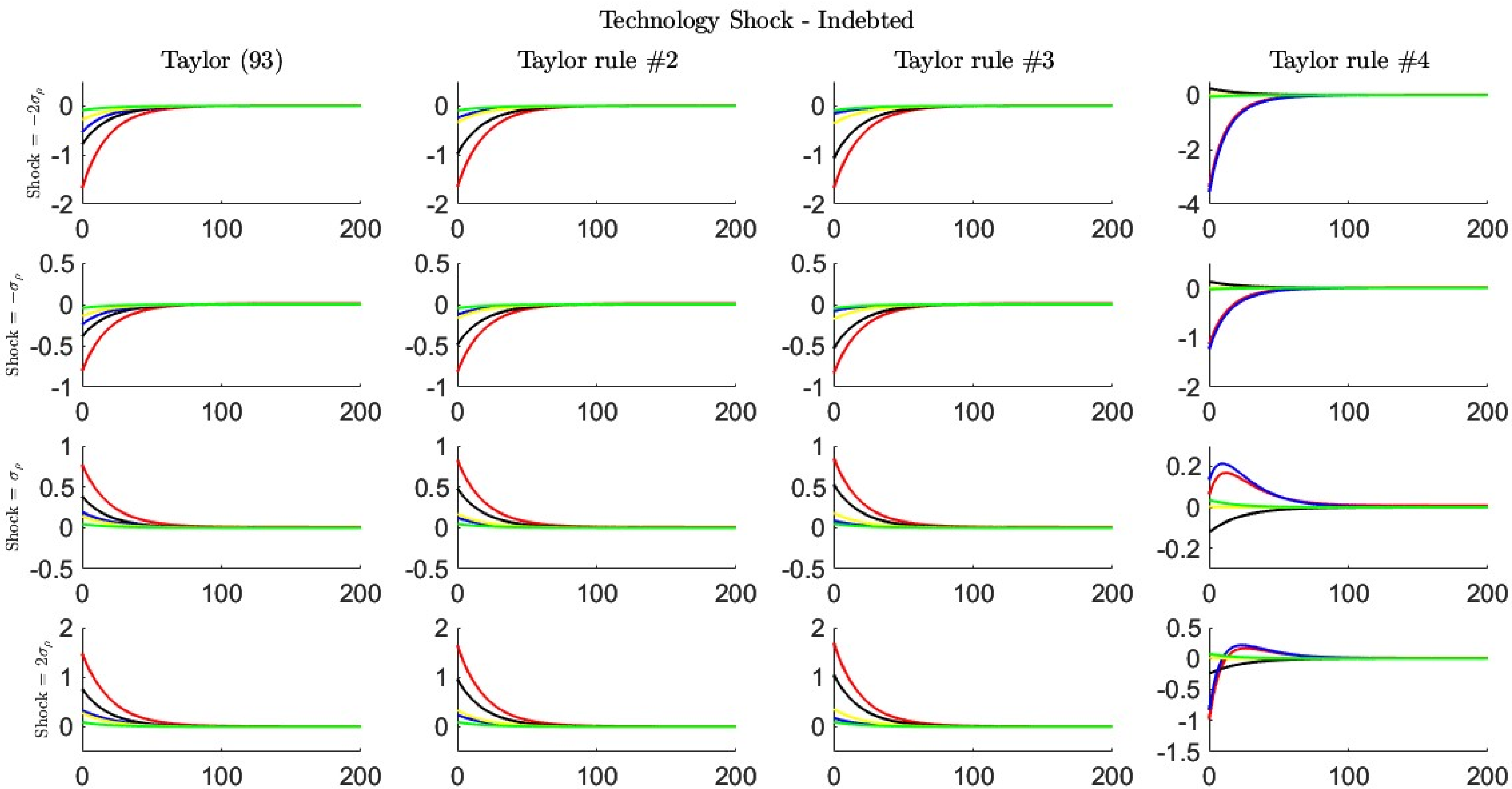

Figure 3.29: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to total income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

4
High Liquidity and High Unemployment

Now, we wish to extend the experiment from subsection 3.3. Changing the calibration used so far, we can check how robust our previous results are, and how much they are dependent on fundamental parameters in our environment.

We run more two simulations for both shocks, so we can further analyze the impact of the interest rate effect on transfers and financial income. In the first, we raise liquidity by increasing government debt to 6 times the steady state output. In the second, we increase the arrival rate of the unemployed status, so the unemployment rate is 25% in the steady state.

In the former, we observe a smaller indebted population, while all indebted and non-indebted households own and hold more assets, respectively. Because of the increase in net supply of bonds, the non-indebted can increase their wealth by buying more government bonds. At the same time, it makes it easier for them to lend, and for indebted households to borrow. The calibrated steady-state discount factor decreases, getting closer to the steady state real interest rate, which we kept at 0.5%.

Finally, as we can see in table 4.1, the change in calibration alters the steady-state distribution. Each class has a different a different mass, wealth range and average when compared to those of table 3.2. Later, we will see it will have consequences for the impact of interest rates on transfers and financial income, as well as for policy preferences of each class.

Table 4.1: Distribution Characteristics - High Liquidity

Class	Frac. Pop.	Wealth Range	Wealth Avg.
Top 1%	1.0%	$[17.24, 28.00]$	19.3
Top 1-10%	9.0%	$[11.60, 17.24)$	13.4
Top 10-30%	19.9%	$[8.10, 11.60)$	9.5
Top 30-50%	19.9%	$[5.68, 8.10)$	6.9
Top 50-70%	18.9%	$[3.80, 5.68)$	4.9
Top 70%-Indebted	26.6%	$[0.034, 3.80)$	2.3
Indebted	4.6%	$[-4.00, 0.034)$	-1.24

In the latter simulation, we increase the unemployment rate in this economy, increasing the urgency for precautionary savings. As a result, non-indebted agents also accumulate more wealth. As there are more households unemployed, there will be more agents borrowing to smooth consumption, therefore, the indebted population and its average debt level surge. Also, the calibrated steady-state discount factor will be significantly higher than the real interest rate's steady state, going up to 0.0076.

The change on the arrival rate of the unemployment state changes the steady-state distribution. We can check in table 4.2 that each class has a different mass, wealth range and average, when compared to those of table 3.2. We will see later that it will have consequences for the impact of interest rates on transfers and financial income, as well as for policy preferences of each class. Especially on this case, the mass of indebted grow to such a point we can no longer define a class between the top 70% and the indebted households.

Table 4.2: Distribution Characteristics - High Uncertainty

Class	Frac. Pop.	Wealth Range	Wealth Avg.
Top 1%	0.9%	$[5.29, 10.00]$	5.61
Top 1-10%	9.2%	$[3.65, 5.29)$	4.22
Top 10-30%	19.8%	$[2.24, 3.65)$	2.83
Top 30-50%	20.9%	$[1.06, 2.24)$	1.59
Top 50%-Indebted	19.0%	$[0, 1.06)$	0.50
Indebted	30.2%	$[-4.00, 0)$	-1.27

Before we can discuss our new results, we need to describe how aggregate variables paths change with our new settings. If we re-run the IRFs in subsection 3.2, all aggregate variables' deviation from steady state are equal to the ones from the previous model setting, with the exception of transfers which will have its dynamics changed in the high liquidity simulation.

We change the idiosyncratic shock distribution and the liquidity level in our Economy, however our aggregate variables deviation paths from the steady state do not change, except for transfers in the high liquidity case. In other words, we don't need to worry about comparing the behavior of these variables in the modified model and the original one, which makes our exercise easier.

Now we briefly discuss what changes under the new calibrations proposed. First, we analyze the welfare outcomes after demand shocks, and afterwards, we discuss the technology shock case.

4.1 Demand Shock

Bellow we discuss welfare outcomes in the same manner of subsection 3.3, but now adopting the calibration for the high liquidity and high uncertainty environments, described above. Anticipating our main results, under the high liquidity calibration, the rise in national debt increases the effect interest rates have on transfers, changing its dynamics and intensity observed in the original calibration. Now, real rates always boost transfers, when they fall, always contract transfers, when they rise, and transfers' impact on total income deviation will be stronger than in the baseline calibration.

Furthermore, average wealth and debt increases for all non-indebted and indebted households, respectively. A higher level of either wealth or debt boosts interest rates' impact on financial income. As a result, financial income's contribution to total income deviation will be stronger than in the original calibration.

Given a movement in the interest rate, for all classes except the indebted, financial income and transfers' contributions will have opposite signs. As in the baseline environment, labour income and profits will practically cancel each other's impact on total income change. In the end, the relative magnitudes of financial income and transfers' contributions will determine which policy delivers the biggest income stream for a given class. Finally, only the top $10-30\%$ change their preferences from table 3.3.

Under the high uncertainty calibration, the national debt remains unaltered in relation to the baseline calibration. As none of the other aggregate variables' dynamics change compared to those observed in subsection 3.2, transfers' dynamics will not change from the baseline simulation as well. Nonetheless, as idiosyncratic risk augmented, non-indebted households will hold more assets for precaution, while indebted households will hold more debt. It means each class will hold in average more assets or debt in relation to the original calibration. This magnifies the effect of movements in the interest rates on financial income.

As in the baseline environment, labour income and profits will practically cancel each other's impact on total income change. In the end, the relative magnitudes of financial income and transfers' contributions will determine which policy delivers the biggest income stream for a given class. Once again, only the top $10-30\%$ change their preferences from table 3.3.

4.1.1 High liquidity

Take figures 4.1 and 4.2, and compare them with figures 3.3 and 3.6, respectively. It shows what was already mentioned previously, the series on each couple of figures are the same, apart from transfers.

