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ESCOLA DE ECONOMIA DE SÃO PAULO

ESSAYS ON ECONOMIC POLICY THROUGH DSGE MODELS

GUSTAVO ARRUDA

São Paulo
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Tese apresentada à Escola de Economia de São Paulo da Fundação Getulio Vargas, como requisito à obtenção do título de **Doutor em Economia**.

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À minha familia.

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Muita coisa aconteceu nesses últimos quatro anos. Quem imaginaria, que no meio dessa caminhada teríamos uma pandemia. Um choque que mudaria a maneira como nos relacionamos, trabalhamos. Apesar de tanta coisa ter acontecido, uma coisa nunca mudou: o apoio incondicional da minha esposa, minha família, dos meus amigos e do meu orientador, a quem eu dedico esse trabalho.

RESUMO

Esta tese consiste em dois ensaios sobre dois desafios econômicos enfrentados pelos formuladores de políticas (uma crise e um desenho de politica fiscal visando arrecadação). No primeiro ensaio, buscamos avaliar os efeitos de diferentes tipos de políticas econômicas e de saúde pública, e suas interações, durante a crise do COVID-19. O surto de COVID-19 no início de 2020 instou os governos em todo o mundo a agirem. Em resposta ao evento inesperado, governos em todo o mundo começam a anunciar medidas econômicas e de saúde com tempo limitado para projetar, preparar ou coordenar medidas dentro de países e regiões. No ensaio encontramos evidencias de que as políticas de restrição de circulação endógenas desaceleram a infecção como esperado, mas aprofundando a crise econômica. Dentre as politicas introduzidas durante a crise, os empréstimos garantidos pelo governo podem ser uma política eficaz com custos fiscais potencialmente menores; nas políticas fiscais, transferir dinheiro para empresas pode ser mais eficaz do que transferir dinheiro para famílias.

No segundo ensaio, analisamos os possíveis efeitos de uma tributação financeira em uma economia. Para isso, implementamos algumas possibilidades tributárias no modelo apresentado por Gerali et al. (2010). Quando comparada ao sistema de tributação da renda do trabalho, a economia que enfrenta um sistema de tributação financeira tende a ter menor estoque de capital em estado estacionário, maiores spreads no mercado de crédito e menores rendimentos salariais, com maior impacto negativo nas famílias impacientes (as famílias que toma emprestado na economia).

Palavras-chave: Modelos DSGE, Politica economica, modelos epidemologicos, sistema tributário.

ABSTRACT

This thesis consists of two essays on economic challenges faced by policy makers analysed through DSGE models. In the first essay, we seek to evaluate the effects of different types of economic and public health policies, and its interactions, during COVID-19 crisis. The COVID-19 outbreak at beginning of 2020 urged governments across the globe to act. In response to the unexpected event, governments across the globe start to announce economic and health measures with limited time to design, prepare or coordinate measures within countries and regions. We found that the endogenous stringency lockdown policies decelerate infection as expected, but deepening the economic crisis; government-guaranteed loans can be an effective policy with potentially smaller fiscal costs; on fiscal policies, to transfer money to companies to prevent employment loss can be more effective than to transfer money to the households.

In the second essay, we analyzed the possible effects of a financial taxation in an economy. In order to do so, we have implemented several tax possibilities in the model presented by Gerali et al. (2010). When compared to the labour income taxation system, the economy that faces a financial taxation system tends to have smaller stock of capital at steady state, higher spreads in the credit market and lower wages income, with greater negative impact in the impatient household (the households that borrows in the economy).

Keywords: DSGE Models, Economic policy, epidemic models, tax system.

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SUMMARY

1 ECONOMIC POLICIES IN THE TIME OF COVID-19

1.1 INTRODUCTION

The COVID-19 outbreak at the beginning of 2020 urged governments across the globe to act. The health disease that started in China rapidly became a global problem, with the World Health Organization (WHO) classifying it as a pandemic on 11 March 2020. In response to the unexpected event, governments across the globe start to announce economic and health measures with limited time to design, prepare or coordinate measures within countries and regions. Several economies globally have closed part of the economy, tested population, expanded fiscal spending, and acted in the monetary and credit front.

This paper seeks to evaluate the effects of different economic and public health policies and their interactions during the COVID-19 crisis. To this end, we extend a SIR-New Keynesian Model (ATKESON et al., 2021; EICHENBAUM et al., 2020a; EICHENBAUM et al., 2020b) in three crucial aspects.

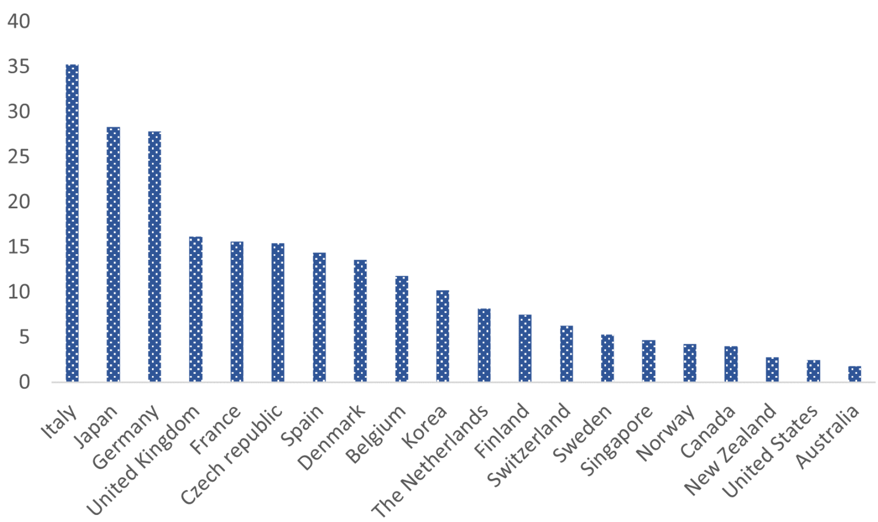
First, we modeled the lockdown stringency policy throughout an endogenous rule depending on the number of new infections. This extension allows us to observe the interaction between economic and health policies and the subsequent consequences on the economy and epidemic evolution. This novelty provided a critical feature to explain economic outcomes, particularly in the labor market. In the benchmark models by Eichenbaum et al. (2020a) and Eichenbaum et al. (2020b), the fall in labor supply caused by households' reaction to epidemics generates an increase in wages. The inclusion of lockdown policies corrects this direction since it reduces the labor demand too, provoking a fall in wages, as it pushes down the activity, making the results consistent to the pieces of evidence presented by Coibion et al. (2020) and Jones et al. (2020). The lockdown policy also played a crucial impact on the economy with fiscal and financial consequences.

Therefore, the second significant extension is the inclusion of financial frictions following the framework proposed by Bernanke et al. (1999). In that sense, the 2020 lockdown may be identified with a "medically-induced coma" voluntary and temporary, imposed on the economy to limit contagion, flattening the infection curve. An immediate

consequence is an increase in the probability of entrepreneurs' default, reducing the supply of credit and investment. Thus, the inclusion of financial frictions to the benchmark epidemiological model provides additional damage from COVID-19 to the economy: A risk shock; that is a significant propagation channel (CHRISTIANO et al., 2014), and demand the use of financial stabilization policies in addition to monetary policy by Central Banks (CARRILLO et al., 2021).

In that sense, we investigate carefully the efficacy of some financial crisis policies adopted by Central Banks as a stabilization package. Notably, we model the government-guaranteed provisions for firms' loans, the primary policy tool adopted by many countries to mitigate the risk shock faced by small and medium enterprises during the COVID-19 period ((OECD, 2020; OECD, 2021), Figures 1.1 and 1.2).

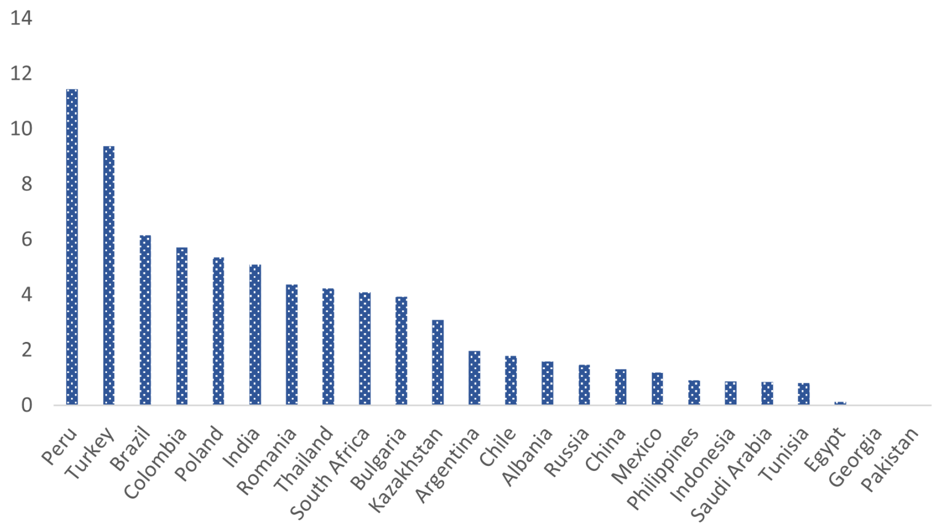
Figure 1.1 – Covid-19 related guarantees, loans and equity policies in Advanced economies (as % of GDP)



Source: (OECD, 2020). Produced by the author.

At the same time that lockdown policies flattened the infection curve, it steepened the macroeconomic recession curve too (GOURINCHAS, 2020). In order to avoid this "economic infection," governments have expanded fiscal policy in about 6.5 % of GDP, with great dispersion of amounts and types of programs (IMF, 2021) suspending fiscal rules during this period. In advanced economies, the fiscal expansion reached about 10 % of GDP within additional spending and forgone revenue; while in emerging economies, the fiscal expansion reached about 4.0 % of GDP (Figures 1.3 and 1.4). These measures triggered a sizeable increase in government deficits and debt levels, and a natural question arises: What would be the effects of redesign the fiscal automatic stabilizers after the COVID-19 crisis? (BLANCHARD et al., 2021).

Figure 1.2 – Covid-19 related guarantees, loans and equity policies in Emerging economies (as % of GDP)



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In order to provide a numerical answer to this question, we suggest a third extension on the benchmark model, including a detailed specification of the fiscal sector to conduct a meaningful quantitative analysis of the impact of fiscal policy on real GDP. We considered the following features:

1. Heterogeneous households (Ricardian and non-Ricardian), in order to observe the alternative contamination paths and the effects of heterogeneous transfers from government;

2. Government consumption, which is valued by households in a non-separable way;

3. Public capital subject to a time-to-build technology, which can be either a complement or a substitute to private capital;

4. Distortionary tax rates;

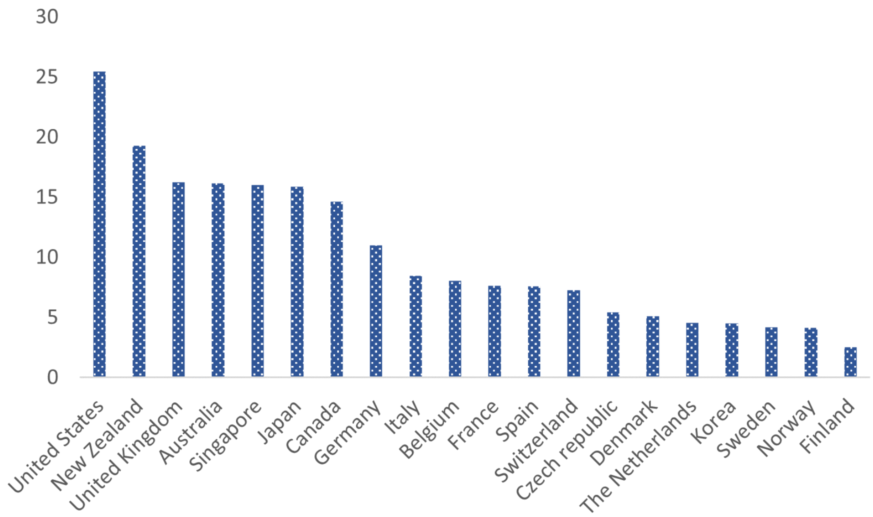
5. Labor subsidies to compensate lockdown policies;

6. Time-varying fiscal rules, capturing the operation of automatic stabilizers, and the possibility of adjusting fiscal rules parameters after the crisis.