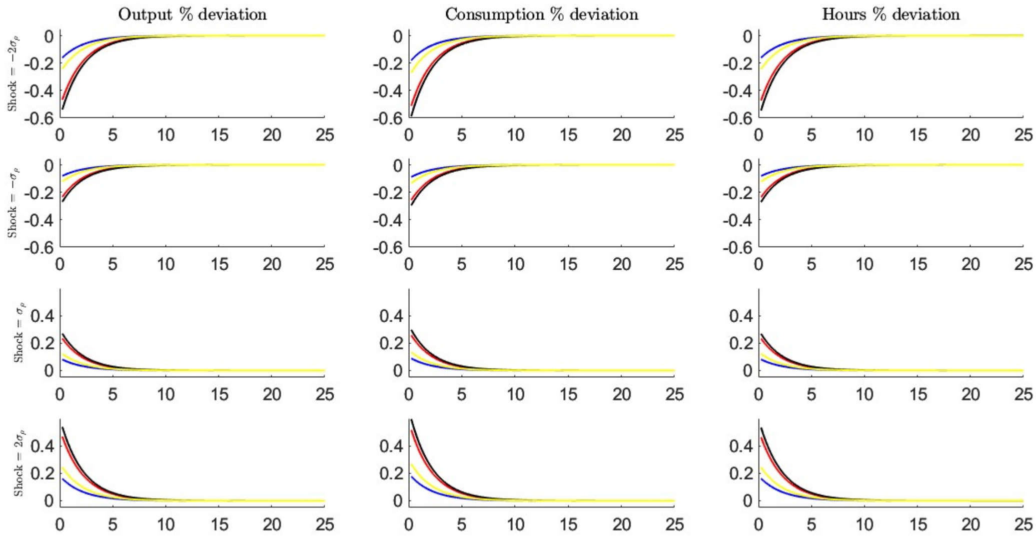

Figure 4.1: Output, consumption and hours deviation after a one-time discount factor shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

Transfers: Now, Taylor rules won't matter to determine whether transfers will rise or fall after a shock. After a contractionary shock, as the national debt is multiplied by 6, the relief that comes from interest rates falling is much bigger than on the baseline calibration. Tax revenue still decreases, but as wages' steady-state and after shock dynamics remains the same, each class' labour income's variation won't change much relative to the previous calibration. We observe the interest rate's increased impact on debt service is dominant.

In a negative shock, Taylor rule #3 decrease interest rates and debt service the most, therefore transfers will also increase the most. In turn, Taylor rule #2 decrease interest rates and debt service the least, thus transfers will also increase the least.

After an expansionary shock, as the national debt is multiplied by 6, the extra burden that comes from interest rates rising is much bigger than on the baseline calibration. Once again, tax revenue still increases, but as wages' steady-state and after shock dynamics remains the same, each class' labour income's variation won't change much relative to the previous calibration. We observe the interest rate's increased impact on debt service is dominant.

In a positive shock, Taylor rule #2 increase interest rates and debt ser-

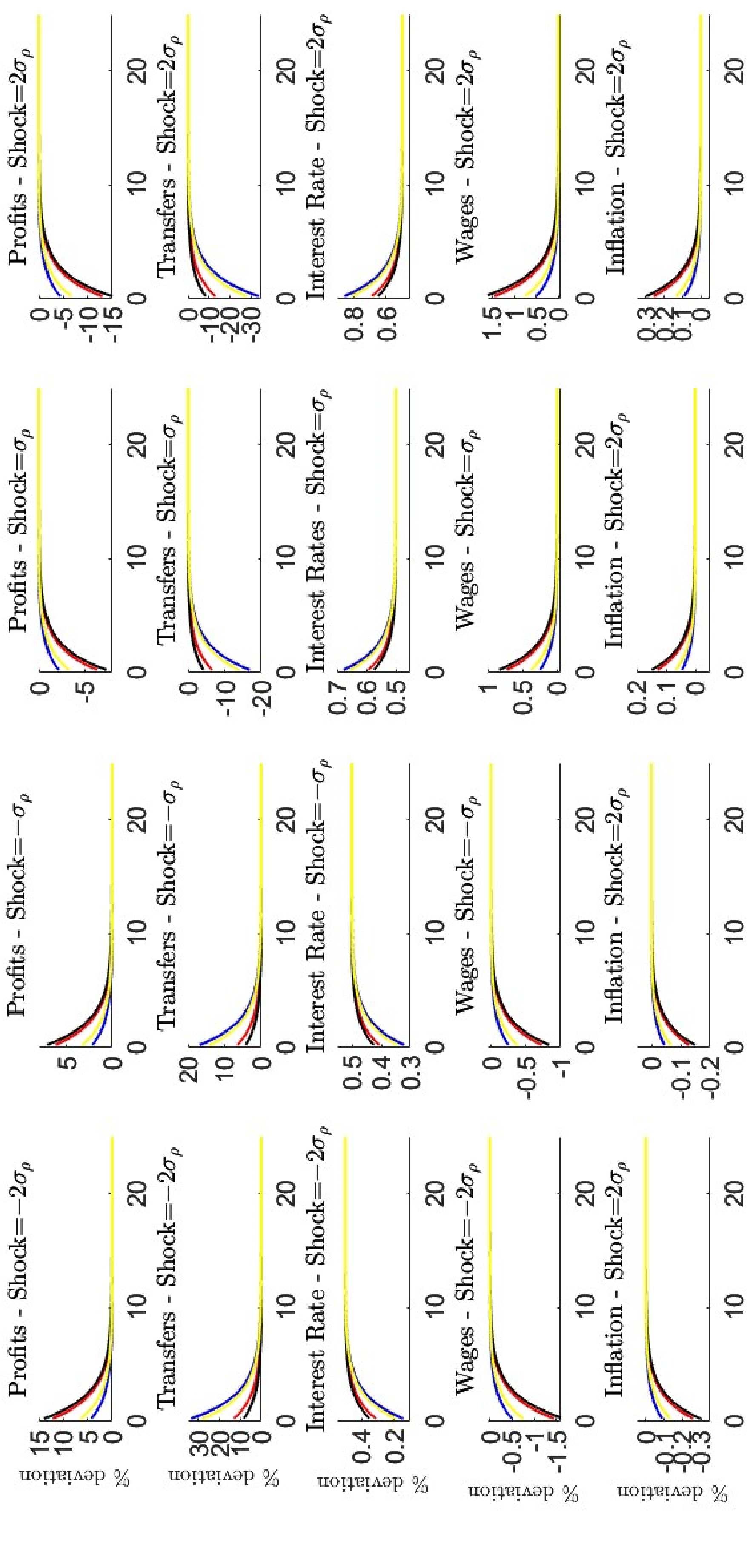

Figure 4.2: Aggregate variables deviation after a one-time discount factor shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

vice the least, therefore transfers will also decrease the least. In turn, Taylor rule #3 increase interest rates and debt service the most, thus transfers will also decrease the most.

Financial income: Each class' average wealth or debt increases as result of the change in calibration. Therefore, financial income's contribution to income deviation will be more affected by interest rates movements than under the original calibration.

After a contractionary shock, Taylor rule #2 decrease interest rates the least, therefore interest payments to or by households will also decrease the least. In turn, Taylor rule #3 decrease interest rates the most, thus decreasing financial income the most for non-indebted households and increasing it the most for indebted ones.

In an expansionary shock case, however, Taylor rule #3 increases interest rates the most, increasing non-indebted households' financial income contribution to its highest level possible. For indebted households, interest payments rise the most, however. Taylor rule #2 won't be as reactive, interest rates will rise by the least, and so will the non-indebted households' financial component contribution to income deviation. For indebted households, interest payments rise the least.

Analyzing table 4.3, we can see almost the same pattern present in table 3.3, with only one exception. Now, on average, the households on the top $10-30\%$ share the same policy preferences with the top 10%. It so happens the policies that deliver the biggest income streams for the top $10-30\%$ under the original calibration, aren't the same for the new calibration.

Looking at figure 4.3, we can observe that profits (in blue) and labour income (in black) still annul each other, while both financial and transfers' components have a higher impact on total income deviation (in red). Nonetheless, financial income's contribution (in green) relative to transfers' contribution (in yellow) become higher for this class, than in the previous calibration.

Consequently, after a negative shock, financial income will drop the least under Taylor rule #2. Even with transfers increasing the most under Taylor rule #3, it doesn't compensate the stronger blow financial income endure under this rule. After a positive shock, the opposite happens. Financial income will rise the most under the most hawkish rule. Although, under the most dovish rule, transfers decrease the least, once again, it doesn't compensate the financial income gain that is loss by living in a world with a less reactive policy.

In sum, although policy preferences change for one of the classes, the motive behind their preferences doesn't. They prefer the policies delivering the highest levels of income throughout the transition path after the shock. The higher the income the larger the set of consumption-leisure streams to choose from.

Table 4.3: Demand Shock - High Liquidity

	$(\phi_\pi, \phi_y) = (1.5, 0.125)$	$(\phi_\pi, \phi_y) = (1.5, 0)$	$(\phi_\pi, \phi_y) = (5.0, 0)$	$(\phi_\pi, \phi_y) = (1.5, 1.0)$
Contractionary shock: $-2\sigma_\gamma$				
Top 1%	0.0629	0.0610	0.0732	0.0705
Top 1-10%	0.0636	0.0627	0.0676	0.0664
Top 10-30%	0.0646	0.0643	0.0661	0.0657
Top 30-50%	0.0653	0.0653	0.0653	0.0653
Top 50-70%	0.0661	0.0665	0.0647	0.0651
Top 70%-Indebted	0.0645	0.0660	0.0579	0.0597
Indebted	0.0621	0.0663	0.0438	0.0488
Contractionary shock: $-\sigma_\gamma$				
Top 1%	0.0310	0.0302	0.0346	0.0336
Top 1-10%	0.0315	0.0311	0.0333	0.0328
Top 10-30%	0.0321	0.0319	0.0328	0.0326
Top 30-50%	0.0324	0.0324	0.0324	0.0324
Top 50-70%	0.0328	0.0330	0.0321	0.0323
Top 70%-Indebted	0.0320	0.0328	0.0287	0.0296
Indebted	0.0309	0.0330	0.0219	0.0243
Expansionary shock: σ_γ				
Top 1%	-0.0316	-0.0309	-0.0348	-0.0340
Top 1-10%	-0.0322	-0.0318	-0.0340	-0.0335
Top 10-30%	-0.0327	-0.0326	-0.0334	-0.0332
Top 30-50%	-0.0331	-0.0331	-0.0330	-0.0330
Top 50-70%	-0.0334	-0.0336	-0.0327	-0.0329
Top 70%-Indebted	-0.0325	-0.0333	-0.0292	-0.0301
Indebted	-0.0313	-0.0334	-0.0225	-0.0248
Expansionary shock: $2\sigma_\gamma$				
Top 1%	-0.0627	-0.0613	-0.0690	-0.0673
Top 1-10%	-0.0640	-0.0632	-0.0674	-0.0665
Top 10-30%	-0.0650	-0.0647	-0.0664	-0.0660
Top 30-50%	-0.0656	-0.0657	-0.0655	-0.0655
Top 50-70%	-0.0664	-0.0667	-0.0649	-0.0653
Top 70%-Indebted	-0.0646	-0.0661	-0.0580	-0.0598
Indebted	-0.0624	-0.0665	-0.0449	-0.0496

4.1.2 High Uncertainty

Take figures 4.4 and 4.5, and compare them with figures 3.3 and 3.6, respectively. It shows what was already mentioned previously, the series on each couple of figures are the same.

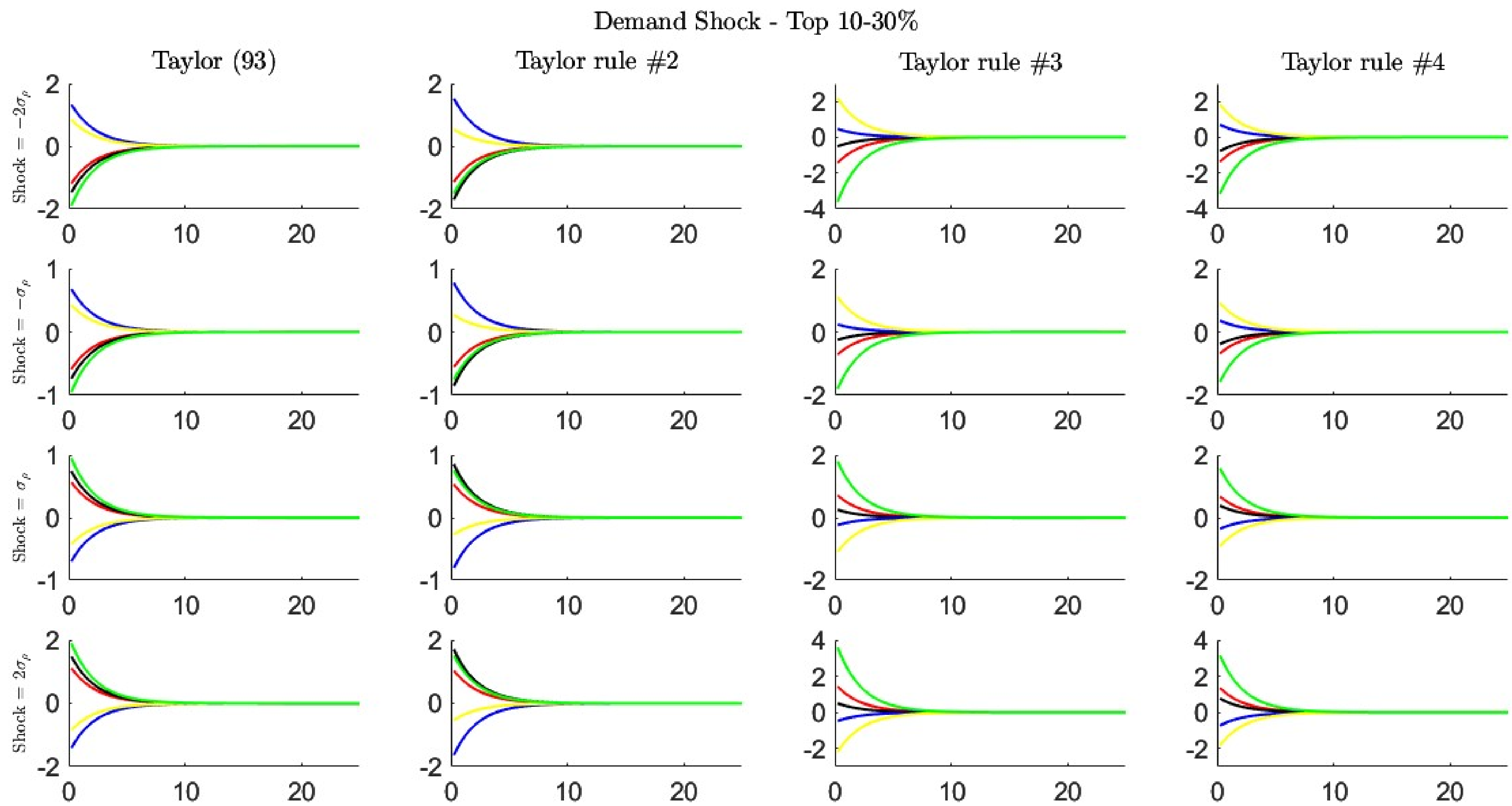

Figure 4.3: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

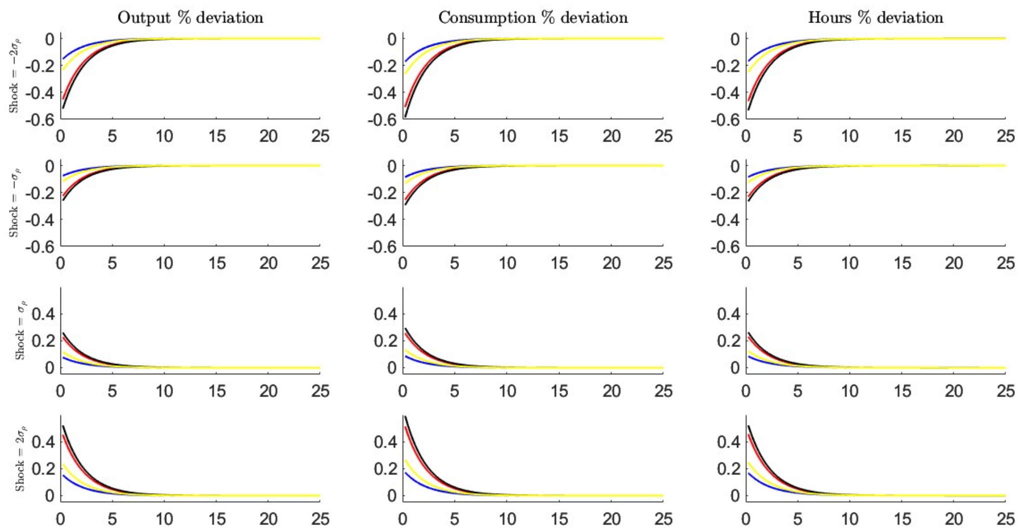

Figure 4.4: Output, consumption and hours deviation after a one-time discount factor shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

Financial income: Each class' average wealth or debt increases as result of the change in calibration. As the idiosyncratic risk augmented, non-indebted households will accumulate more wealth for precaution, while the indebted will increase their debt. Therefore, financial income's contribution to income deviation will be more affected by interest rates movements than under the original calibration.

After a contractionary shock, Taylor rule #2 decrease interest rates the least, therefore interest payments to households will also decrease the least. In turn, Taylor rule #3 decrease interest rates the most, thus decreasing financial income the most. In an expansionary shock case, however, Taylor rule #3 increases interest rates the most, increasing financial income's contribution to its highest level possible. Nonetheless, Taylor rule #2 won't be as reactive, interest rates will rise by the least, and so will the financial component's contribution to income deviation.

Analyzing table 4.4, we can see almost the same pattern present in table 3.3, with only one exception. As in the high liquidity simulation, on average, the households on the top $10-30\%$ share the same policy preferences with the top 10%. It so happens the policies that deliver the biggest income streams for the top $10-30\%$ under the original calibration, aren't the same for the new calibration.

Looking at figure 4.6, we can observe that profits (in blue) and labour income (in black) still annul each other, while the financial component have a

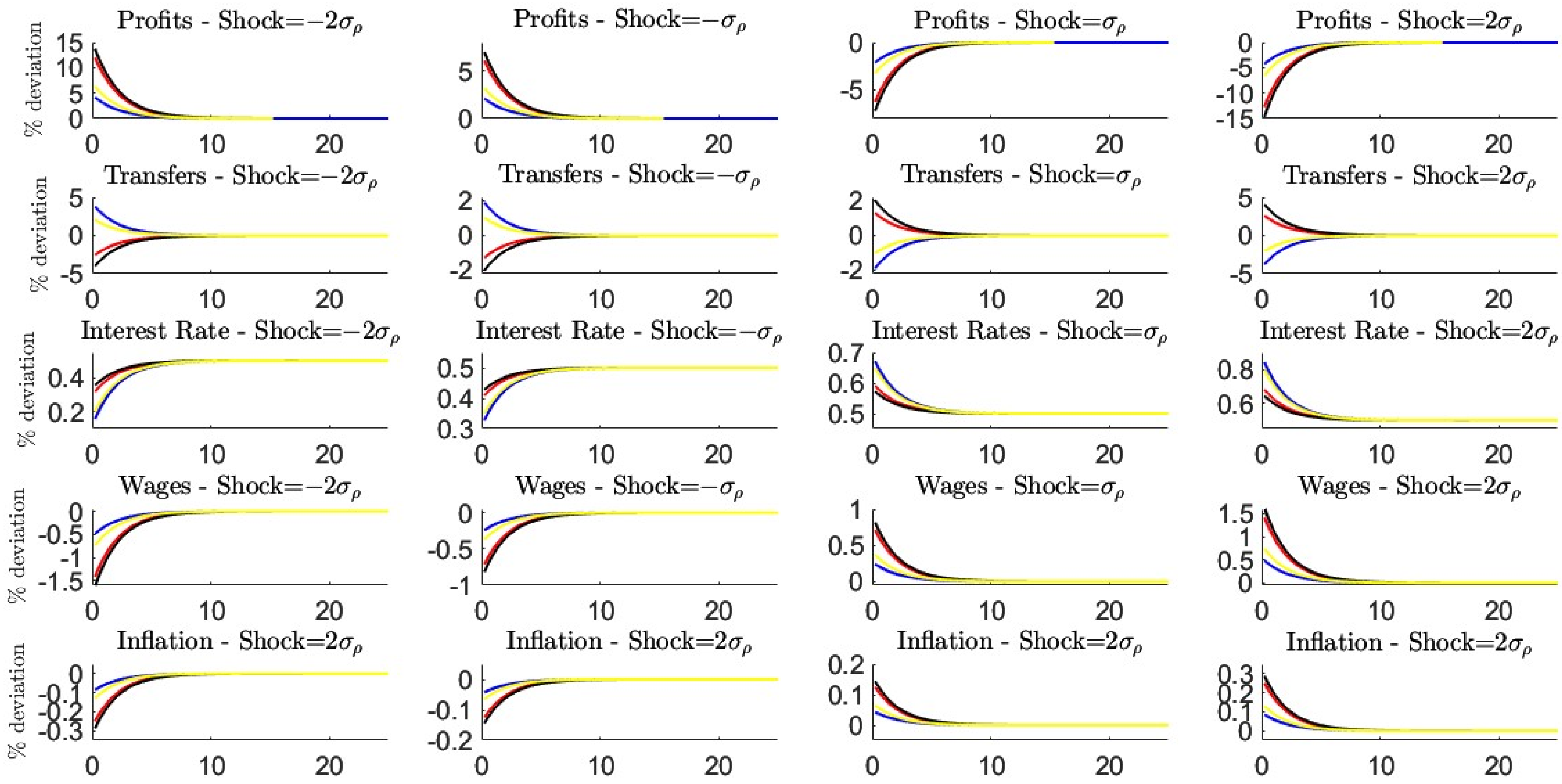

Figure 4.5: Aggregate variables deviation after a one-time discount factor shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

higher impact on total income deviation (in red). Therefore, financial income's contribution (in green) relative to transfers' contribution (in yellow) become higher for this class, than in the previous calibration.