Our main findings can be summarized as follows. We found that the endogenous stringency lockdown policies decelerate infection but worsening the economic crisis; government-guaranteed loans can be an effective policy with potentially smaller fiscal

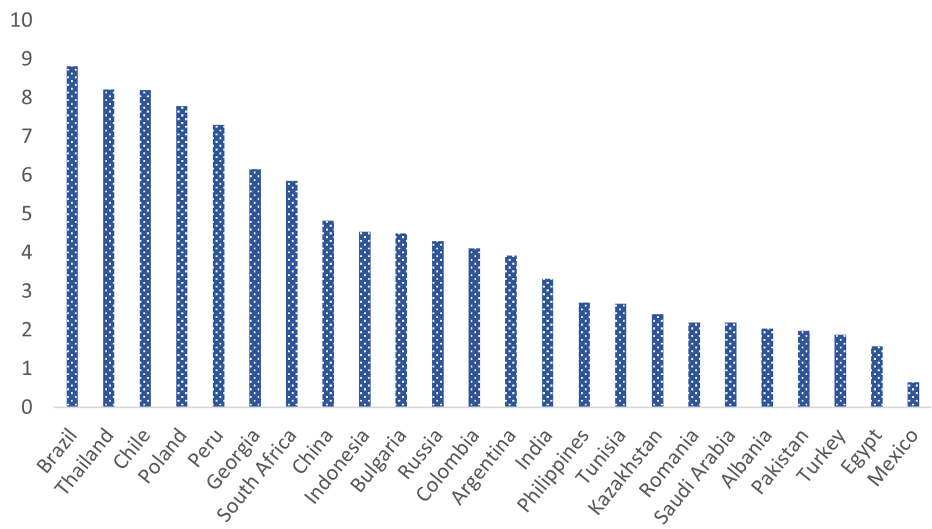
costs; on fiscal policies, to transfer money to companies to prevent employment loss can be more effective than to transfer money to the Non-Ricardian households.

Figure 1.3 – Covid-19 related fiscal expending in Advanced economies (as % of GDP)



Source: (IMF, 2021). Produced by the author.

Figure 1.4 – Covid-19 related fiscal expending in Emerging economies (as % of GDP)



Source: (IMF, 2021). Produced by the author.

1.2 THE MODEL

1.2.1 Households

We assume a continuum of infinitely lived households, indexed by $i \in [0.1]$. A fraction of these, $1 - \lambda^{NR}$, households can save, having to make intertemporal decisions about consumption. We use the term *Ricardian* to refer to that subset of households. The remaining fraction λ^{NR} households do not have access to the capital market and only consume their current income. We can understand this fraction of households, which we will call *rule-of-thumb* or *non-Ricardian*, whose income is very close to their subsistence consumption, with no room to save. As already demonstrated extensively in Campbell e Mankiw (1989), Galí et al. (2007), Coenen e Straub (2005), Coenen et al. (2012) such a modeling strategy can reconcile micro and macroeconomic facts on the correlation between fiscal policy, labor market, and consumption with the predictions of dynamic equilibrium models, and are relevant to understand the evolution of economies in times of recessions.

Households make their consumption and labor supply decisions considering the risk of infection with COVID-19. The propagation of epidemics is modeled following the traditional SIR model, where people are divided into four groups: susceptible (people who have not yet been exposed to the disease), infected (people who contracted the disease), recovered (people who survived the disease and acquired immunity), and deceased (people who died from the disease).

Following Eichenbaum et al. (2020a), Eichenbaum et al. (2020b) we will endogenize the behavior related to economic activity by assuming that working or consuming increases the probability of being infected. Thus, one way to understand the model is to consider that the utility parameters of consumption and disutility at work incorporate the fear of being infected, whose probability is endogenous and varies over time according to the spread of the disease as predicted in the SIR model.

We augmented the Eichenbaum et al. (2020a), Eichenbaum et al. (2020b) model by considering that agents may have their working activities restricted by a lockdown policy determined by the planner in order to contain the spread of the disease. In this sense, a fraction θ of workers are prohibited from working. We will consider that the workers decide their labor supply knowing the value of θ_t, but they do not know if they

will be drawn not to work. All workers receive the same wage per hour by the company, which the government may compensate in one of the fiscal policies that we will consider later. Therefore lockdown policies will affect the economic decisions and will affect fiscal policy outcomes. Those infected at work, consumption, or other activities are infected at the end of the same period as they performed the activities.

Fiscal policy interacts directly with households by an income tax on Ricardian households labor (τ_n), by direct transfers to non-Ricardian households (T_t^H) acting as a social protection policy during the epidemic, and by government consumption (G_t) that affect optimal private consumption decisions directly.

1.2.1.1 Ricardian Households

A typical household has a continuum of measure one of family members and maximizes the discounted utility function with indivisible labor supply:

$$U^R = \sum_{t=0}^{\infty} \beta^t \left\{ \sum_{j=(s,i,r)} j_t \left[\ln(\tilde{c}_t^{j,R}) - \frac{B}{2}(n_t^{j,R})^2 \right] \right\}, \tag{1}$$

where,

$$\tilde{c}_t^{j,R} = \left(\alpha_G^{\frac{1}{\upsilon_G}} c_t^{j,R\,\frac{\upsilon_G - 1}{\upsilon_G}} + (1-\alpha_G)^{\frac{1}{\upsilon_G}} G_t^{\frac{\upsilon_G - 1}{\upsilon_G}} \right)^{\frac{\upsilon_G}{\upsilon_G - 1}} \tag{2}$$

subject to the budget constraint:

$$D_{t+1} + P_t(s_t^R c_t^{s,R} + i_t^R c_t^{i,R} + r_t^R c_t^{r,R} + S_t) = R_{t-1}^d D_t + W_t(1-\tau_n)(s_t^R n_t^{s,R} + i_t^R n_t^{i,R} + r_t^R n_t^{r,R}) + \Pi_{t,h} - \chi_t$$

where c_t^j represents the consumption of private goods and G_t the government consumption, α_G is a share parameter, υ is the elasticity of substitution between private and government consumption, β is the discount rate, s_t, i_t and r_t are the fractions of suscetibles, infected and recovered family members respectively. Consumption and labor hours supplied by suscetible, infected and recovered are c_t^j and n_t^j with $j \in (s,i,r)$. S_t is household's real equity investment (private equity) in the firms at the beginning of time t, and χ_t are

lump-sum taxes. $\Pi_{t,h}$ represents the household's lump-sum transfer from firms, realized at the end of period t. An implicit simplifying assumption is that every ricardian household holds the same mutual fund so that the economy's total profit is equally distributed among households. P_t is the price index, and W_t the nominal wages. D_t represents the household's holding of real deposits with the banking sector at the beginning of time t, R_t^d is interest rates on deposits.

The labor income tax is a fiscal component that interacts directly with households decision. The most important feature behind the inclusion of this component is the insertion of a massive fall in government receipts during the crisis. Since the labor supply falls, once households are risk-averse to being infected, and labor demand falls in consequence of the fall in demand for goods and the lockdown policy, the aggregate labor income tax falls, worsening the fiscal situation. It will be an essential component of the dynamics of public debt with critical economic effects.

1.2.1.2 Non-Ricardian Households

Non-Ricardian households have the same preferences as Ricardian households, but they cannot save or invest in capital or hold bonds. Thus, their budget constraint is given by:

$$P_t(s_t^{NR}c_t^{s,NR} + i_t^{NR}c_t^{i,NR} + r_t^{NR}c_t^{r,NR}) = W_t(s_t^{NR}n_t^{s,NR} + i_t^{NR}n_t^{i,NR} + r_t^{NR}n_t^{r,NR}) + T_t^H$$

Note that non-Ricardian households behave in a "hand-to-mouth" fashion, entirely consuming their income. We consider that government does not tax non-Ricardian labor income and pay them some direct lump-sum transfer.

1.2.1.3 Epidemic Dynamics

Households consider the risk of their members being contaminated when they decide on labor supply and consumption. Thus, we assume that families' exposure to the virus is endogenous, affecting their economic decisions as well as the aggregated spread of the epidemic.

Households know their health status perfectly and the fractions of susceptible, infected, and recovered in the population, but they do not internalize the impact of their choices on aggregate infection rates. Several articles consider these hypothesis in the economic literature, as well as Alvarez et al. (2020), Eichenbaum et al. (2020a), Eichenbaum et al. (2020b), Glover et al. (2020), Jones et al. (2020). The number of newly infected people in the family is given by:

$$\tau_t^h = \pi_1^h s_t^h c_t^{s,h}(I_t C_t^I) + \pi_2^h s_t^h n_t^{s,h}(1-\theta_t)(I_t N_t^I(1-\theta_t)) + \pi_3^h s_t^h I_t \tag{3}$$

where $h \in [R, NR]$ is the type of household (Ricardian or Non-Ricardian), I_t is the aggregate number of infected people, and C_t^I and N_t^I are aggregate consumption and hours worked by infected people. Thus, π_1 and π_2 reflects the probability of being infected in consumption and working in market good interactions. In turn, $\pi_3 S_t I_t$ is the probability of being infected in other activities unrelated to work or consumption. In this sense, this component incorporates virus transmissions that are not the result of economic activity, which are a substantial part, as highlighted by Ferguson et al. (2006). At each period, the government decides that a fraction of θ_t of workers will not work, although they will receive their wages. This lockdown modeling is similar to that suggested by Alvarez et al. (2020). At the same time, the government may adopt compensation measures for firms, as we will explain later.

The fraction of each household type that is susceptible, infected and recovered is given by:

$$s_{t+1}^h = s_t^h - \tau_t^h \tag{4}$$

$$i_{t+1}^h = i_t^h + \tau_t^h - (\pi_r + \pi_d) i_t^h \tag{5}$$

$$r^h_{t+1} = r^h_t + \pi_r i^h_t \tag{6}$$

The household maximizes lifetime utility, subject to the budget constraint, and the equations that govern the health status of the household's members. Thus, families consider the risk of being infected, reducing the exposure by reducing their consumption and labor supply.

1.2.2 Final Good Producers

Competitive firms produce a homogeneous final good using a CES technology:

$$Y_t = \left(\int_0^1 Y_{i,t}^{\frac{1}{\gamma}} di \right)^{\gamma}, \gamma > 1 \tag{7}$$

where $Y_{i,t}$ is the quantity of intermediate good i by firm. Profit maximization give us the demand curve for each input:

$$Y_{i,t} = P_{i,t}^{-\frac{\gamma}{\gamma-1}} Y_t \tag{8}$$

where $P_{i,t}$ is the price of the intermediate i.

1.2.3 Intermediate Goods Sector

The i^{th} intermediate good is produced by a monopolist in product market, with the following production function:

$$Y_{i,t} = A\omega_{i,t} K_t^G K_{i,t}^{1-\alpha} (N_{i,t}(1-\theta_t))^{\alpha} \tag{9}$$

where $K_{i,t}$ is the amount of capital purchased from capital producers, K_t^G is public capital, A is the productivity, ω_i is an idiosyncratic productivity shock to firm i, $N_{i,t}$ is the labor hired by the firm. The planner decides θ, the fraction of hired workers that will be prohibited to work.

Intermediate goods profits are given by:

$$\pi_{i,t} = P_{i,t}Y_{i,t} - r_t^k K_{i,t} - w_t N_{i,t} + N_{i,t}T_t^N \tag{10}$$

Intermediate firm i choose it the labor demand maximizing their profits (10) subject to demand curve (8) and a Calvo sticky price-setting friction. With probability $1-\epsilon$ firm reoptimize and chooses a new $P_{i,t}$, and with probability ϵ firm keeps the price unchanged.

Lockdown policies reduce production and the marginal product of labor, as it drops the productivity of a portion of workers to zero. The government may compensate for lockdown policies by providing transfers to firms proportional to contracted labor hours. This policy is explicit at profit function by $N_{i,t}T^N$.

Financial frictions limit the capital demand by firms. In that sense, we model firm defaults and financial intermediation closely to the seminal paper of Bernanke et al. (1999), making a simple extension by considering a government-guaranteed provision for firms' loans as a policy that aims to avoid the financial acceleration channel for the propagation of the crisis.

Firms decide on demand for capital in advance, at the beginning of the period, financing it through the equity investment from the households $S_{i,t}$ and borrowing the rest from the financial sector (external finance), $L_{i,t}$. Therefore:

$$Q_t K_{i,t} = L_{i,t} + S_{i,t} \tag{11}$$

where Q_t is the price of capital. Thus, the consumer's contribution to capital acquisition can be viewed as private-equity investment with possible gains/losses to be settled at the end of the period.

We consider that each firm is subject to idiosyncratic shocks $\omega_{i,t}$, which are not observed by the bank. The bank demands payment of the principal plus an interest rate. The entrepreneur pays the bank such an amount or declares bankruptcy. In the latter case, the bank incurs agency costs paying a proportion μ of firm payoff, i.e. $\mu\omega_i R_{t+1}^k Q_t K_{t+1i}$, where R_{t+1}^k is the aggregate return to capital.

Given the cost of capital purchase $Q_t K_{t+1i}$, the amount chosen for the loan $L_{t+1,i}$, and the aggregate return on capital R_{t+1}^k, the optimal contract can be characterized by

the loan interest rate $Z_{t+1,i}$ and the threshold value for the idiosyncratic shock $\bar{\omega}^j$, where when $\omega^j \geq \bar{\omega}_i$ the entrepreneur will be able to repay the loan, where $\bar{\omega}^j$ is defined by,

$$\bar{\omega}_i R^k_{t+1} Q_t K_{i,t+1} = Z_{i,t+1} L_{i,t+1} \tag{12}$$

We included in the Bernanke et al. (1999) model a government-guaranteed provision for firms' loans, where the government compromises to pay to the bank up to a share, ξ, of the firm debt in the case of default, compensating part of the loan risk. Therefore, part (or all) of the loan losses incurred if the borrower cannot repay would be covered by the government.