Consequently, after a negative shock, financial income will drop the least under Taylor rule #2. Even with transfers increasing the most under Taylor rule #3, it doesn't compensate the stronger blow financial income endure under this rule. After a positive shock, the opposite happens. Financial income will rise the most under the most hawkish rule. Although, under the most dovish rule, transfers decrease the least, once again, it doesn't compensate the financial income gain that is loss by living in a world with a less reactive policy.

In sum, although policy preferences change for one of the classes, the motive behind their preferences doesn't. They prefer the policies delivering the highest levels of income throughout the transition path after the shock. The higher the income the larger the set of consumption-leisure streams to choose from.

Table 4.4: Demand Shock - High Uncertainty

	$(\phi_\pi, \phi_y) = (1.5, 0.125)$	$(\phi_\pi, \phi_y) = (1.5, 0)$	$(\phi_\pi, \phi_y) = (5.0, 0)$	$(\phi_\pi, \phi_y) = (1.5, 1.0)$
Contractionary shock: $-2\sigma_\gamma$				
Top 1%	0.0796	0.0773	0.0902	0.0872
Top 1-10%	0.0819	0.0806	0.0878	0.0862
Top 10-30%	0.0855	0.0850	0.0879	0.0873
Top 30-50%	0.0909	0.0910	0.0905	0.0906
Top 50-HtM	0.0960	0.0969	0.0922	0.0932
Indebted	0.1099	0.1149	0.0884	0.0942
Contractionary shock: $-\sigma_\gamma$				
Top 1%	0.0397	0.0386	0.0448	0.0434
Top 1-10%	0.0409	0.0402	0.0438	0.0430
Top 10-30%	0.0427	0.0424	0.0439	0.0436
Top 30-50%	0.0454	0.0454	0.0452	0.0452
Top 50-HtM	0.0479	0.0484	0.0460	0.0465
Indebted	0.0549	0.0574	0.0441	0.0471
Expansionary shock: σ_γ				
Top 1%	-0.0395	-0.0385	-0.0443	-0.0430
Top 1-10%	-0.0408	-0.0402	-0.0436	-0.0428
Top 10-30%	-0.0426	-0.0423	-0.0437	-0.0434
Top 30-50%	-0.0453	-0.0453	-0.0450	-0.0451
Top 50-HtM	-0.0478	-0.0483	-0.0458	-0.0463
Indebted	-0.0547	-0.0572	-0.0440	-0.0469
Expansionary shock: $2\sigma_\gamma$				
Top 1%	-0.0789	-0.0768	-0.0881	-0.0856
Top 1-10%	-0.0815	-0.0802	-0.0871	-0.0855
Top 10-30%	-0.0851	-0.0846	-0.0873	-0.0867
Top 30-50%	-0.0904	-0.0906	-0.0899	-0.0900
Top 50-HtM	-0.0955	-0.0964	-0.0915	-0.0925
Indebted	-0.1092	-0.0905	-0.1142	-0.0879

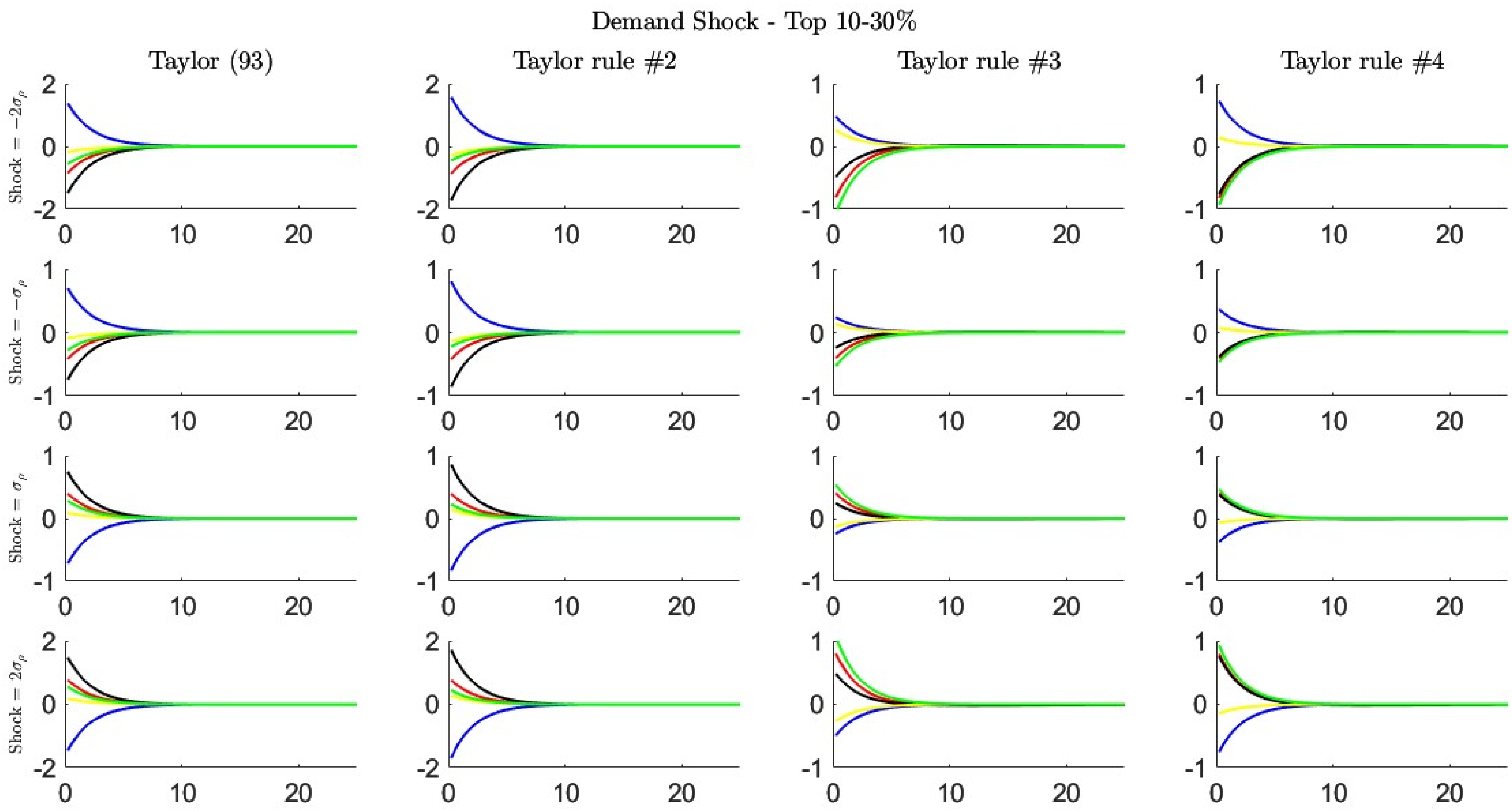

Figure 4.6: In red we have the total income percentage deviation from its steady state. In black we have labour income contribution to income deviation. In blue we have the profit contribution. In yellow we have the transfer contribution, and in green the financial income contribution.

4.2 Technology Shock

Bellow we discuss welfare outcomes in the same manner of subsection 3.3, but now adopting the calibration for the high liquidity and high uncertainty environments, described above. Anticipating our main results, under the high liquidity calibration, the rise in national debt increases the effect interest rates have on transfers, changing its intensity observed in the original calibration.

Furthermore, average wealth and debt increases for all non-indebted and indebted households, respectively. A higher level of either wealth or debt boosts interest rates' impact on financial income. As a result, financial income's contribution to total income deviation will be stronger than in the original calibration.

Given a movement in the interest rate, for all classes except the indebted, financial income and transfers' contributions will have opposite signs. After an expansionary shock, for the non-indebted, the financial component impacts income negatively, nonetheless, transfers will rise more than in the baseline calibration. Although total income still rises after a positive shock, under all rules except Taylor rule #4, its magnitude relative to the original calibration will depend on each class' average wealth. For the indebted, both components move in the same direction, leading to a higher rise in income compared to the previous calibration.

In the contractionary shock case, however, the opposite happens. For all non-indebted total, financial income will rise more than under the baseline calibration, while transfers will fall. Although total income still falls after a negative shock, its magnitude relative to the original calibration will depend on each class' average wealth. For the indebted, both components move in the same direction, leading to a more accentuated fall in income compared to the previous calibration.

As income may rise and fall more or less than in the original calibration, total deviation of savings will change. Nonetheless, its pattern will not change among classes, just its magnitude. Finally, households' preferences will remain the same.

Under the high uncertainty calibration, the national debt remains unaltered in relation to the baseline calibration. As none of the other aggregate variables' dynamics change compared to those observed in subsection 3.2, transfers' dynamics will not change from the baseline simulation as well. Nonetheless, as idiosyncratic risk augmented, non-indebted households will hold more assets for precaution, while indebted households will hold more debt. It means each class will hold in average more assets or debt in relation to the original calibration. This magnifies the effect of movements in the interest rates on financial income.

Although the magnified financial contribution will change by how much income deviates from steady-state, it won't have a significant impact on savings dynamics. Finally, policy preferences for all classes will not change from the baseline calibration.

4.2.1 High Liquidity

Take figures 4.7 and 4.8, and compare them with figures 3.9 and 3.8, respectively. It shows what was already mentioned previously, the series on each couple of figures are the same, except for transfers.