The realized values of ω_i lead to three possible situations for banks, depending on if it is greater than the threshold $\bar{\omega}_i$ when the firm can repay the bank entirely, or if it is greater than the threshold $\underline{\omega_i}$, when the government can fully compensate the losses by banks:

- When $\omega_i > \bar{\omega}_i$ the entrepreneur pays the loan and gets the difference, equal to $\omega_i R^k_{t+1} Q_t K_{t+1i} - Z_{t+1i} B_{t+1i}$.
- When $\underline{\omega_i} < \omega_i < \bar{\omega}_i$ the entrepreneur declares bankruptcy, and the bank pays the agency costs and gets to keep what it finds added to the difference payed by the government, which fully compensates the losses. That is, the financial intermediary receives $\bar{\omega}_i R^k_{t+1} Q_t K_{t+1i}$, and the entrepreneur receives nothing.
- When $\omega_i < \underline{\omega_i}$ the entrepreneur declares bankruptcy, the bank pays the agency cost, and gets to keep what it finds plus the guarantee payed by the government. That is, the financial intermediary receives $(1-\mu)\omega_i R^k_{t+1} Q_t K_{t+1i} + \xi \bar{\omega}_i R^k_{t+1} Q_t K_{t+1,i}$, and the entrepreneur receives nothing.

For simplicity we are considering perfect competition in the financial market, so that the values of $\bar{\omega}_i$, $\underline{\omega_i}$ and Z_{t+1i} under the optimal contract are determined by the requirement that the expected return received by the financial intermediary must equal the opportunity cost. Thus, the loan agreement must satisfy the condition:

$$\underbrace{\underbrace{[1-F(\underline{\omega_i})] Z_{i,t+1} L_{i,t+1}}_{\text{Return on Payed Loans}} + \underbrace{(1-\mu) \int_0^{\underline{\omega_i}} \omega R^k_{t+1} Q_t K_{i,t+1} dF(\omega) + F(\underline{\omega_i}) \xi Z_{i,t+1} L_{i,t+1}}_{\text{Return on Non-Payed Loans}}}_{\text{Gross Expected Return}} = R_{t+1} L_{i,t+1} \tag{13}$$

Considering that $(1-\xi)\bar{\omega} = \underline{\omega}$ and $\frac{L_i}{Q_t K_i} = \frac{\Upsilon - 1}{\Upsilon}$, where Υ is leverage, we can rearrange the previous equation to obtain:

$$\left\{\left[\int_{(1-\xi)\bar{\omega}_i}^{\infty} \bar{\omega}_i dF(\omega)\right] + (1-\mu)\left[\int_0^{(1-\xi)\bar{\omega}_i} \omega dF(\omega)\right] + \xi\left[\int_0^{(1-\xi)\bar{\omega}_i} \bar{\omega} dF(\omega)\right]\right\} = \frac{R_{t+1}}{R_{t+1}^k}\frac{\Upsilon - 1}{\Upsilon} \tag{14}$$

Thus, as the guarantee increases, i.e., higher ξ, the lower will be the $\underline{\omega_i}$ and so the government's policy of guaranteeing the loans of firms reduces the lending risk and also reduces the agency cost for bankruptcies, generating a lower Z_{t+1} in equilibrium.

Therefore, it is a clear relationship between the share of guarantees provided by the government, ξ, and the leverage rate allowed by the bank, Υ, so that, in this model, the government can always respond to adverse macroeconomic shocks in R^k with a compensation policy adjusting ξ, in order to keep the leverage rate unchanged, and neutralizing the financial accelerator channel during the crisis period.

Since the equations (11) to (14) have described how the state-contingent values of $\bar{\omega}_i$ and Z_i are determined in optimal contract, the firm determine his demand for capital maximizing its expected return.

Following the derivations directly from Bernanke et al. (1999) and as widely known in the subsequent literature, optimal capital purchases will be given by a function ψ, of the expected return on investment/return on a risk-free investment ratio:

$$Q_t K_{i,t} = \psi\left[\xi_t, E_{t-1}\left(s_t\right)\right] S_{i,t} \tag{15}$$

where $s_t = R_{t+1}^k / R_{t+1}$ is the expected discounted return to capital and $\psi'(\cdot) > 0$. The novelty here is the role of ξ_t, which affect the leverage and also reduces the magnitude of the financial accelerator, by smoothing the impact of changes in s_t.

1.2.4 The Banking Sector

When firm i does not default the bank is paid by the principal and the interest on the loan $(Z_t L_{i,t})$. Thus, the average transfer from firms to households, $\Pi_{t,h}$ is given by

$\Pi_{t,h} = P_t Y_t - w_t N_t + N_t T_t^N - Z_t L_t.$

The bank will receive $Z_t L_t$ from non defaulters and gets to keep what it finds plus the guarantee payed by the government, by defaulters. Consequently the average transfer to the bank, $\Pi_{t,b}$ will be given by:

$$\Pi_{t,b} = Y_t - w_t N_t + N_t T_t^N - \Pi_{t,h} \tag{16}$$

Banks are an intermediary that receives deposits from households, D_t, and lends them to companies, L_t, after complying with central bank regulation determinations:

$$L_t = \Theta_t D_t \tag{17}$$

where Θ_t is a bank regulation parameter imposed by the central bank. In this sense, we can interpret this parameter as a compulsory reserve deposit required by the central bank. Thus, the central bank can adjust the value of Θ_t as an instrument of macroprudential policy by controlling the expansion of liquidity in the banking system.

Assuming that banks transfer their profits to families as interest payments,

$$(1 + r_{d,t}) D_t = \Pi_{t,b} \tag{18}$$

1.2.5 Capital Producers

The capital goods production sector follows Christiano et al. (2005). The representative capital producer buys I_t of final goods each period and the non-depreciated capital $(1-\delta)K_{t-1}$. Non-depreciated capital is transformed into new capital at no additional cost, however the new investment I_t is subject to an adjustment cost $\Phi(I_t/I_{t-1})$, assuming that $\Phi(1) = \Phi'(1) = 0$. Therefore, the technology for capital production will be given by:

$$K_{t+1} = (1-\delta)K_t + \left(1 - \Phi\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \tag{19}$$

where δ is depreciation. The new capital is then sold in a perfectly competitive market, so the real price Q_t will be equal to the marginal cost of capital production. The first order conditions associated with capital and investment decisions, respectively, are as follows

$$Q_t = E_t\left[\left(\frac{1}{1+rr_{t+1}}\right)\left(Q_{t+1}(1-\delta)+\frac{(1-\alpha)Y_{t+1}}{K_{t+1}}\right)\right] \tag{20}$$

$$Q_t\Phi'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}} - E_t\left[Q_{t+1}\left(\frac{1}{1+R^k_{t+1}}\right)\Phi'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right]+1 = Q_t\left(1-\Phi\left(\frac{I_t}{I_{t-1}}\right)\right) \tag{21}$$

Equation 20 simply states that the value of installed capital, K_t, depends on the expected future value of capital, taking into account the depreciation rate and the expected future return on rental given by the the interest rate, r^k_{t+1}.

Equation 21 implicitly defines a demand function for investment. It states that the marginal benefit (in terms of the real value of capital) of investing one additional unit must equal its costs. Notice that if $I_t = I_{t-1}$ so that $\Psi(1) = 0$, the equation reduces to $Q_t = 1$. This means that in the absence of adjustment costs, Tobin's marginal Q should be equal to the replacement cost of installed capital measured in terms of the consumption good.

We assume the following functional form for Ψ, which is standard in the literature:

$$\Phi\left(\frac{I_t}{I_{t-1}}\right) = \frac{\psi}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2 \tag{22}$$

In short, introducing capital producers is a modeling tool to derive a market price for capital, which determines the value of firms' collateral against bank loans.

1.2.6 Policy Rules

We assume the government is composed of three institutions: the Central Bank, responsible for choosing the monetary policy; the Treasury, responsible for the fiscal policy; and a Ministry of Health, responsible for the lockdown policy.

1.2.6.1 Monetary Policy

We assume the Central Bank targets a zero inflation path for prices and desire not to deviate from the natural output (Y^n):

$$R_t^b = \frac{1}{\beta}\left(\frac{P_t}{P_{t-1}}\right)^{\phi_\pi}\left(\frac{Y_t}{Y^n}\right)^{\phi_Y} \tag{23}$$

where ϕ_π and ϕ_Y are the non-negative Taylor Rule feedback parameters, the term $1/\beta$ imposes the nominal interest rate to be equal the real interest rate in the steady-state

1.2.6.2 Fiscal Policy

The government has a target for the debt over annual GDP ($\bar{D}^{GDP}$). We designed the fiscal policy assuming that the government has a mandatory role in converging the debt to an exogenously defined level of debt over GDP. The fiscal adjustment can be made through revenue and expenses. The overall debt dynamics can be expressed by

$$D_t = D_{t-1}(rr_{t-1} - 1) + G_t^T + X_t^G - R_t \tag{24}$$

where the D_t is the total amount of public debt in real terms, $\bar{D}$ is the $\bar{D}^{GDP}$ multiplied by the GDP, and rr is the monetary policy rate in real terms.

In the expenses side, the G_t^T is the public spending not related to public investment; and it is divided in two components.

$$G_t^T = G_t^A + G_t^S \tag{25}$$

The first component is the autonomous spending, G_t^A. It can be read as the part of public spending unrelated to social transfers or COVID-19 related policy. It represents an exogenously defined fixed proportion α^{GX} of the tax collected by $T_t + \tau^t \sum_{j=(s,i,r)} W_t(j_t n_t^j)$.

G_t^A is subjected to the austerity policy. The Treasury decides if it will be used as part of the adjustment to guarantee the convergence to the target.

$$G_t^A = [T_t + \tau^t[\sum_{j=(s,i,r)} W_t(j_t n_t^j)]]\alpha^{GX} - \rho(D_{t-1} - \bar{D})\varphi^{GA} \tag{26}$$

The amount of resources available for the autonomous spending depends on the tax collected by $T_t + \tau^t \sum_{j=(s,i,r)} W_t(j_t n_t^j)$ and from the contribution for the austerity effort based on the deviation of debt in t-1 from the target $(D_{t-1} - \bar{D})$. The contribution will also depend on the coefficient that soften the adjustment (ρ) and the coefficient that sets the size of the contribution of this spending to the overall austerity plan (φ^{GA}). If $\varphi^{GA} = 0$, this spending is excluded from the austerity effort $(0 \geq \varphi^{GA} \geq 1)$. The second component (G_t^S) performs the social policy role. It accounts for the permanent cash transfer program to the Non-Ricardian household T_t^h; and for the COVID-19 outbreak-related policies ($T_t^{h-covid}$ and NT_t^N). G_t^S is also subjected to the austerity policy through cuts in the permanent cash transfer program.

$$G_t^S = T_t^h + T_t^{h-covid} + NT_t^N, \tag{27}$$

where

$$T_t^h = \bar{T^h} - \rho(D_{t-1} - \bar{D})\varphi^{Th} \tag{28}$$

The amount of resources available for the permanent cash transfer program depends on an exogenously defined value, $\bar{T^h}$, and a contribution for the austerity policy based on the deviation of debt in t-1 from the target $(D_{t-1} - \bar{D})$. Similar to the autonomous spending case, the contribution will depend on the coefficient that softens the adjustment (ρ) and the coefficient that sets the size of the contribution of this spending to the overall austerity plan (φ^{Th}). If $\varphi^{Th} = 0$, this policy is excluded from the austerity effort $(0 \geq \varphi^{Th} \geqq 1)$.

For the CoVID-19 related policies, the government transfers resources direct to Non-Ricardian households $(T_t^{h-covid})$ or to the Intermediate good producer (NT_t^N).In both cases, we considered that the resource would be conditional to the proportion of infected households in the population (i_{t-1}). So

$\mathrm{T}_t^{h-covid} = i_{t-1}\zeta^h$ where ζ^h is the parameter used to defined the amount to be transferred to households

$\mathrm{T}_t^N = i_{t-1}\zeta^N$ where ζ^N is the parameter used to defined the amount to be transferred to intermediate goods producer.

Finally, the public investment (X_t^G) uses the remaining portion (1- α^{GX}) of the tax collected by $T_t + \tau^t \sum_{j=(s,i,r)} W_t(j_t n_t^j)$. X_t^G is also subjected to the austerity policy. As in other expenses, the contribution of public investment to the austerity policy will depend on the coefficient that softens the adjustment (ρ) and on the coefficient that sets the size of the contribution of this spending to the overall austerity plan (φ^X)

$$X_t^G = (T_t + \tau^t) \sum_{j=(s,i,r)} W_t(j_t n_t^j))(1 - \alpha^{GX}) - \rho(D_{t-1} - \bar{D})\varphi^X \tag{29}$$

On the revenue side (R_t), the government can be funded in three forms.

$$R_t = T_t + \tau^t \sum_{j=(s,i,r)} W_t(j_t n_t^j) + T_t^{adj} \tag{30}$$

First, a lump sum tax (T_t) is calibrated to obtain a specific level of public revenue as a percentage of GDP, similar to Eichenbaum et al. (2020a). Second, an income tax only applied to the Ricardian households ($\tau^t \sum_{j=(s,i,r)} W_t(j_t n_t^j)$). Third, another lump-sum tax, (T_t^{adj}), is used to fund the permanent cash transfer program, to finance the interest burden, as well as for austerity purposes. As in the expenses side, T_t^{adj} considers the deviation of the debt to its target over time.

$$T_t^{adj} = D_{t-1}(rr_{t-1} - 1) + T_t^h + \rho(D_{t-1} - \bar{D})(1 - \varphi^{Th} - \varphi^{GA} - \varphi^X) \tag{31}$$

In absence of other austerity measures ($\varphi^{Th} = 0$, $\varphi^{GA} = 0$, and $\varphi^X = 0$), T_t^{adj} guarantees the debt convergence to the target overtime via revenues. The size of T_t^{adj} is subjected to the coefficient that soften the adjustment (ρ).