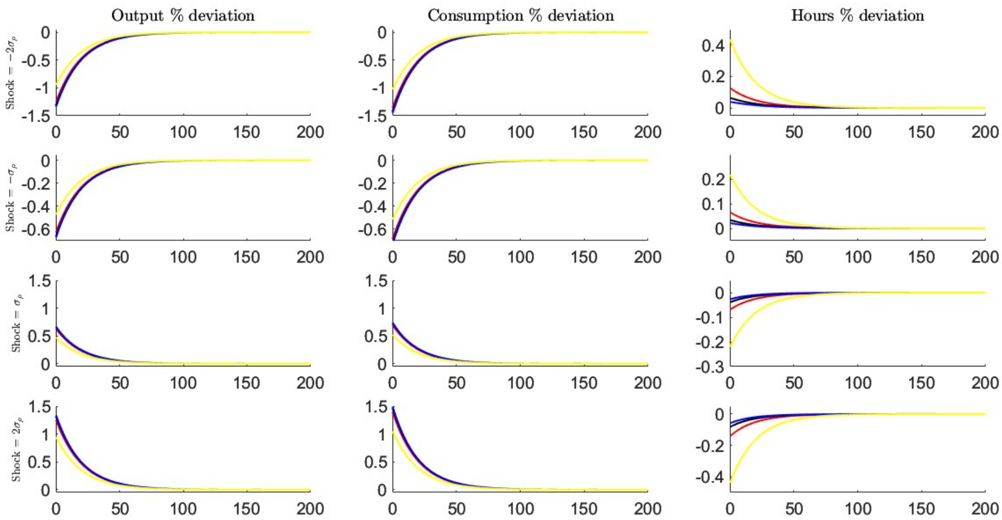

Figure 4.7: Output, consumption and hours deviation after a one-time technology shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

Transfers: After a contractionary shock, as the national debt is multiplied by 6, the burden that comes from interest rates raising is much bigger than on the baseline calibration. Tax revenue still decreases, and as wages and hours worked after shock dynamics remain the same, each class' labour income's variation won't change much relative to the previous calibration. In a negative shock, Taylor rule #3 increase interest rates and debt service the most, therefore transfers will also decrease the most. In turn, Taylor rule #4 increase interest rates and debt service the least, thus transfers will also decrease the least.

After an expansionary shock, as the national debt is multiplied by 6,

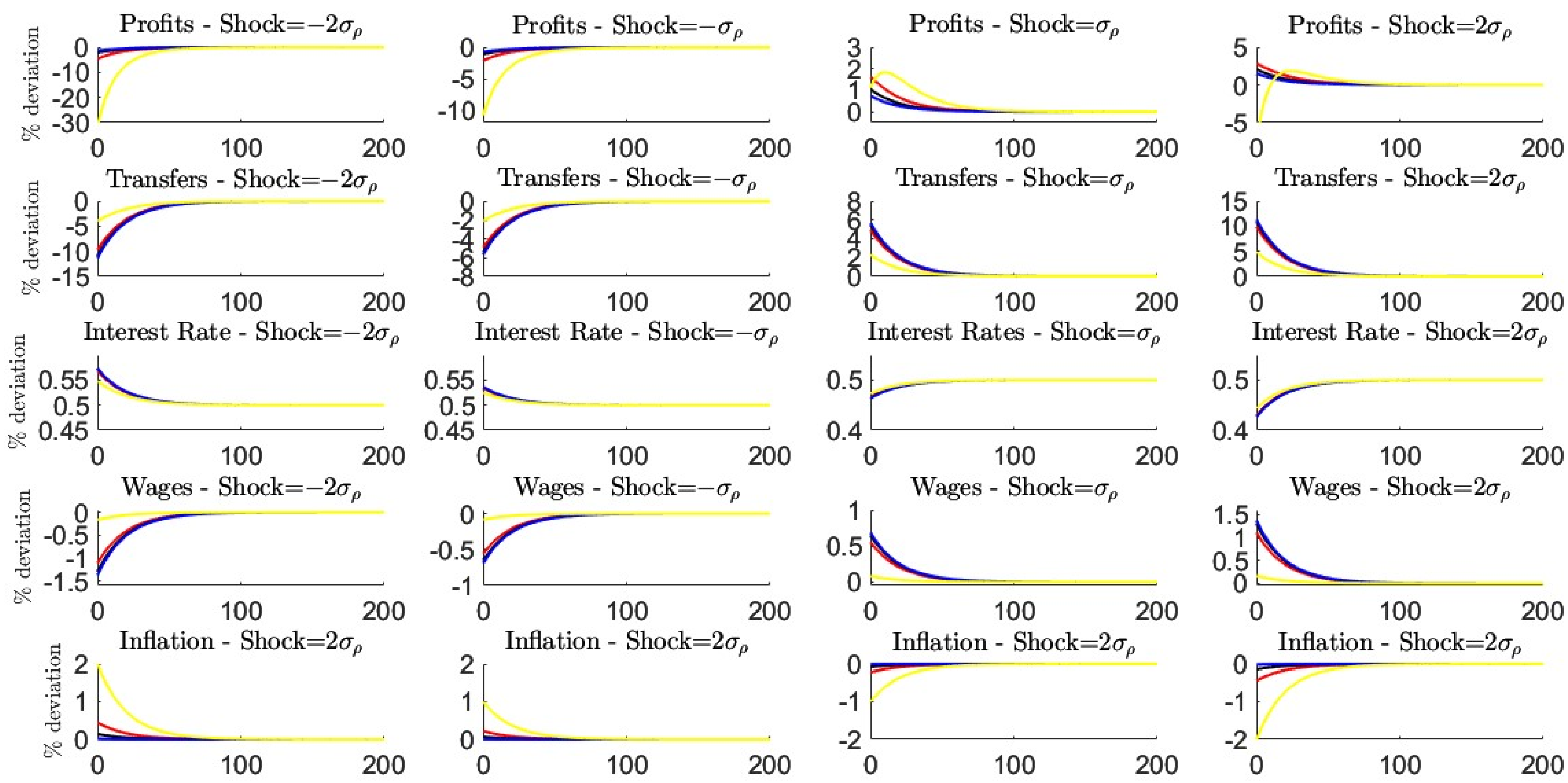

Figure 4.8: Aggregate variables deviation after a one-time technology shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

the relief that comes from interest rates falling is much bigger than on the baseline calibration. Once again, tax revenue still increases, but as wages and hours worked after shock dynamics remain the same, each class' labour income's variation won't change much relative to the previous calibration. In a positive shock, Taylor rule #4 decrease interest rates and debt service the least, therefore transfers will also increase the least. In turn, Taylor rule #3 decrease interest rates and debt service the most, thus transfers will also increase the most.

Financial income: Each class' average wealth or debt increases as result of the change in calibration. Therefore, financial income's contribution to income deviation will be more affected by interest rates movements than under the original calibration. After a contractionary shock, Taylor rule #4 increase interest rates the least, therefore interest payments to households will also increase the least. In turn, Taylor rule #3 increase interest rates the most, thus increasing financial income the most.

In an expansionary shock case, however, Taylor rule #3 decreases interest rates the most, decreasing financial income's contribution to its lowest level possible. Nonetheless, under Taylor rule #4, interest rates rise the least, and so will the financial component's contribution to income deviation.

Analyzing table 4.5, we see the exact same pattern of table 3.4. After a negative shock, all classes still prefer Taylor rule #4, while, after a positive shock, they prefer policy #3. However, as both financial income and transfers have their contribution's magnitude increased, total income may deviate less or more than under the baseline calibration, depending on the effect the financial component relative to transfers.

We can check this by comparing figures 4.9 and 3.21. Consequently, some classes' households will change their savings behavior, by saving less or more than they do under the original calibration, as we can see by comparing figures 4.9 and 3.22. Nonetheless, the income and intertemporal substitution's net effect is the same for each class, shock and policy rule in both simulations. As only the magnitude of savings and income deviation change, and policy preferences remain the same, we won't decompose each component's impact for each class as we did in subsection 3.3.

Table 4.5: High Liquidity - Technology Shock

	$(\phi_\pi, \phi_y) = (1.5, 0.125)$	$(\phi_\pi, \phi_y) = (1.5, 0)$	$(\phi_\pi, \phi_y) = (5.0, 0)$	$(\phi_\pi, \phi_y) = (1.5, 1.0)$
Contractionary shock: -$2\sigma_\gamma$				

Top 1%	0.1321	0.1331	0.1335	0.1334
Top 1-10%	0.1372	0.1384	0.1389	0.1390
Top 10-30%	0.1406	0.1420	0.1425	0.1346
Top 30-50%	0.1441	0.1456	0.1462	0.1365
Top 50-70%	0.1471	0.1487	0.1494	0.1385
Top 70%-Indebted	0.1495	0.1516	0.1525	0.1389
Indebted	0.1554	0.1576	0.1585	0.1449
Contractionary shock: $-\sigma_\gamma$				
Top 1%	0.0661	0.0666	0.0669	0.0640
Top 1-10%	0.0688	0.0694	0.0697	0.0655
Top 10-30%	0.1406	0.1420	0.1425	0.1346
Top 30-50%	0.0722	0.0730	0.0733	0.0683
Top 50-70%	0.0737	0.0746	0.0750	0.0693
Top 70%-Indebted	0.0749	0.0760	0.0765	0.0695
Indebted	0.0779	0.0790	0.0795	0.0724
Expansionary shock: σ_γ				
Top 1%	-0.0660	-0.0666	-0.0668	-0.0617
Top 1-10%	-0.0690	-0.0697	-0.0700	-0.0655
Top 10-30%	-0.0708	-0.0715	-0.0719	-0.0669
Top 30-50%	-0.0725	-0.0733	-0.0737	-0.0683
Top 50-70%	-0.0740	-0.0749	-0.0753	-0.0694
Top 70%-Indebted	-0.0752	-0.0764	-0.0768	-0.0696
Indebted	-0.0782	-0.0794	-0.0799	-0.0721
Expansionary shock: $2\sigma_\gamma$				
Top 1%	-0.1319	-0.1332	-0.1337	-0.1056
Top 1-10%	-0.1384	-0.1399	-0.1405	-0.1211
Top 10-30%	-0.1419	-0.1435	-0.1442	-0.1322
Top 30-50%	-0.1454	-0.1471	-0.1479	-0.1368
Top 50-70%	-0.1484	-0.1503	-0.1511	-0.1388
Top 70%-Indebted	-0.1509	-0.1532	-0.1542	-0.1392
Indebted	-0.1568	-0.1593	-0.1603	-0.1440

4.2.2
High Uncertainty

Take figures 4.11 and 4.12, and compare them with figures 3.9 and 3.8, respectively. It shows what was already mentioned previously, the series on each couple of figures are the same.

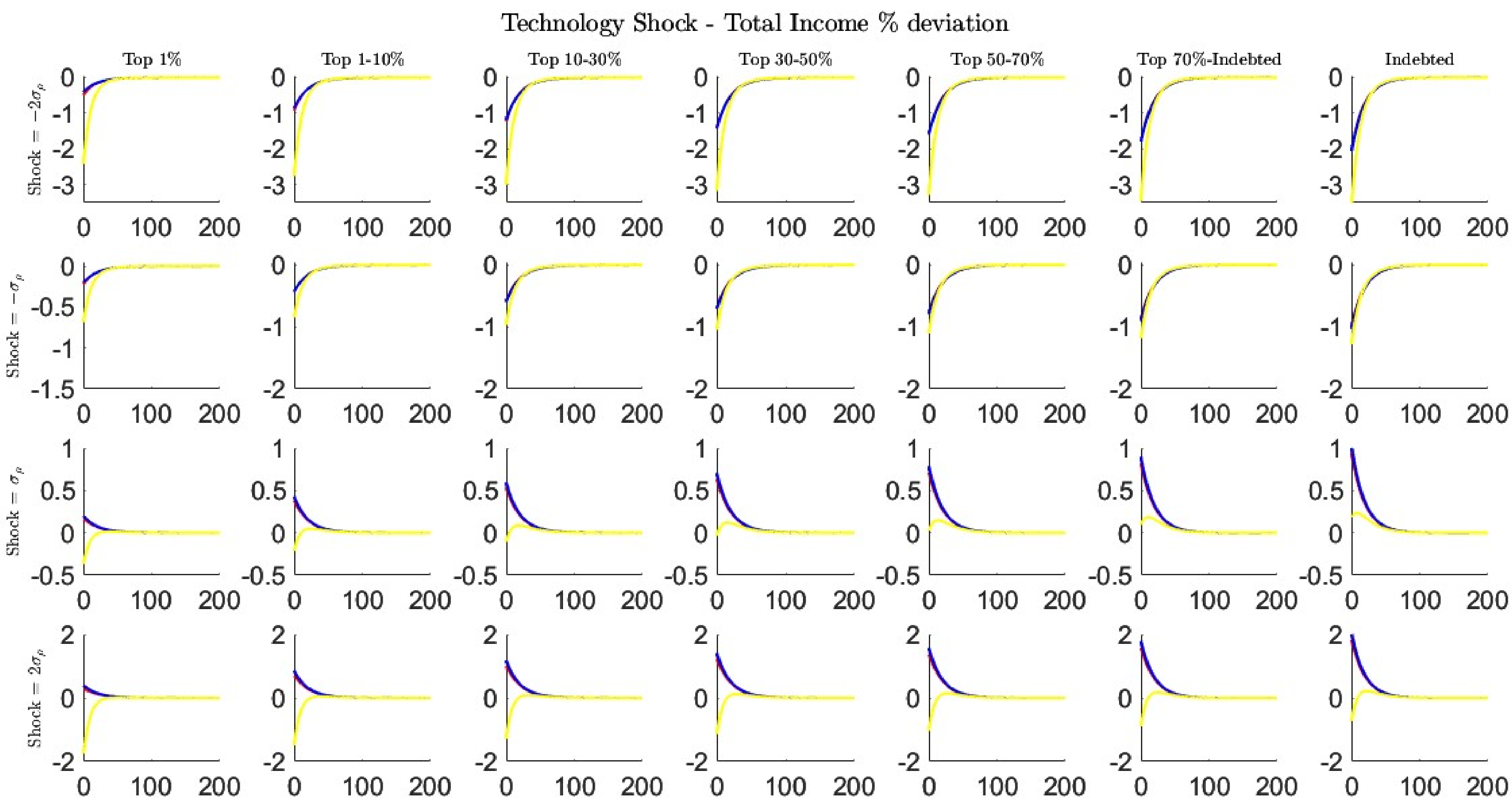

Figure 4.9: Total income deviation after a one-time technology shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

Figure 4.10: Savings change as percentage of total income at the steady-state after a one-time technology shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

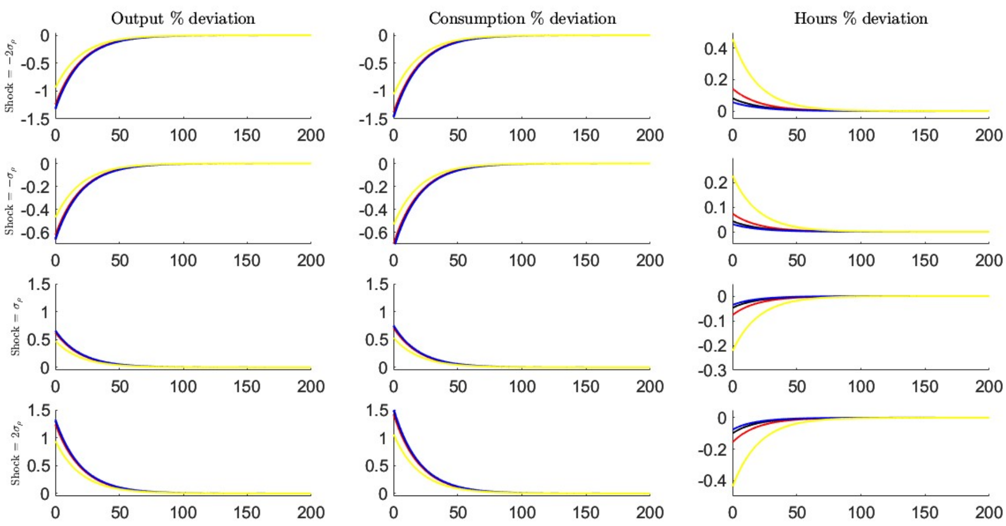

Figure 4.11: Output, consumption and hours deviation after a one-time technology shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

Financial income: Each class' average wealth or debt increases as result of the change in calibration. As the idiosyncratic risk augmented, non-indebted households will accumulate more wealth for precaution, while the indebted will increase their debt. Therefore, financial income's contribution to income deviation will be more affected by interest rates movements than under the original calibration.

After a contractionary shock, Taylor rule #4 increase interest rates the least, therefore interest payments to households will also increase the least. In turn, Taylor rule #3 increase interest rates the most, thus increasing financial income the most. In an expansionary shock case, however, Taylor rule #3 decreases interest rates the most, decreasing financial income's contribution to its lowest level possible. Nonetheless, under Taylor rule #4, interest rates rise the least, and so will the financial component's contribution to income deviation.

Analyzing table 4.6, we see the exact same pattern of table 3.4. After a negative shock, all classes still prefer Taylor rule #4, while, after a positive shock, they prefer policy #3. However, as financial income has its contribution's magnitude increased, after a negative shock, non-indebted households' total income will decrease less than under the baseline calibration, while for non-indebted, it will decrease more. After a positive shock, non-indebted households' total income will increase less than under the baseline calibration, while for non-indebted, it will increase more.

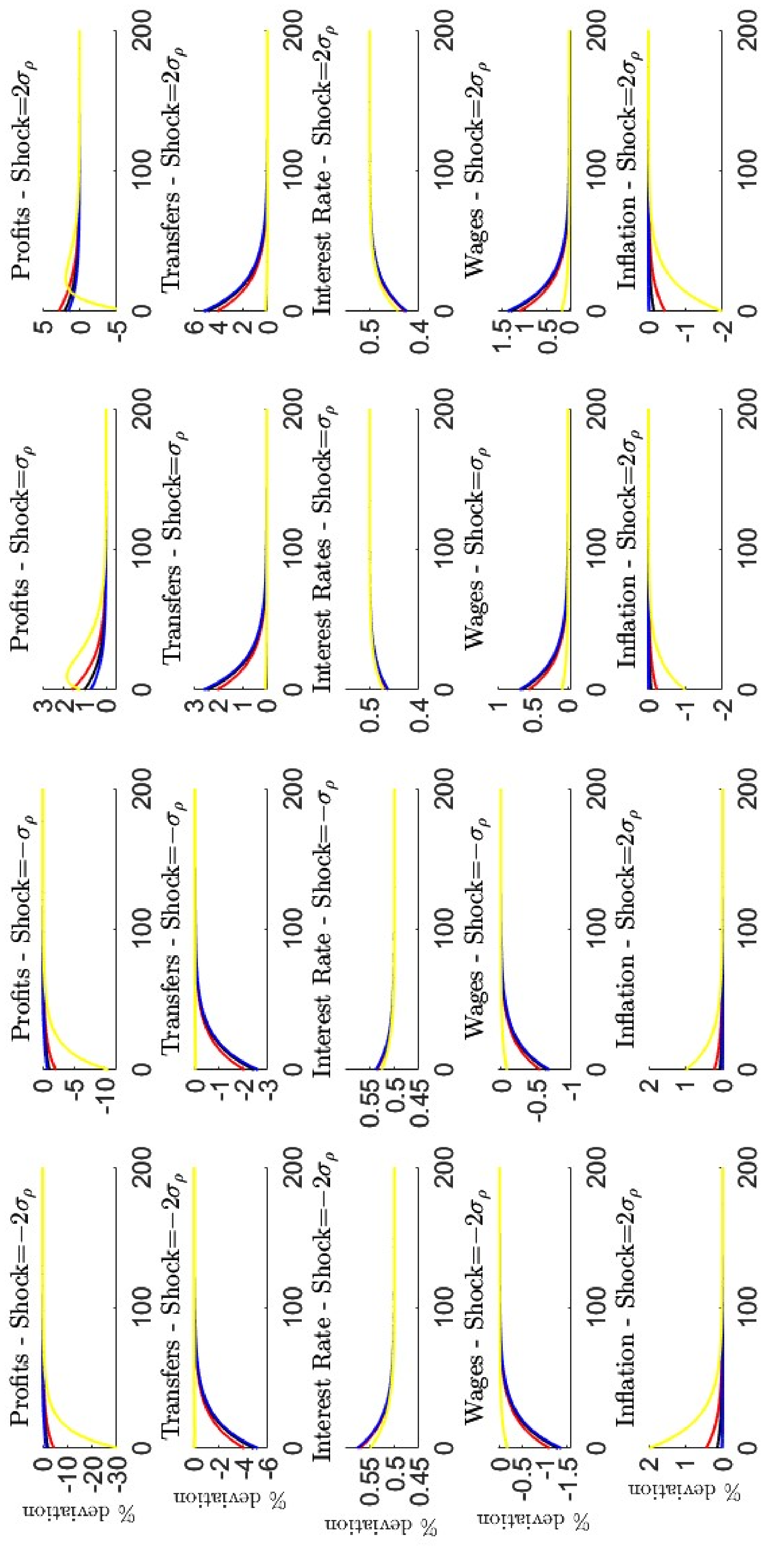

Figure 4.12: Aggregate variables deviation after a one-time technology shock. In red we have their dynamics under the Taylor (1993) calibration for monetary policy parameters. In black, under Taylor rule #2. In blue, under Taylor rule #3. In yellow, under Taylor rule #4, as in Table 3.1.

Although the different income deviations under the new calibration have an impact on savings' dynamics, it will be negligible. As mentioned, once again, all classes keep their policy preferences from the original simulation.