1.2.6.3 Health Policy

The Ministry of Health can decide to lockdown a fraction θ_t of workers to slow down the spread of the virus. We assume that the lockdown is only partially effective in eliminating the transmission of the virus since a substantial part of virus transmissions are not the result of economic activity, as highlighted by Ferguson et al. (2006).

We assume the health authority react to the number of infections to decide the value of θ at each period of time:

$$\theta_t = \phi_I I_{t-1} \tag{32}$$

At the beginning of the epidemic, there are a large number of susceptibles. Consequently, the number of infections increases abruptly, leading to a strong reaction of health authority increasing θ_t, and, after some months, the increase in the number of recovered reduces the infections rate, implying a reduction in the value of θ_t.

Since monetary and fiscal policies stimulate economic activity, all the economic and epidemiological dynamics will depend on the adopted economic policies and monetary, fiscal, and lockdown reaction parameters.

1.2.7 Equilibrium Conditions

In the model, a competitive equilibrium is defined as a sequence of prices and wages, allocations such that

- Households maximizes lifetime utility, subject to the budget constraint, and the equations that govern the health status of the household's members;
- Firms maximize profit subject to the resource constraint;
- The Central Bank abides by the Taylor rule;

- The Treasury abides by the fiscal rule;
- The Ministry of Health abides by the lockdown rule;
- The labor and good markets clear.

Regarding the last item, the market clearing in the goods market requires:

$$AK_t^{1-\alpha}(N_t(1-\theta_t))^\alpha = C_t + X_t - FE_t \tag{33}$$

where FE_t is the fiscal effort in period t, defined as $FE_t = s_t - \overline{s}$, and K_t is the aggregate supply of capital,

$$K_t = k_t$$

and C_t and X_t are aggregate consumption and investment, respectively. These variables are given by:

$$C_t = \sum_{j=(s,i,r)} j_t c_t^j$$

$$X_t = x_t$$

The law of motion for the aggregate capital stock is:

$$K_{t+1} = X_t + (1-\delta)K_t$$

Since the two types of households have different dynamics of contamination in response to each decision on consuming and working, the population in each health status will be the sum of health status in each household type

$$S_t = (1-\lambda^{NR})s_t^R + \lambda^{NR} s_t^{NR}$$

$$I_t = (1-\lambda^{NR})i_t^P R + \lambda^{NR} i_t^{NR}$$

$$R_t = (1-\lambda^{NR})r_t^R + \lambda^{NR} r_t^{NR}$$

1.3 DATA AND CALIBRATION

As in Eichenbaum et al. (2020b) we have calibrated the model considering each period as a week. To facilitate the reading, we decided to keep most parameters in the table with the annual figure divided by 52 (weeks). Also, we kept the assumption of two weeks for an infected household to recover or to die. For mortality rate, we kept the assumption from Eichenbaum et al. (2020b) of 0.2 percent based on South Korea data for people younger than 65 years old. The country had an intensive testing policy and tracking, (HASELL et al., 2020) diminishing the changes bias in the calculation.

For the transmission parameters (π_1^h,π_2^h and π_3^h), we have calibrated all to reflect the same probability of contamination for both types of household at the beginning of the pandemic. Again, we have used Eichenbaum et al. (2020b) as reference for the probabilities. The authors considered probability of 1/6 for π_1 and π_2 and 2/3 for π_3. For the Ricardian Household, we have set π_1^R at $1.9701e^{-7}$, π_2^R at $1.5936e^{-4}$ and π_3^R at 0.4997. For the same probability, the Non- Ricardian household requires different value for π_1. We have set π_1^{NR} at $6.1393e^{-7}$, π_2^{NR} at $1.9701e^{-7}$ and π_3^{NR} at 0.4997. This difference is explained by the fact that each household type have different value of consumption in steady state:

$$\frac{\pi_1^h (C^h)^2}{\pi_1^h (C^h)^2 + \pi_2^h N^2 + \pi_3^h} = 1/6$$

$$\frac{\pi_2^h N^2}{\pi_1^h (C^h)^2 + \pi_2^h N^2 + \pi_3^h} = 1/6$$

For the population size, we normalized the pre-covid steady-state as one. This population is divided into two types of households according to λ^{NR}. We decided to set λ^{NR} at 0.33, following Kaplan et al. (2014). The authors have estimated that about 33% of the households can be considered Non-Ricardian, in the US. Campbell e Mankiw (1989) estimated λ^{NR} at 0.5 based on data for the US pre-1990. Coenen e Straub (2005) found a posterior mean of λ^{NR} between 0.246 and 0.370 when estimating different models using Bayesian techniques for the Euro area. Casto et al. (2011) calibrates λ^{NR} at 0.40, which

represents, for the case of Brazil, all households that receive up to 2.5 minimum wages an approximation for the non-Ricardian population.

For fiscal policy, on revenues, we calibrated the income tax parameter (τ^t) and lump sum (T_t). For the labor income tax (τ^t), we considered 30 percent of labor income, in line with the cost of labor in the US following OECD (2018). For the lump-sum (T_t), we assumed the equivalent to 2 percent of GDP. With that, in steady-state, we reach fiscal revenues of about 24% of GDP in line with OECD (2018) calculation.

On the spending side, we have calibrated the parameters to reach government participation of GDP similar to Eichenbaum et al. (2020b). The authors imposed government participation of 19 percent of overall GDP in a steady state. Within spending, the permanent cash transfer $\bar{T}$ was set at 150, which translates to 5% of GDP in cash benefits policies, in line with OECD (2019). We also calibrated the two policy tools for the government to assist households and the intermediate goods sector while the pandemic is evolving. Both policies are linked to the overall percentage of the infected population. In the simulation considering only households' assistance, we calibrated ζ^h from 0 to 3500, while in the simulation considering only intermediate goods sector assistance, we calibrated ζ^N from 0 to 100.

For the fiscal adjustment after the shock, we have implemented two parameters to change the speed and timing of the fiscal consolidation. The ρ sets the pace of the adjustment. For any time t, when $\rho = [0 : 1]$, the impact of any divergence between debt and debt target will only partially affect the fiscal policy in time t. When $\rho = 1$, for instance, the lump-sum, T^{adj}, will have to incorporate the entire difference between the debt and debt target in time t. Finally, when $\rho = 0$, the lump-sum will be calculated without considering the gap between debt and debt target. The second parameter related to fiscal adjustment was implemented to partially postpone the adjustment while in the pandemic. It links the percentage of the infected population and the fiscal adjustment. The idea behind this parameter is to partially prevent the fiscal consolidation from happening while the infection is impacting the population.

Table 1.1 – Parameters

Parameters	Value	Description	Source
β	0.98/52	Weekly household discount factor	Eichenbaum et al. (2020a)
α	0.66	Labor share	Eichenbaum et al. (2020a)
δ	0.06/52	Capital depreciation rate (weekly)	Eichenbaum et al. (2020a)
ξ	0.98	Calvo price stickiness (weekly)	Eichenbaum et al. (2020a)
Y_{ss}	1115	Calibration target for weekly GDP	Eichenbaum et al. (2020a)
n_{ss}	28	Calibration target for weekly hours	Eichenbaum et al. (2020a)
rpi	1.5	Taylor rule coefficient inflation	Eichenbaum et al. (2020a)
rx	0.5/52	Taylor rule coefficient output gap	Eichenbaum et al. (2020a)
δ^{MP}	0.98	Taylor rule smoothing parameter	Our assumption
γ	1.35	Steady state gross price markup	Eichenbaum et al. (2020a)
$\bar{D}^{GDP}$	106%	Debt to GDP ratio before the pandemic	U.S. Office of Management and Budget and Federal Reserve Bank of St. Louis
τ_n	30%	Income tax (% of income)	OECD (2021)
η	2%	Exogenous spending as % of GDP	Based on Eichenbaum et al. (2020a)
λ^{NR}	33%	Non-Ricardian share of households	Kaplan et al (2014)
ψ	3.00	Parameter for investment adjustment cost	
α^{GX}	3%	% of government spending in public investment	OECD (2021)
α_G	80%	% of private consumption at Effective Consumption	Simms and Wolf (2017)
υ_G	1.1	Parameter of CES Utility function	Our assumption
T^h	150	Value of permanent cash transfer to Non-Ricardian HH	Our assumption
π^r	0.499	Weekly probability of recovering	Eichenbaum et al. (2020a)
π^d	0.001	Weekly probability of dying	Eichenbaum et al. (2020a)

Source: Produced by the author

Table 1.2 – Parameters for Lockdown

Parameters	Value	Description
κ	[0:5]	Multiplicative lockdown parameter
κ^{pw}	[1:3]	Exponential lockdown parameter

Source: Produced by the author

Table 1.3 – Parameters for Government assistance

Parameters	Value	Description
ζ^h	[0:3500]	Parameter for household assistance
ζ^N	[1:100]	Parameter for intermediate goods producer assistance

Source: Produced by the author

Table 1.4 – Parameters Fiscal adjustment

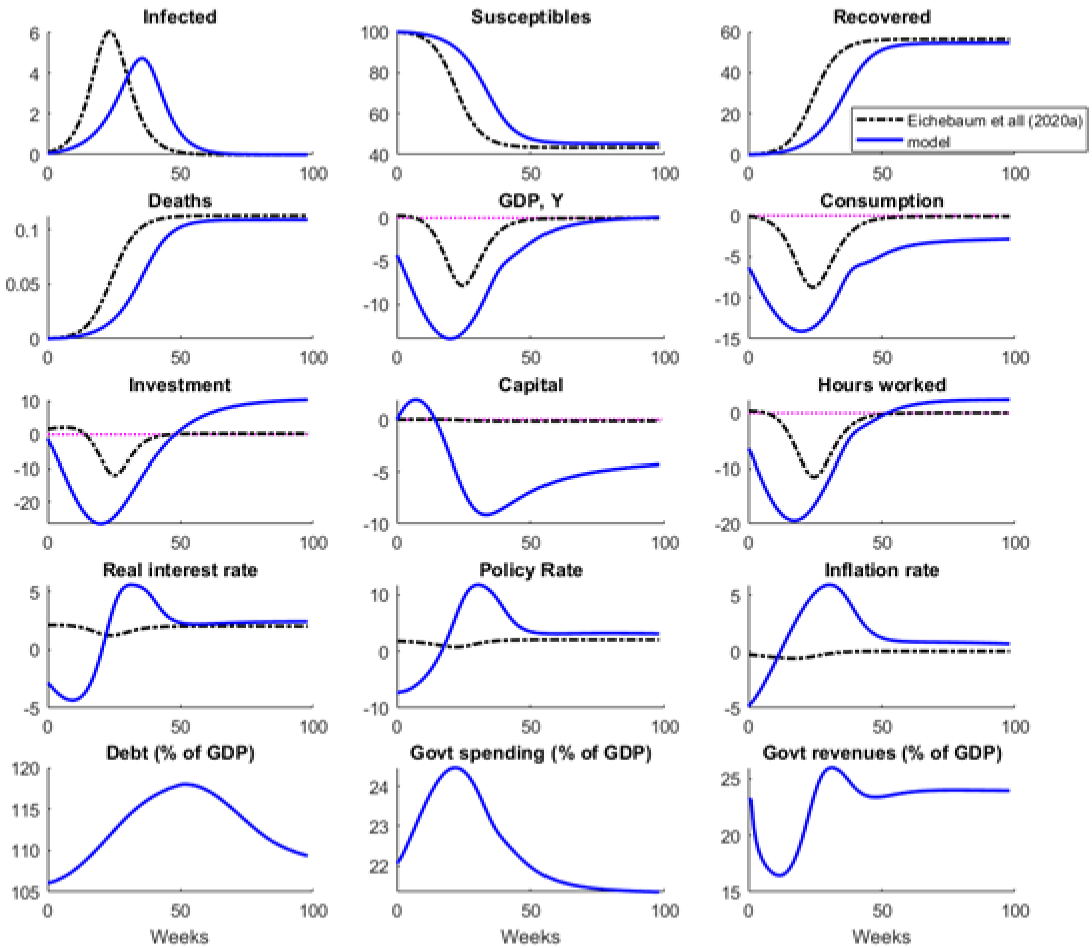
Parameters	Value	Description
φ^{G^A	[0:1]	% of the fiscal adjustment by cutting public consumption
φ^X	[0:1]	% of the fiscal adjustment by cutting public investment
φ^{Th}	[0:1]	% of the fiscal adjustment by cutting public transfer to households
ρ	[0:1]	Smooths the fiscal adjustment
ρ^I	[0:30]	Smooths the fiscal adjustment during the pandemic

Source: Produced by the author

1.4 RESULTS

The figure 1.5 shows the different dynamic of our model when compared to Eichenbaum et al. (2020b) for selected variables. The result suggests more volatility when assuming no fiscal or guarantee policy in place.