Table 4.6: High Uncertainty - Technology Shock

	$(\phi_\pi, \phi_y) = (1.5, 0.125)$	$(\phi_\pi, \phi_y) = (1.5, 0)$	$(\phi_\pi, \phi_y) = (5.0, 0)$	$(\phi_\pi, \phi_y) = (1.5, 1.0)$
Contractionary shock: -$2\sigma_\gamma$				
Top 1%	0.1516	0.1565	0.1586	0.1267
Top 1-10%	0.1541	0.1548	0.1551	0.1503
Top 10-30%	0.1650	0.1664	0.1670	0.1581
Top 30-50%	0.1714	0.1732	0.1740	0.1662
Top 50-HtM	0.1772	0.1794	0.1802	0.1665
Indebted	0.1914	0.1945	0.1958	0.1784
Contractionary shock: $-\sigma_\gamma$				
Top 1%	0.0759	0.0784	0.0794	0.0634
Top 1-10%	0.0772	0.0776	0.0778	0.0752
Top 10-30%	0.0827	0.0834	0.0837	0.0791
Top 30-50%	0.0859	0.0868	0.0872	0.0811
Top 50-HtM	0.0888	0.0899	0.0904	0.0833
Indebted	0.0959	0.0975	0.0982	0.0883
Expansionary shock: σ_γ				
Top 1%	-0.0762	-0.0787	-0.0798	-0.0636
Top 1-10%	-0.0777	-0.0781	-0.0783	-0.0754
Top 10-30%	-0.0832	-0.0840	-0.0843	-0.0793
Top 30-50%	-0.0864	-0.0874	-0.0879	-0.0813
Top 50-HtM	-0.0893	-0.0905	-0.0910	-0.0835
Indebted	-0.0963	-0.0981	-0.0988	-0.0868
Expansionary shock: $2\sigma_\gamma$				
Top 1%	-0.1527	-0.1577	-0.1599	-0.1272
Top 1-10%	-0.1557	-0.1567	-0.1571	-0.1508
Top 10-30%	-0.1668	-0.1684	-0.1691	-0.1586
Top 30-50%	-0.1732	-0.1753	-0.1762	-0.1627
Top 50-HtM	-0.1790	-0.1814	-0.1825	-0.1670
Indebted	-0.1929	-0.1966	-0.1981	-0.1718

5
Conclusion

We simulate transition dynamics after one and two standard contractionary and expansionary demand and technology MIT-shocks, for a continuous-time one-asset HANK model and compared different Taylor rules specifications using the steady-state as benchmark.

We separate households in classes by wealth, and compute life-time consumption equivalents for each class under different Taylor rules specifications relative to their steady-state. In the demand shock case, the classes are separate in two irreconcilable positions. The top 10% prefer the most dovish policy, Taylor rule #2, after a contractionary shock, while it prefers the most hawkish policy, Taylor rule #3, after an expansionary shock. On the other hand, the bottom 90% prefer a hawkish policy, Taylor rule #4, after a negative shock, and a dovish policy, Taylor rule #2, after a positive one.

Labour income and profits always have contributions with opposite signs, and their joint impact on income deviation is almost null. Thus, they don't play an important role in determining income's behavior. Total income deviation is mainly determined by transfers and the financial component. While the latter has a stronger impact for the wealthiest 10%, its effect is weaker for the bottom 90%. Transfers will increase under hawkish policies, after a negative shock. As interest rates fall the most under these rules, it compensates for the fall in labour tax revenue. Under dovish rules, however, this compensation doesn't take place, and transfers fall. After a positive shock, dovish rules increase the rates the least, and so the increased labour tax revenue surpass the higher debt service, increasing transfers. The opposite happens with hawkish rules.

For the top 10%, after a contractionary shock, higher transfers under hawkish rules don't compensate the smaller interest rates payments relative to those under dovish policies. So, the top 10% will have their least intense income drop under dovish rules, specially Taylor rule #2. After an expansionary shock, higher transfers under dovish rules don't compensate the smaller interest rates payments relative to those under hawkish policies. So, the top 10% will have their most intense income rise under hawkish rules, specially Taylor rule #3.

For the bottom 90%, however, the increase in transfers compensate the increased loss from financial income under a hawkish policy, after a negative shock. In the same manner, the increase in transfers compensate the smaller increase in financial income under dovish policies, after a positive shock. Specially for the indebted, hawkish rules decrease the most their interest payments, after a contractionary shock, while dovish rules increase the least those same payments, after an expansionary shock. Therefore, the bottom 90% will have their most intense rise in come under dovish rules after a positive shock, especially Taylor rule #2. Also, they will have its smallest income drop under hawkish rules, specially Taylor rule #3.

Households prefer the policies which deliver the highest income stream possible. It makes it possible for them to increase their choices among consumption and leisure streams, and to enhance their welfare.

We also run additional simulations, one increasing the liquidity in the economy and the other augmenting the probability of entering in the low labour productivity state. In the former, the higher liquidity increases the quantity of government bonds in the economy, therefore more assets are held by non-indebted agents, and more debt by the indebted. It increases households' exposure to movements in the interest rate and enhances the impact debt service have in transfers' dynamics.

Nonetheless, policy preferences will remain unchanged except for the top $10-30\%$. Although the impact of transfers rise, this class accumulate much more wealth, making financial income the determinant component of income variation. Now, the top $10-30\%$ change policy preferences, agreeing with the top 10%.

A higher unemployment rate on the other hand enhances the exposure to the interest rate income effect, as non-indebted households wish to accumulate more wealth to build a buffer in the case of arriving at the bad state of labour productivity. Indebted households however accumulate more wealth. Therefore, households' exposure to movements in the interest rate is increased. It makes the top $10-30\%$ change policy preferences, agreeing with the top 10%, as in the high liquidity simulations.

In the technology shock case, given a shock, all classes prefer the same policies. After a negative shock, households prefer Taylor rule #4 while after a positive shock, they prefer Taylor rule #3. Under any rule, financial income and transfers will play a minor role in deciding income behavior. Labour income and profits move together for most rules, apart from Taylor rule #4. These two components will be the most important determinants of income.

After a contractionary shock, under Taylor rule #4, income falls mostly driven by decreasing profits, while, under every other rule, income decreases mostly driven by a falling labour income. After an expansionary shock, under Taylor rule #4, income falls momentarily, before increasing again, once again led by profits, while under any other rule, it rises led by labour income.

After a negative shock, under Taylor rule #4, although income will suffer its biggest fall, interest rates increase the least, making it easier for households to cushion the shock by borrowing, which is why this rule is preferred by all. On the other hand, after a positive shock, under Taylor rule #3, income rises the most, so households prefer this policy.

In the high liquidity and high uncertainty simulations, although financial income and transfers have their dynamics changed by the new calibration, influencing income and savings dynamics, it doesn't change household's policy preferences.

A few critics must be draw, though. Our model is simple, it lacks many important features from the HANK literature, like the inclusion of an illiquid asset, i.e. firms' shares and capital. Consequently, we cannot both match empirically observed population fractions of indebted or hand-to-mouth households while simulating an asset distribution that matches the 2004 **SCF** data. The literature estimates around a third of the population is hand-to-mouth, i.e. households holding zero bonds and choosing to expend all income in consumption. For them, interest rate movements' direct effect is smaller than its indirect effect, acting through wages and transfers.

In our model, the hand-to-mouth are a small share of the population, consequently, throughout our work we focused on indebted and non-indebted households. Future improvements should center in increasing the hand-to-mouth proportion in the total population.

Finally, the lack of capital prevents us to explore how monetary policy affects investment and, consequently, wealthy households and wealthy hand-to-mouth, i.e. hand-to-mouth agents with positive illiquid assets positions. The investment channel is central to determine policy preferences.

It determines the quantity of capital in the economy, which is important to determine aggregate output and bares consequence for wages and hours worked dynamics in the technology shock. Illiquid assets' return and share price reacts to monetary policy, determining how wealthy hand-to-mouth benefit from monetary shocks. As they are closer to the median of the wealth distribution, it would be interesting to check if it changes the middle-class preference for dovish policy from our model. Unfortunately, we cannot capture these aspects present in the two-asset HANK models. Future work should include this feature.

Bibliography

Achdou, Y., Han, J., Lasry, J.M., Lions, P.L., & Moll, B. 2022. Income and Wealth Distribution in Macroeconomics: A Continuous-Time Approach. *The Review of Economic Studies*, **89**(1), 45–86.

Ahn, S., Kaplan, G., Moll, B., Winberry, T., & Wolf, C. 2018. When inequality matters for macro and macro matters for inequality. *NBER Macroeconomics Annual*, **32**(1), 1–75.

Ahn, SeHyoun. 2017. *PHACT Toolbox*. Disponível em: <https://github.com/gregkaplan/phact>. Acesso em: 5 abr. 2017.

Aiyagari, S. R. 1994. Uninsured Idiosyncratic Risk and Aggregate Saving. *The Quarterly Journal of Economics*, **109**(3), 659–684.

Auclert, A. 2019. Monetary Policy and the Redistribution Channel. *American Economic Review*, **109**(6), 2333–2367.

Auclert, A., Rognlie, M., & Straub, L. 2020. *Micro Jumps, Macro Humps: Monetary Policy and Business Cycles in an Estimated HANK Model*. NBER Working Paper No. 26647, January.

Auclert, A., Rognlie, M., Souchier, M., & Straub, L. 2021. *Exchange Rates and Monetary Policy with Heterogeneous Agents: Sizing up the Real Income Channel*. NBER Working Paper No. 28872, May.

Blundell, R., Pistaferri, L., & Preston, I. 2008. Consumption Inequality and Partial Insurance. *American Economic Review*, **98**(5), 1887–1921.

Broda, C., & Parker, J.A. 2014. The Economic Stimulus Payments of 2008 and the aggregate demand for consumption. *Journal of Monetary Economics*, **68**, S20–S36.

Broer, T., Hansen, N.H., Krusell, P., & Öberg, E. 2020. The New Keynesian Transmission Mechanism: A Heterogeneous-Agent Perspective. *Review of Economic Studies*, **87**, 77–101.

Calvo, G. A. 1983. Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*, **12**(3), 383–398.

Cooley, T., & Prescott, E. 1995. Economic Growth and Business Cycles. *In:* Cooley (ed), *Frontiers of Business Cycle Research*.

Galí, J. 2015. The Basic New Keynesian Model. *In: Monetary Policy, Inflantion, and the Business Cycle*.

Gornemann, N., Kuester, K., & Nakajima, M. 2016. *Doves for the Rich, Hawks for the Poor? Distributional Consequences of Monetary Policy*. Board of Governors of the Federal Reserve System International Finance Discussion Papers, Number 1167, May.

Huggett, M. 1993. The risk-free rate in heterogeneous-agent incomplete-insurance economies. *Journal of Economic Dynamics and Control*, **17**(5-6), 953–969.

Johnson, D.S., Parker, J.A., & Souleles, N.S. 2006. Household Expenditure and the Income Tax Rebates of 2001. *American Economic Review*, **96**(5), 1589–1610.

Kaplan, G., & Vioante, G. 2018. Microeconomic Heterogeneity and Macroeconomic Shocks. *Journal of Economic Perspectives*, **32**(3), 167–194.

Kaplan, G., Moll, B., & Vioante, G. 2018. Monetary Policy According to HANK. *American Economic Review*, **108**(3), 697–743.

Mckay, A., Nakamura, E., & J., Steinsson. 2016. The Power of Forward Guidance Revisited. *American Economic Review*, **106**(10), 3133–3158.

Rotemberg, J. 1982. Sticky Prices in the United States. *Journal of Political Economy*, **90**(6), 1187–1211.

Taylor, J. 1993. Discretion versus Policy Rules in Practice. *Carnegie-Rochester Series on Public Policy*, **39**, 195–214.

A
Appendix

A.1
HJB

$$\rho V(b_t, z_t, t) = \max_{\{c_t, l_t\}} u(c_t, l_t) + \tag{A-1}$$

$$V_b(b_t, z_t, t)((1-\tau_t)w_t z_t l_t + \pi(z_t) + r_t^b b_t + T_t - c_t) + \tag{A-2}$$

$$\lambda(z, z^{'})(V(a_t, b_t, z^{'}, t) - V(a_t, b_t, z, t)) + V_t(a_t, b_t, z, t) \tag{A-3}$$

$$\tag{A-4}$$

A.2
KF

$$\frac{\partial g(b_t, z_t, t)}{\partial t} = -\frac{\partial}{\partial b}((1-\tau_t)w_t z_t l_t + \pi(z_t) + r_t^b b_t + T_t - c_t)g(b_t, z_t, t) \tag{A-5}$$

$$+\lambda(z, z^{'})g(b_t, z^{'}, t) - \lambda(z^{'}, z)g(b_t, z, t) \tag{A-6}$$

FOC and Envelope Theorem

$$J_p(p_{j,t}, t)p_{j,t} = \theta \pi_t Y_t$$

$$(r_t^a - \pi_{j,t})J_p(p_{j,t}, t) = -\left(\frac{p_{j,t}}{P_t} - m_t\right)\epsilon\left(\frac{p_{j,t}}{P_t}\right)^{-\epsilon-1}\frac{Y_t}{P_t} + \left(\frac{p_{j,t}}{P_t}\right)^{-\epsilon}\frac{Y_t}{P_t} + J_{pp}(p_{j,t}, t)p_{j,t}\pi_{j,t} + J_{pt}(p_{j,t}, t)$$

Impose an symmetric equilibrium:

$$J_p(p_t, t)p_t = \theta \pi_t Y_t$$

$$(r_t^a - \pi_t)J_p(p_t, t) = -\left(1 - m_t\right)\epsilon\frac{Y_t}{P_t} + \frac{Y_t}{P_t} + J_{pp}(p_{j,t}, t)p_t\pi_{j,t} + J_{pt}(p_t, t)$$

Differentiate by time the FOC equation above:

$$J_{pp}(p_t,t)\dot{p}_t + J_{pt}(p_t,t) = \frac{\theta\dot{\pi}_t Y_t}{p_t} + \frac{\theta\pi_t\dot{Y}_t}{p_t} - \frac{\theta\pi_t Y_t}{p_t}\pi_t$$

Substitute in the Envelope Theorem equation, thus getting the Phillips Curve:

$$\left(r_t^a - \frac{\dot{Y}_t}{Y_t}\right)\pi_t = \frac{\epsilon}{\theta}(m_t - m^*) + \dot{\pi}_t, \quad m^* = \frac{\epsilon - 1}{\epsilon} \tag{A-7}$$

A.3 Stationary distribution

Wealth Distributions55 [Stationary Density Employed].5stationary densities employed.jpg [Stationary Density Unemployed].5stationary densities unemployed.jpg

A.4 Achdou *et al.* (2022) and Ahn *et al.* (2018) Methods

A.4.1 Achdou *et al.* (2022) Algorithm

1. Guess aggregate hours worked, $\bar{L}$, and the discount rate, ρ, consistent with the calibrated interest rate, r, in the steady state.

2. Calculate implied prices and quantities

$$\bar{w} = \bar{m} = \frac{\epsilon - 1}{\epsilon}$$
$$\bar{Y} = \bar{\gamma}\bar{N}$$
$$\bar{w} = \bar{\gamma}\bar{m}$$
$$\bar{\Pi} = (1 - \bar{m})\bar{Y}$$
$$B^g = \bar{B} = \bar{Y}$$

3. Calculate worker's bonuses

$$\pi(z) = \frac{z}{\bar{z}}\bar{\Pi}$$

4. Compute Fiscal Policy, considering lump-sum transfers the adjusting fiscal policy variable.

$$T = \bar{\tau}\Big(\bar{w}\sum_z \int zl(b,z)g(b,z)db\Big) + \bar{\Pi} + rB^g - \bar{G}$$

5. Solve the household problem, finding the stationary distribution by the Finite Differences method in Achdou *et al.* (2022).

   Approximate the value and distribution functions using the grid's points for the asset state, for each labour productivity state. Let I be the number of points in the asset grid, and 2 is the number of productivity states. Then, we have a $2 * I$ dimension vector for the value function, $\mathbf{v}$, and another for the distribution function, $\mathbf{g}$. Finally, write equations A-1 and A-5 in its discrete formulation:

$$\rho\mathbf{v} = u(\mathbf{v}) + \mathbf{A}(\mathbf{v}; r, w)\mathbf{v}$$
$$\mathbf{0} = \mathbf{A}^T(\mathbf{v}; r, w)\mathbf{g}$$

   The matrix $\mathbf{A}$ works as a transition matrix, capturing the evolution of states. The matrix working in this same manner for the **KF** equations is the transpose of $\mathbf{A}$, so we only have to solve for the **HJB** equations. Ignore the state z for now. Following the FD method, we approximate the value function derivative by:

$$v^{'}(b_i) \approx \frac{v_{i+1} - v_i}{\Delta b} \text{ or } \frac{v_i - v_{i-1}}{\Delta b}$$

   In order to decide which one to use, we follow the upwind scheme. Lets $s_i = ((1-\tau)wzl(b_i, z) + \pi(z) + rb_i + T - c(b_i, z))$, then if $s_i > 0$ we use the first approximation, and if $s_i < 0$, we use the second. In case $s_i = 0$, then the derivative is 0. So, we can write:

$$\rho v(b_i) = u(c_i, l_i) + \frac{v_{i+1} - v_i}{\Delta b}s_i^+ + \frac{v_i - v_{i-1}}{\Delta b}s_i^-$$

Where $s_i^+ = \max\{s_i, 0\}$, $s_i^- = \min\{s_i, 0\}$, $c_i = u_c^{-1}(v'(b_i, z))$ and $l_i = u_l^{-1}(-(1-\tau)wzv'(b_i, z))$. We can assign state z with values 1 and 2, and represent it with subscript j. Also, assign the subscript F to the first derivative approximation shown, and the subscript B to the second. Now following the implicit method, we can write :

$$\frac{v_{i,j}^{n+1} - v_{i,j}^{n}}{\Delta} + \rho v_{i,j}^{n+1} = u(c_{i,j}^{n}, l_{i,j}^{n}) + (v_{i,j,F}^{n+1})' s_i^+ + (v_{i,j,B}^{n+1})' s_i^- + \lambda_j (v_{i,-j}^{n+1} - v_{i,j}^{n+1}) \tag{A-8}$$

The **FD** algorithm is:

(a) Guess an initial value function, $\mathbf{v}^0$.

(b) Compute $(v_{i,j}^n)'$ using the upwind scheme.

(c) Compute $c_{i,j}^n$ and $l_{i,j}^n$.

(d) Find v^{n+1} from the system described by equation A-8.

(e) If v^n is close enough to v^{n+1}, stop. Otherwise, update guess from (a).

6. Compute households' aggregated effective labour supply and demand for bonds.

$$N^h = \sum_z \int zl(b,z)g(b,z)db$$
$$B^h = \int_0^1 bdg(b,z)$$

7. Check market clearing given a tolerance margin of $\varepsilon = 10^{-5}$:

$$|B^h - B^g| + |N^h - \bar{N}| \leq \varepsilon$$

If it converged, stop. Otherwise, changing the previous guess, using the bisection method to update the discount factor.

A.4.2
Ahn *et al.* (2018) linearization procedure

The system bellow describes the equilibrium of the Economy with a Technology shock:

$$\rho \mathbf{v}_t = u(\mathbf{v}_t) + \mathbf{A}(\mathbf{v}_t; r_t, w_t)\mathbf{v}_t + \frac{1}{dt}\mathbb{E}d\mathbf{v}_t \tag{A-9}$$

$$\frac{d\mathbf{g}_t}{dt} = \mathbf{A}^T(\mathbf{v}_t; r_t, w_t)\mathbf{g}_t \tag{A-10}$$

$$\left(r_t - \frac{\dot{Y}_t}{Y_t}\right)\pi_t = \frac{\epsilon}{\theta}(\frac{w_t}{\gamma_t} - \bar{w}) + \dot{\pi}_t \tag{A-11}$$

$$d\log(\gamma_t) = -(1-\rho_\gamma)\log(\gamma_t)dt + \sigma_\gamma dW_t \tag{A-12}$$

Notice the households' choice variables, c and l are functions of the value functions and distribution. Prices and inflation are a function of the value functions, distribution and the aggregate shock, as is clear in the NKPC equation. Finally, we must include one equation describing the aggregate shock itself.

The next step would be to linearize these equations, making a Taylor first-order approximation, and solve the system. This will wipe-out all direct uncertainty from the aggregate shocks, but not from the idiosyncratic shocks, i.e. the diffusion process dW_t is eliminated by the linearization, but the λ_j aren't. So aggregate shocks do add aggregate uncertainty to the problem, in the sense that it changes the idiosyncratic states' distribution.

To calculate the derivatives for the first-order approximation would be cumbersome, as there are many grid points. In Ahn *et al.* (2018), the authors briefly describe the Automatic differentiation technique, which make this much easier and faster than other numerical methods run on computers. In Ahn (2017), there is a build package, facilitating our work in using this technique to obtain the derivatives. We must also thank the authors to make available a one-asset HANK model script, which we modified for the goals of this work.