Figure 1.5 – Eichenbaum et all (2020a) and model without policies



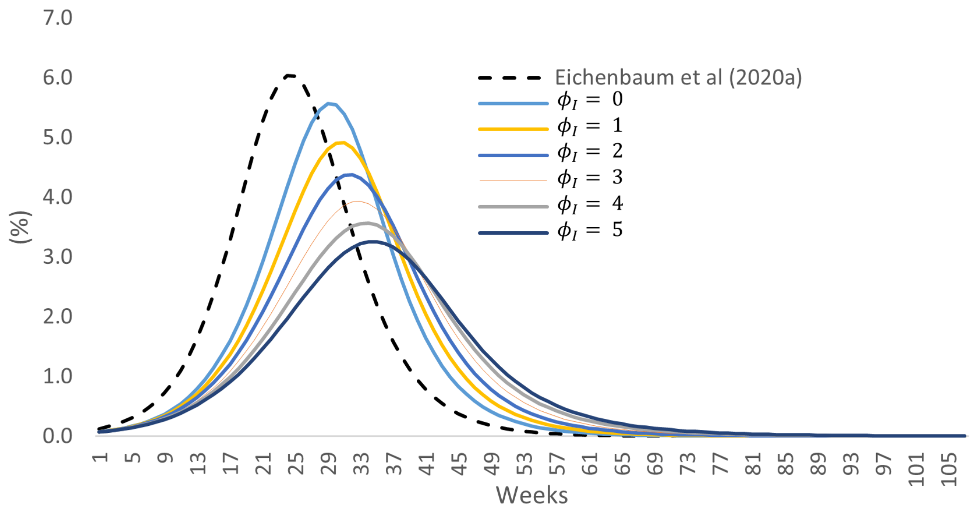
Source: Eichenbaum et all (2020a). Produced by the author

1.4.1 Effects of Lockdown Policies

The experiences of lockdown indicate that the policy tends to be endogenous and related to the stage of contamination (ANSAH et al., 2020). To reproduce such stylized fact, we have conditioned the strictness of the lockdown policy to i in $\theta_t = \phi_I I_t$

When we simulate different lockdown scenarios, the model confirms the expected result of a lower peak of contamination and indicates a long-lasting epidemic. When $\phi_I = 5$, the peak of the epidemic lowers to 3% of the population at week 35. This is compared to 6% of the population in Eichenbaum et al. (2020b) at week 25 and a peak of 5.5% in our model when $\phi_I = 0$. See figure 1.6 below.

Figure 1.6 – Sensitiveness of infection curve to several strictness factor ϕ_I

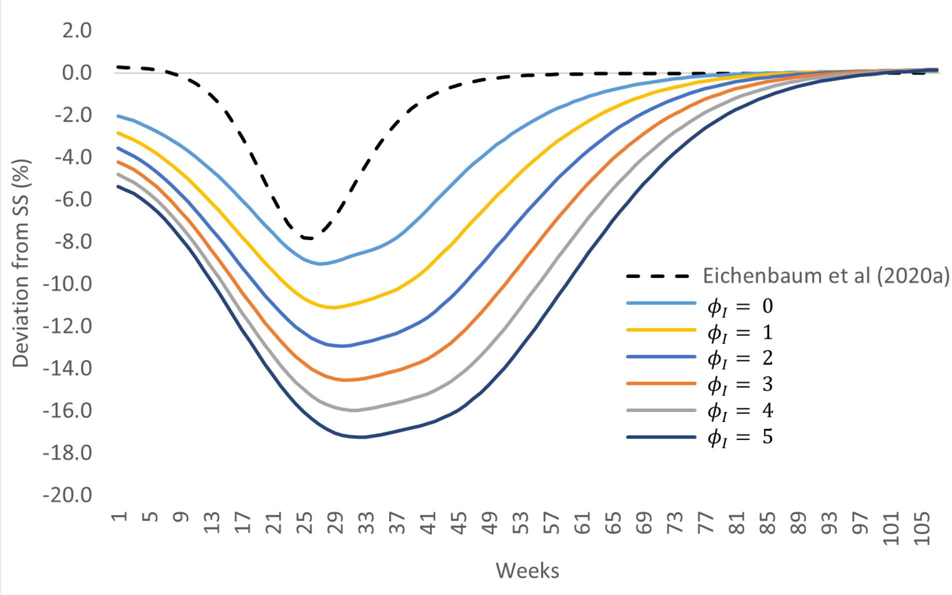


Source: Produced by the author

As a consequence of different lockdown scenarios, the GDP also contracts when not helped by any policy. According to our simulations, in the extreme case of $\phi_I = 5$, the GDP would reach almost 18% below the pre-epidemic levels before starting to recover. This is compared to the trough of 8% below pre-epidemic levels when $\phi_I = 0$. See figure 1.7 below.

The long-lasting recovery process also affects the fiscal policy through denominator and nominator effects. Assuming a pre-pandemic level of debt-to-GDP ratio of 106% and assuming no fiscal policy to fight the effects of the epidemic, the debt ratio reaches 125% of GDP when $\phi_I = 5$, not returning to the pre-epidemic level in the two years horizon (figure 1.8). In our simulation, when assuming $\phi_I = 5$, the debt ratio would converge to

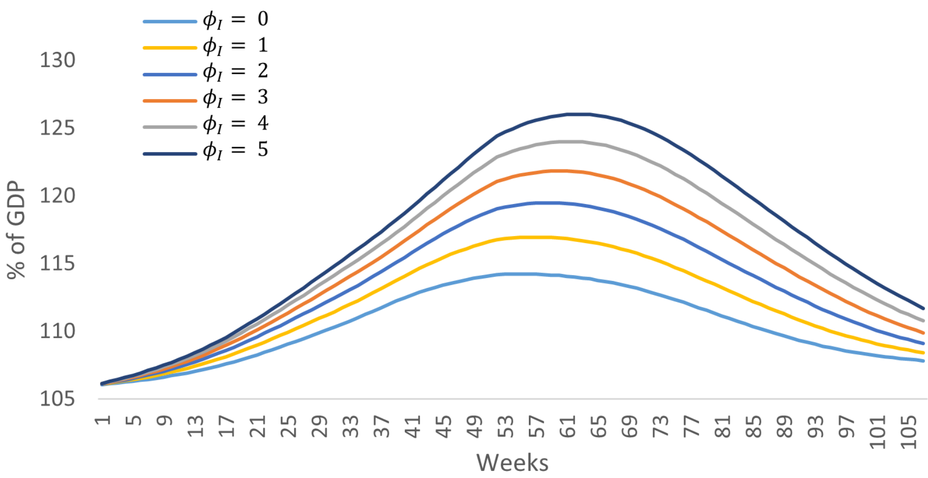
Figure 1.7 – Sensitiveness of GDP to several strictness factor ϕ_I



Source: Produced by the author

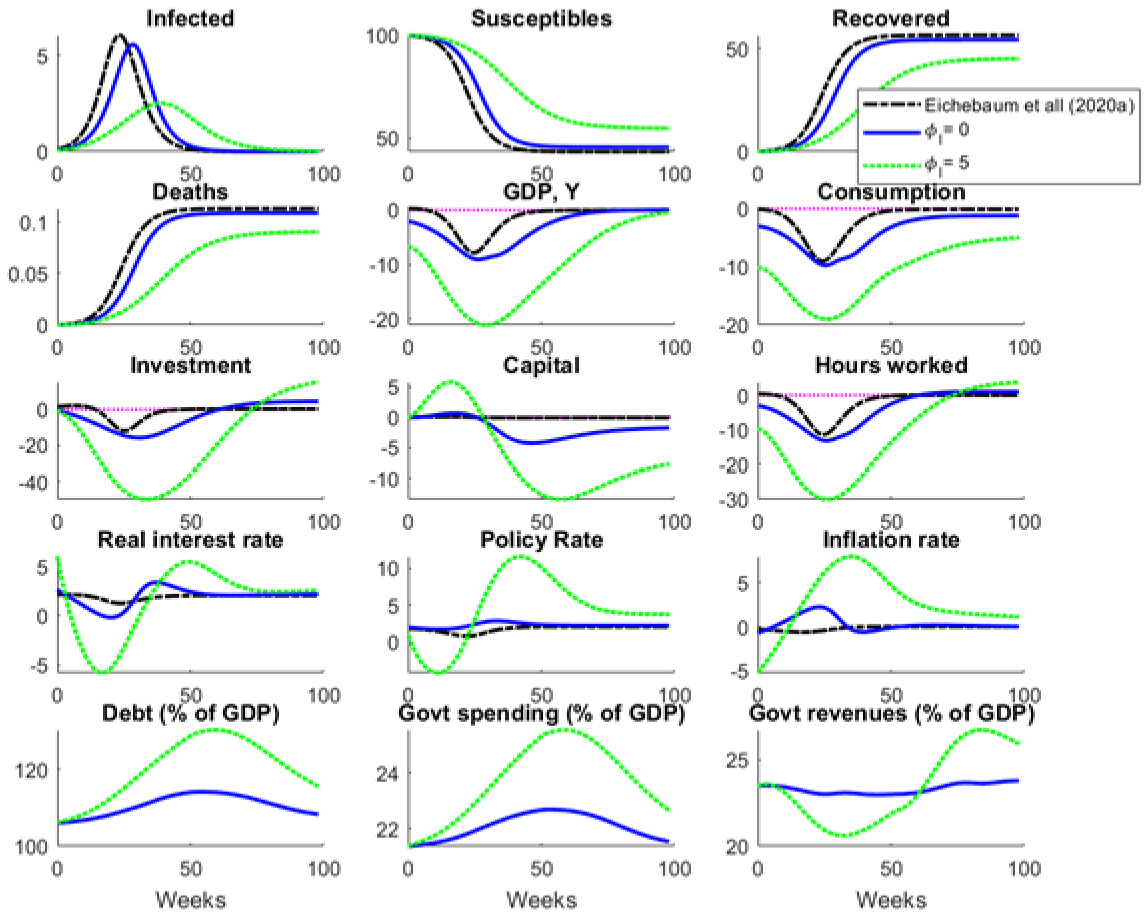
the pre-epidemic level only after three hundred weeks or almost six years. This is compared to about one hundred and fifty weeks or about three years when $\phi_I = 0$.

Figure 1.8 – Sensitiveness of Debt (% of GDP) to several strictness factor ϕ_I



Source: Produced by the author

Figure 1.9 – Eichenbaum et all (2020a) and model without policies and with lockdown Policy



Source: Eichenbaum et all (2020a). Produced by the author

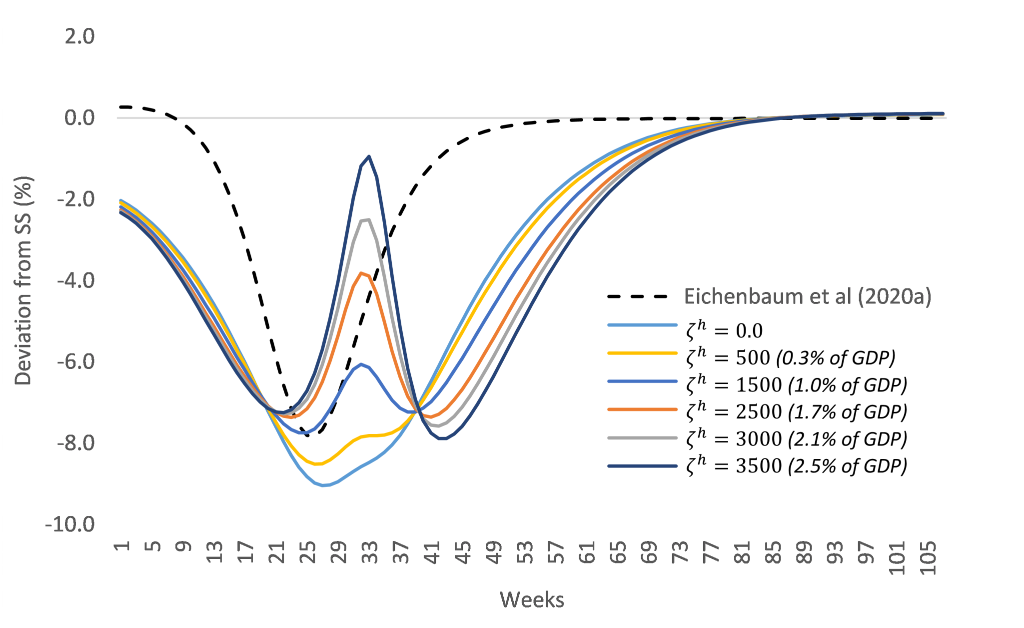
1.5 FISCAL POLICIES

We simulated scenarios for the endogenous fiscal policies to fight the economic effects of the epidemics assuming no extra effect from lockdown policies ($\phi_I = 0$). For each scenario, we calculated the cumulated fiscal impact as % of annual GDP.

1.5.1 Social Protection

The epidemic-related cash transfer to Non-Ricardian, or social protection policy, can compensate or even extrapolate the effects of the epidemics. When we simulate different scenarios for the social protection policy, our model indicates that in an extreme case of $\zeta^h = 7500$ at $T_t^{h-covid} = i_{t-1}\zeta^h$, the policy can push the GDP above the steady-state level. In such a scenario, the monetary policy would act to bring GDP back to the steady-state level. Also, consumption would be the main driver of recovery within components, while investments would take longer to recover.

Figure 1.10 – Sensitiveness of GDP to social protection

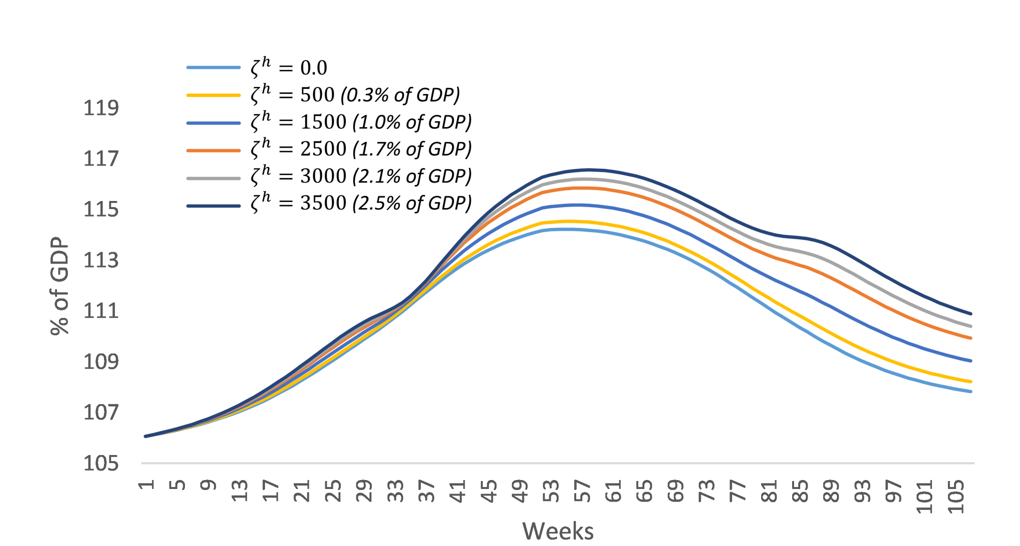


Source: Produced by the author

When assuming $\zeta^h = 3500$, the cash transfer would anticipate the recovery of the GDP to the pre-epidemic in about 20 weeks. In such scenario, the GDP would recover in about 30 weeks, compared to about 50 weeks in the scenario without fiscal policy. (figure 1.10).

To fight the epidemic with a cash transfer to Non-Ricardian has expected fiscal costs. When $\zeta^h = 3500$, the total fiscal cost was 2.5% of GDP. Since $T_t^{h-covid}$ is a function of i_{t-1}, once the epidemic decelerates, the fiscal impulse fades, and the more long-lasting investment contraction effect prevails, and the GDP returns to the negative camp. According to our calculation, still assuming $\zeta^h = 3500$, the debt-to-GDP ratio reaches about 117% of GDP before starting to fall. The debt ratio only converges to the pre-epidemic level after more than four hundred weeks or more than nine years.

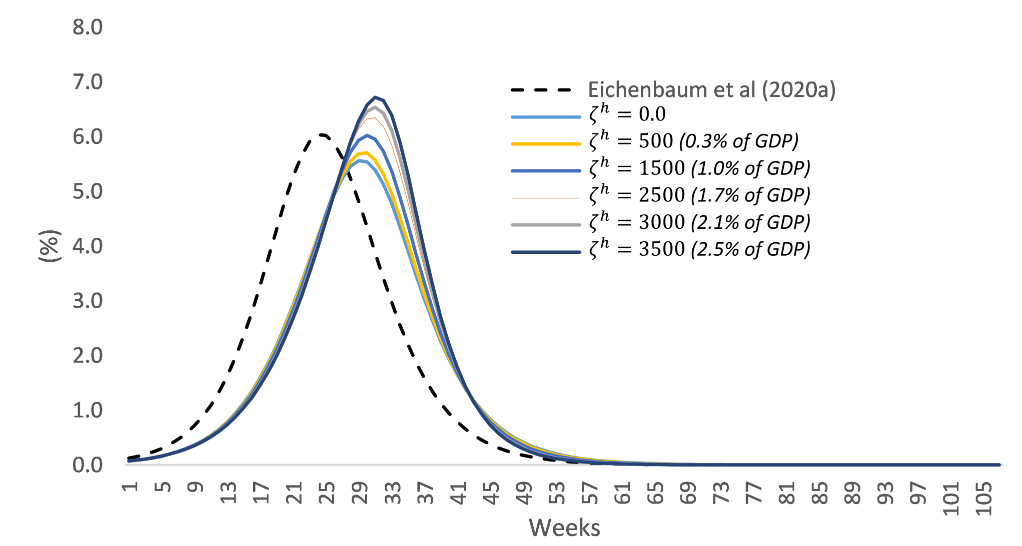
Figure 1.11 – Sensitiveness of Debt (% of GDP) to social protection



Source: Produced by the author

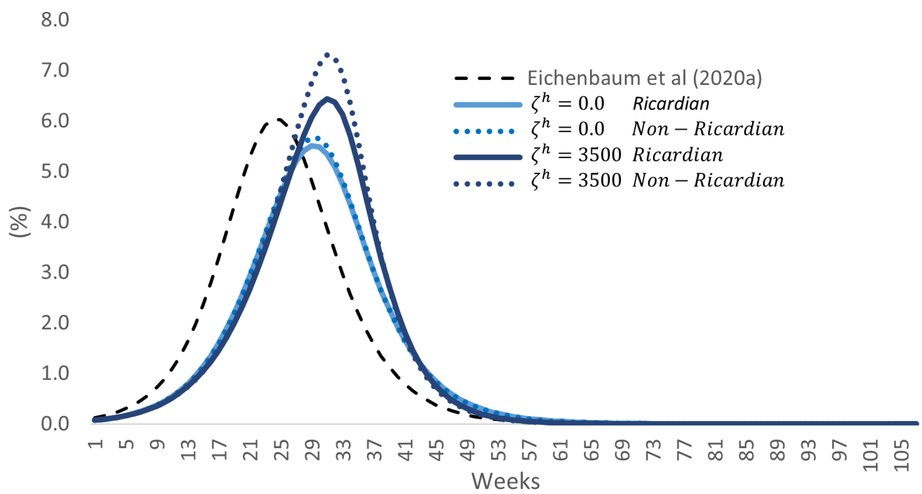
The side effect of the cash transfer to the Non-Ricardian household is to have a later but higher peak of infection. Our simulations show, as the expected, a higher peak of contamination when compared to the base case ($\zeta^h = 0$). When $\zeta^h = 3500$. the peak of the epidemic reaches 7.0% of the population at week 33. This is compared to 6% of the population in Eichenbaum et al. (2020b) at week 25 and peak of 5.5% in our model when $\zeta^h = 0$ (figure 1.12). When we breakdown the infection curve by household type, it is possible to observe an heterogeneity. Non-Ricardian households reach higher peak of contamination when compared to Ricardian household (figure 1.13).

Figure 1.12 – Sensitiveness infection curve to social protection



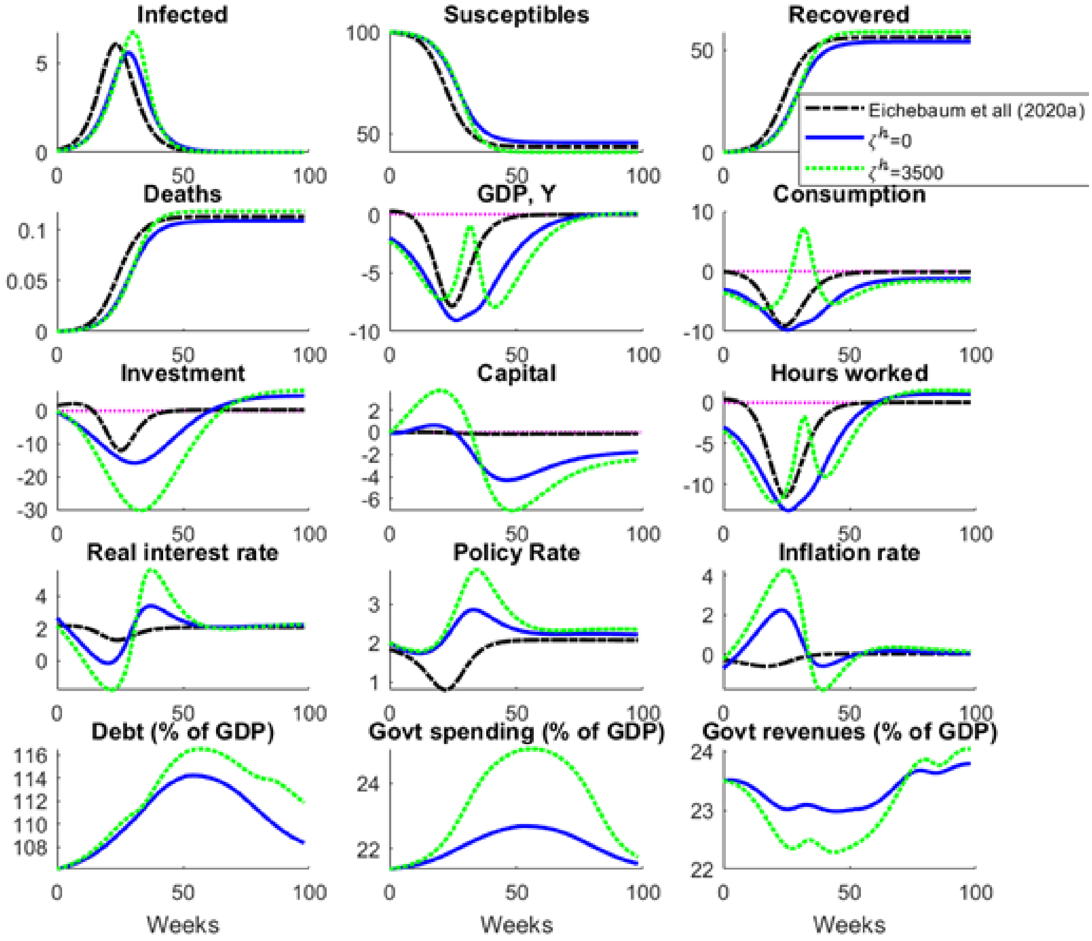
Source: Produced by the author

Figure 1.13 – Sensitiveness of the infection curve by household type to social protection



Source: Produced by the author

Figure 1.14 – Eichenbaum et all (2020a) and model without policies and with social protection policy



Source: Eichenbaum et all (2020a). Produced by the author

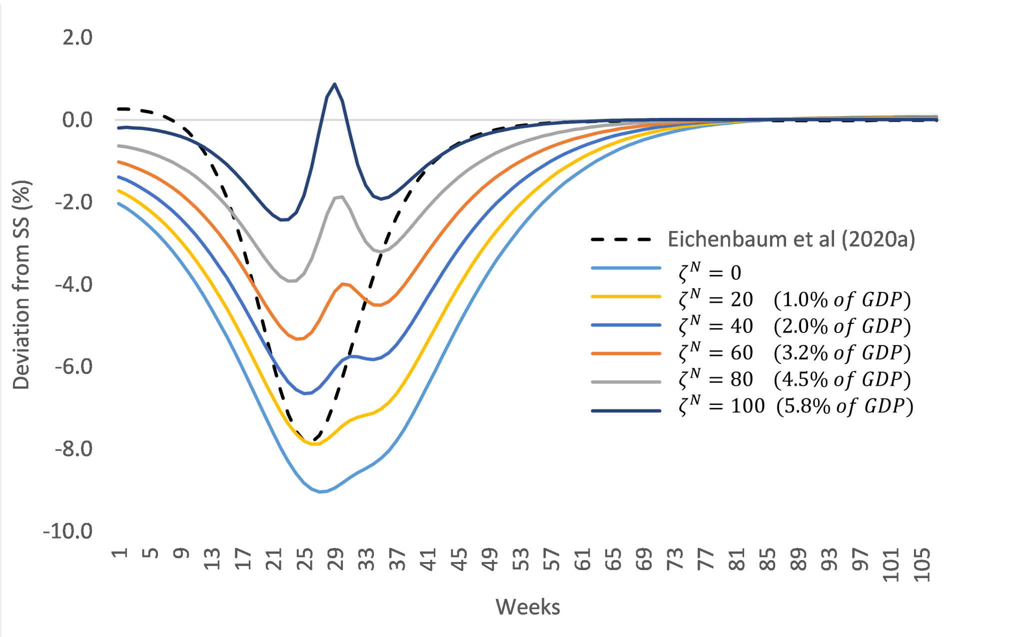
1.5.2 Employment Protection

The epidemic-related cash transfer to intermediate goods producers or employment protection policy can also compensate for the effects of the epidemics. When we simulate different scenarios, our model indicates that in an extreme case of $\zeta^N = 100$ at $T_t^N = i_{t-1}\zeta^N$, the policy can push the GDP above the steady-state level. In such a scenario, the monetary policy would act to bring GDP back to the steady-state level.

Unlike the cash transfer to Non-Ricardian households, investments would not be particularly penalized since this type of transfer would lower the overall marginal cost of the producer of the intermediate goods.

When assuming $\zeta^N = 100$, the cash transfer to the producers would smooth most of the epidemic impact on GDP. In such scenario, the GDP would recover in about 30 weeks, compared to about 50 weeks in the scenario without fiscal policy. (figure 1.15)

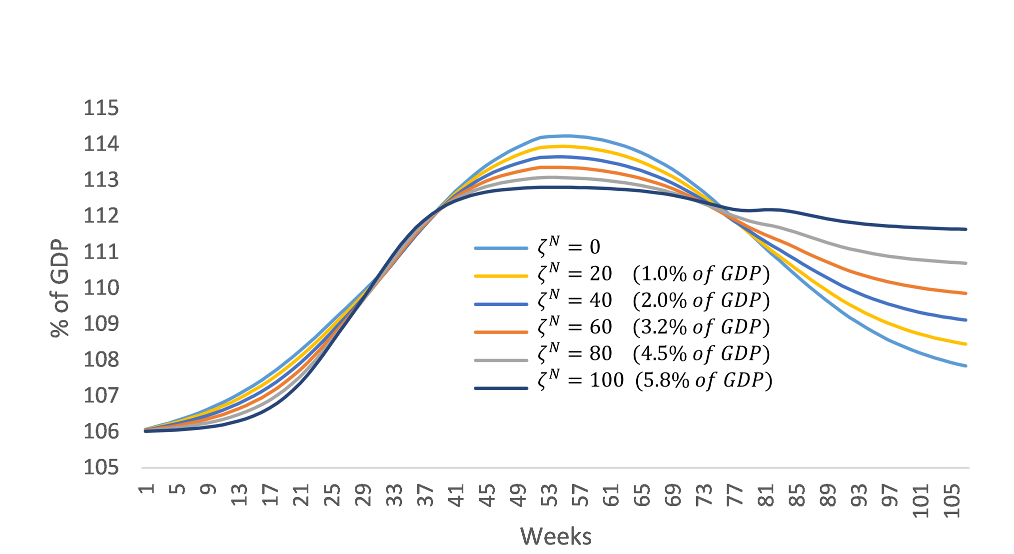
Figure 1.15 – Sensitiveness of GDP to employment protection



Source: Produced by the author

In fiscal policy terms, the cash transfer to intermediate goods producers has higher costs but limited impact over the debt-to-GDP ratio due to the more substantial fiscal multiplier. When $\zeta^N = 100$, the total fiscal cost 5.5% of GDP, while the debt-to-GDP ratio reaches about 113% of GDP before starting to fall.

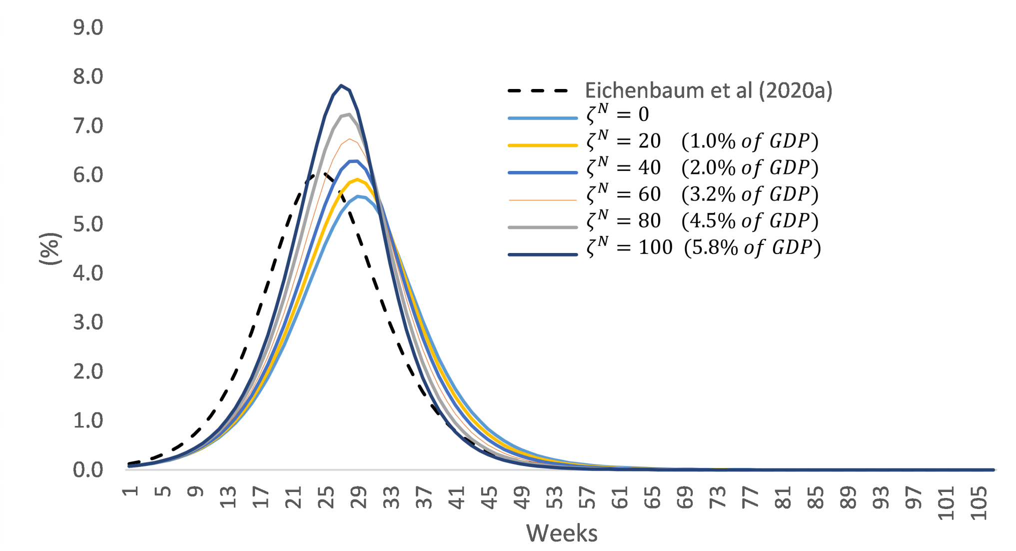
Figure 1.16 – Sensitiveness of Debt (% of GDP) to employment protection



Source: Produced by the author

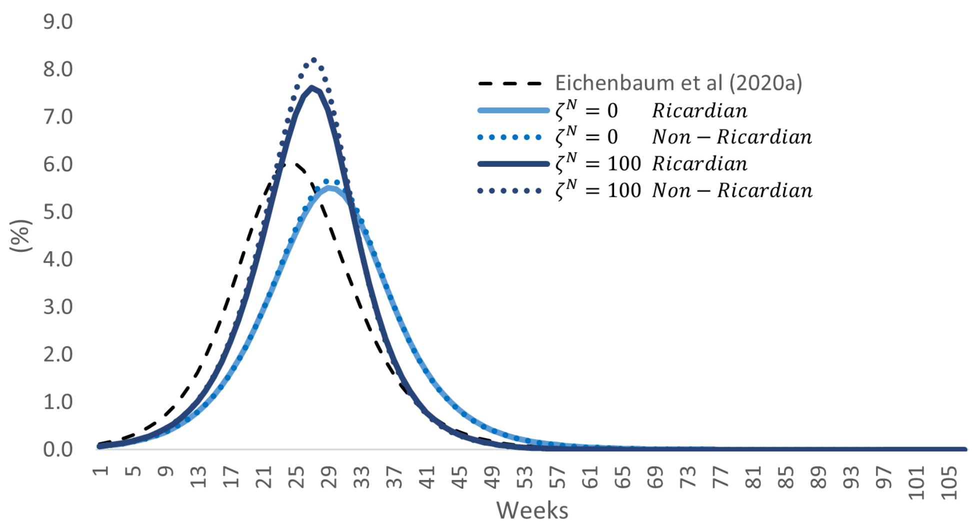
Similar to the cash transfer to Non-Ricardian households, the side effect of the fiscal policy is to cause a higher peak of infection, but now earlier than the base case, instead of later. Our simulations show, as the expected, a higher peak of contamination when compared to the base case ($\zeta^N = 0$). But this time, when $\zeta^N = 100$, the peak of the epidemic reaches 8.0% of the population at week 29. This is compared to 6% of the population in Eichenbaum et al. (2020b) at week 25 and peak of 5.5% in our model when $\zeta^N = 0$ (figure 1.17). When we breakdown the infection curve by household type, it is possible to smaller heterogeneity. Non-Ricardian households reach similar peak of contamination when compared to Ricardian household (figure 1.13).

Figure 1.17 – Sensitiveness infection curve to employment protection



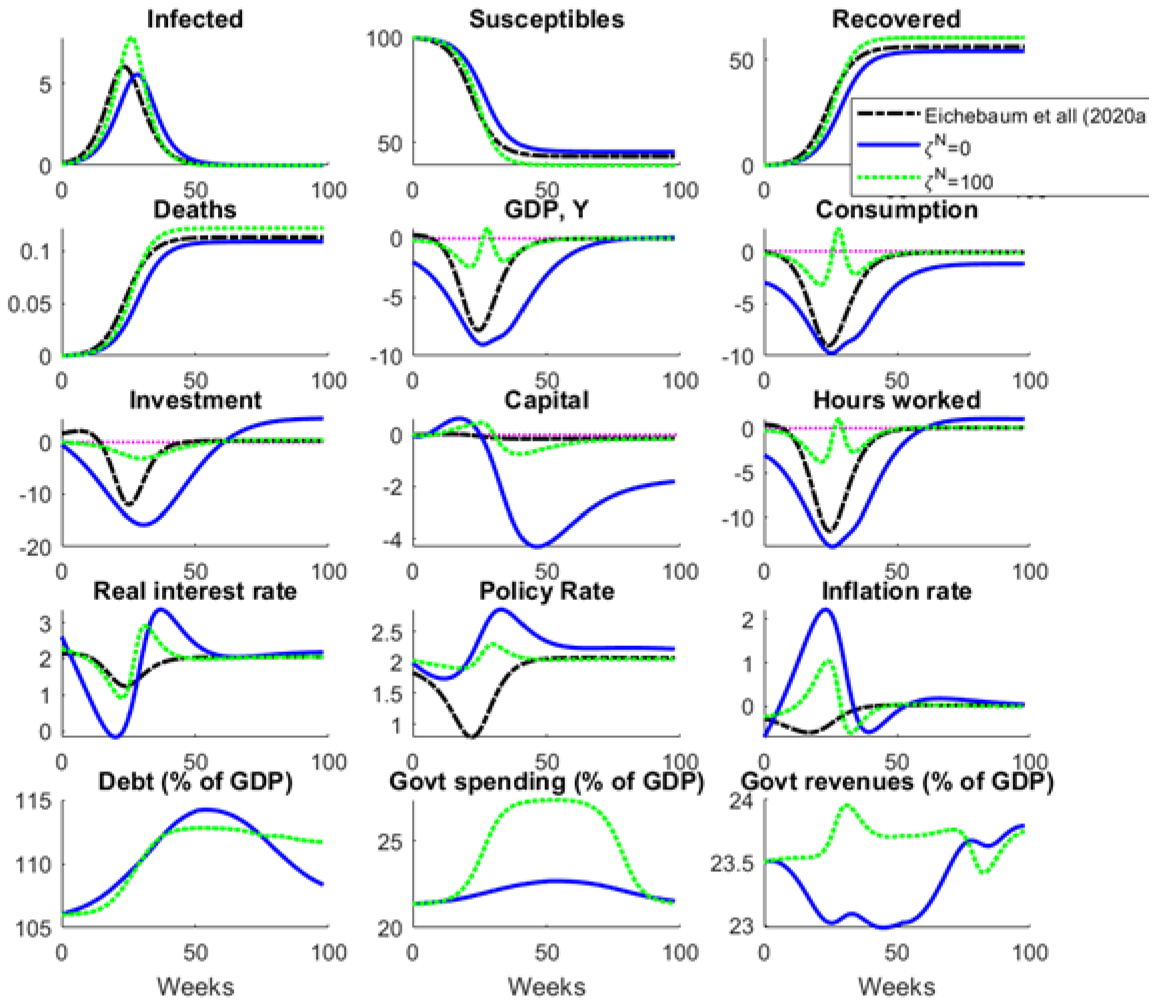
Source: Produced by the author

Figure 1.18 – Sensitiveness of the infection curve by household type to employment protection



Source: Produced by the author

Figure 1.19 – Eichenbaum et all (2020a) and model without policies and with employment protection policy



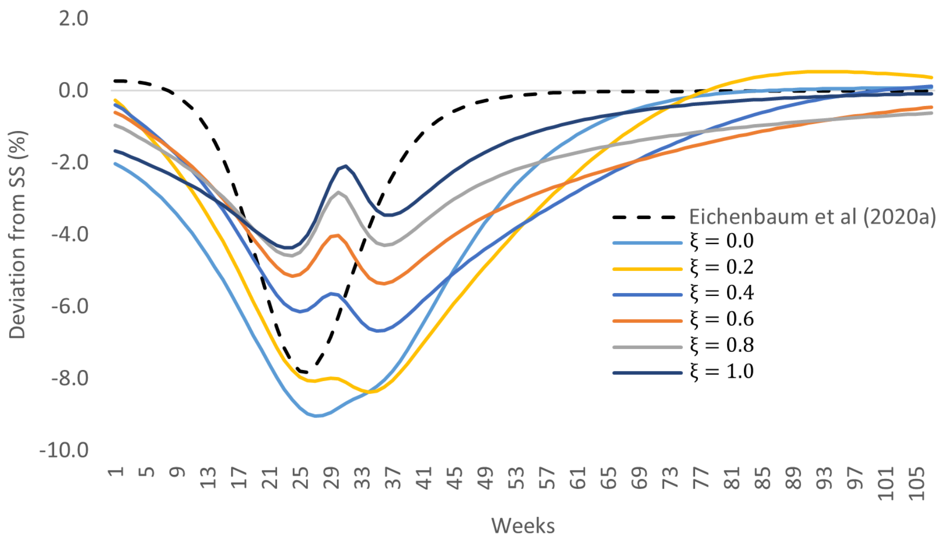
Source: Eichenbaum et all (2020a). Produced by the author

1.5.3 Government Guarantees Policy

The government guarantees to finance the capital also plays a role as a stabilizer as expected with not direct fiscal cost. Unlike the other policies, we considered this policy independent of the pandemic (not related to the epidemic stage). When we simulate different scenarios (figure 1.20), our model indicates that in an extreme case of $\xi = 1$, meaning the government guaranteeing 100% of demand for loans, the policy would smooth the overall impact of the pandemic, but would not prevent the economy from contracting. In such a scenario, the trough in terms of distance of GDP to pre-epidemic levels would be -4.0%. This is compared to -9.0'%, when $\xi = 0$, our base case scenario (without any

policy applied).

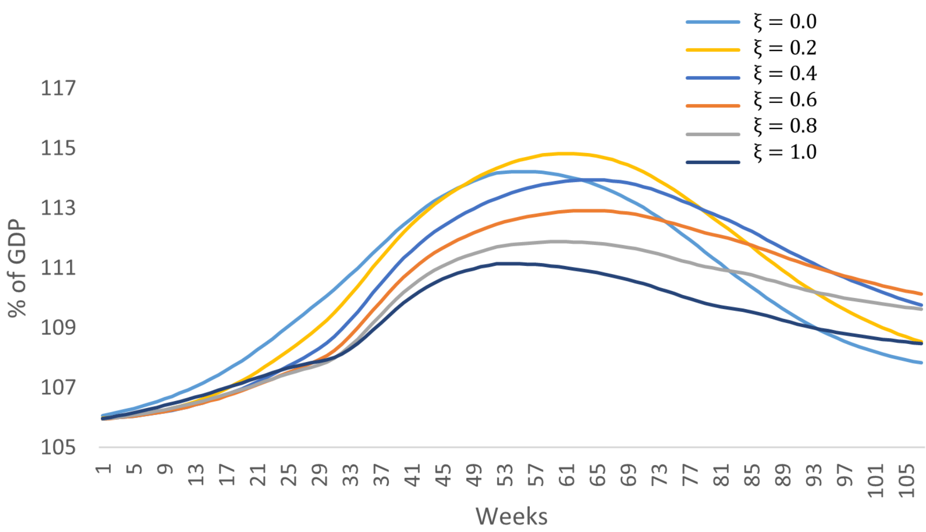
Figure 1.20 – Sensitiveness of GDP to different levels of Government guarantees



Source: Produced by the author

In fiscal policy terms, the government guarantees have their cost transferred through lump sum to the economy, so the debt-to-GDP ratio increases mainly due to the denominator effect and indirect negative effects in fiscal revenues. As consequence, under this policy, the extreme case of $\xi = 1$ causes the smaller increase in the debt-to-GDP ratio (peaking at 111% of GDP, compared to 114% when $\xi = 0$).

Figure 1.21 – Sensitiveness of Debt (% of GDP) to different levels of Government guarantees

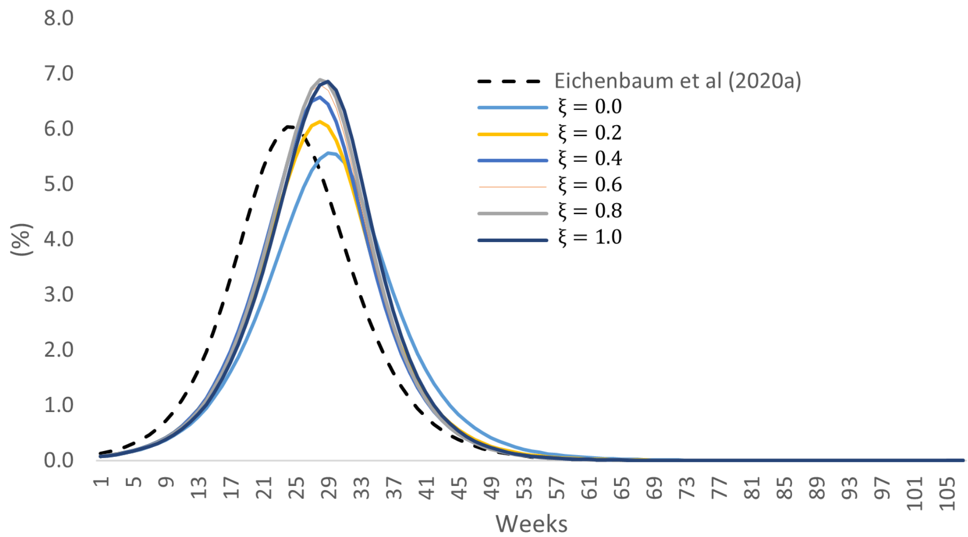


Source: Produced by the author

Similar to both cash transfer policies, the side effect of the government guarantee

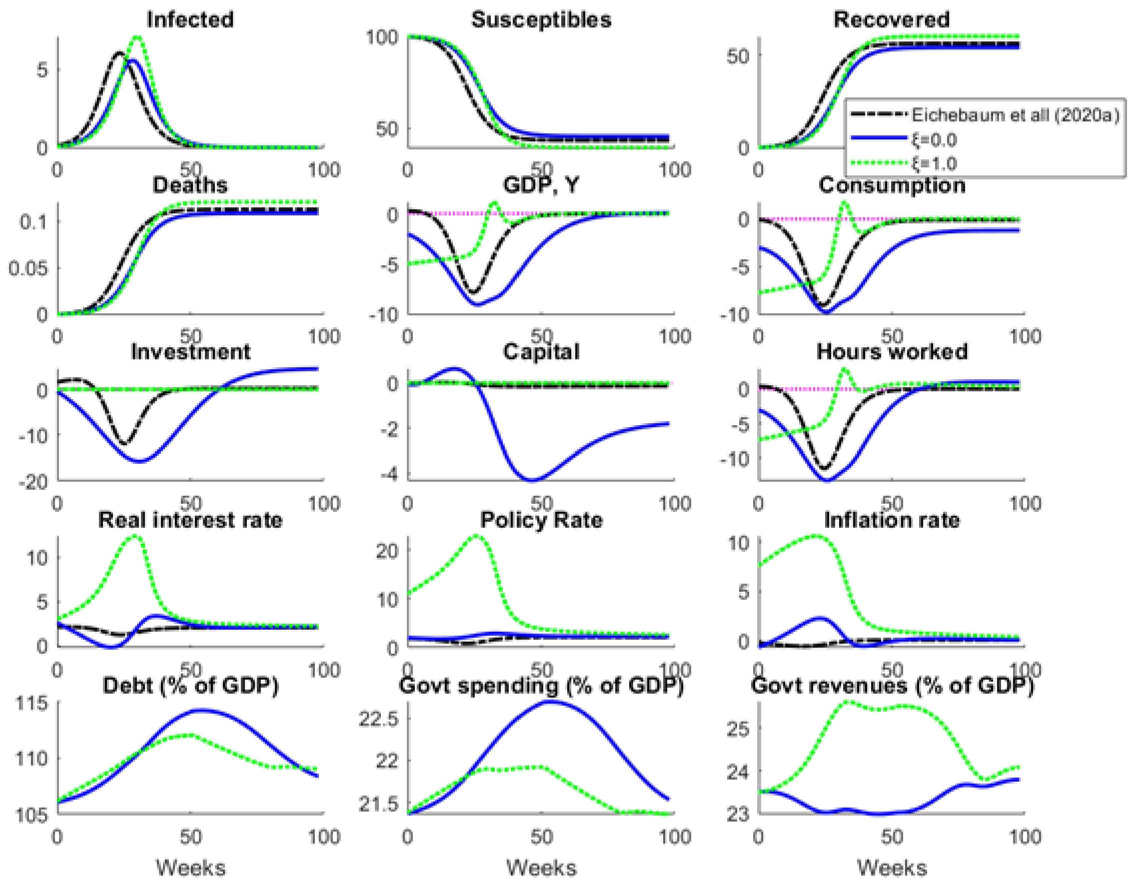
policy is to cause a higher peak of infection. Our simulations show a higher peak of contamination when $\xi > 0$ compared to the base case ($\xi = 0$). (figure 1.22).

Figure 1.22 – Sensitiveness of infection curve to to different levels of Government guarantees



Source: Produced by the author

Figure 1.23 – Eichenbaum et all (2020a) and model without policies and with Government guarantee policy



Source: Eichenbaum et all (2020a). Produced by the author

1.6 CONCLUSION

The COVID-19 outbreak at the beginning of 2020 urged governments across the globe to act. In response to the unexpected event, governments across the globe start to announce economic and health measures with limited time to design. Looking at the period and modeling the most common applied policies, we found that the endogenous stringency lockdown policies decelerate infection but deepen the economic crisis; the government-guaranteed loans can be an effective policy with potentially smaller fiscal costs; on fiscal policies, to transfer money to companies to prevent employment loss can be more effective than transfer money to Non-Ricardian households.

On lockdown stringency policy, modeling throughout an endogenous rule helps to produce the stylized fact of health policy intending to flatten the infection curve, generate

as a cost the deepening of the economic recession. Also, by flattening the curve, the epidemic evolution would last longer, which seems to align with what we observe in several economies. Within the benefits of this policy not contemplated in our model are that by flattening the curve, the health policy gives time to the development of vaccines and can avoid the collapse of the hospitals. On the other hand, one risk of the same health policy, also not embedded in our model, is the risk of mutation of the virus, which could limit herd immunity.

On financial frictions, we were able to observe additional damage from COVID-19 to the economy. With the risk shock, we included major propagation channel (CHRISTIANO et al., 2014), and demand the use of financial stabilization policies in addition to monetary policy by Central Banks (CARRILLO et al., 2021). Our results suggest a positive contribution of these policies with limited fiscal cost. One possible limitation not explored in the model is the possible moral hazard effect due to the government-guaranteed loans policy. However, in an extreme situation as an epidemic impact, this risk tends to be put on the side to be analyzed affect the dissipation of the shock (BERNANKE, 2015).

On fiscal policy, our model suggests that epidemic-related employment protection policy is more effective than epidemic-related social protection policy in terms of GDP impact. Although both policies exacerbate the infection curve, for the same fiscal cost, to transfer money to intermediate goods producer generated positive effects via smaller marginal cost of production. One limitation of our result is that our model does not have a more developed labor market with unemployment.

A more developed labor market could be considered as an extension in future work. Since the epidemics directly affect the dynamics of the labor markets, the model could benefit from a more detailed labor market modeling process.

The second line of future research could be to assess the optimum fiscal adjustment policy after the epidemics. Our model allows us to promote fiscal adjustments through four channels: lump-sum tax households; cuts in government consumption; cuts in government investments; and cuts in the permanent social transfer to Non-Ricardian households. Although not the subject of this paper, the model could eventually help to answer this relevant research question.

2 THE EFFECTS OF TAX ON FINANCIAL TRANSACTIONS

2.1 INTRODUCTION

After the financial crisis, several countries have implemented or have planned to implement some tax on the financial transaction (FTT). Within the reasons, the idea of the FTT was to curb speculation, guarantee financial stability, substitute other taxes, and fund the fiscal gaps (ANTHONY et al., 2012). Some countries also discussed implementing a tax on financial transactions (FTT) to discourage excessive risk-taking and volatility in line with suggestion from Tobin (1978) on currency transaction and Keynes (1936) on stock markets.

In the European Union, legislators proposed in 2010 the introduction of the EU financial transaction tax in the entire region (MENKVELD, 2011). The idea was to charge within 0.01% to 0.10% every financial transaction. However, after years of controversies, the European Parliament approved the co-operation act, allowing countries that wished to apply the tax on financial transactions to implement the system – opposite to the original idea of a cross-national mandatory tax.

Several countries in Latam have implemented some form of banking transaction tax (COELHO et al., 2001). In Brazil, for several years, the government applied an BTT known as CPMF – charged in most financial transactions. Asides from the CPMF, Brazil charges the IOF, also a tax applied, within several possibilities, when a banking transaction is done. Matheson (2011) indicated that as of 2005 eight Latin American countries and five Asian countries used to use BTT as a tax possibility. After years, the Brazilian Congress has decided to eliminate the CPMF tax, besides the proven potential of fiscal revenues, but kept the IOF tax alive. Still, in Brazil, some specialists suggest recreating a CPMF type of tax to substitute other taxes in place.

We decided to modify the Gerali et al. (2010) model to analyze the possible effects of a financial taxation in the steady-state levels, as well as in the impulse-response dynamics of an economy. In order to do so, we have implemented several tax possibilities

in the original Gerali et al. (2010) model. Besides the several options, we decided to focus the paper on the results of tax applied to new loans compared to the tax applied to labor income. Matheson (2011) call the tax on bank activity as banking transaction tax (BTT) in oppose to others tax possibilities related the financial sector. The original model (GERALI et al., 2010) ignores the role of the fiscal policy, limiting the possibility of comparing results.

We found that type of taxation matters. When compared to the labor income taxation system, the economy that faces a banking transaction taxation system has a lower capital level at steady state, higher spreads in the credit market and lower wages income, with more significant negative impact in the impatient household (the households that borrow in the economy). This result goes in line to Coelho et al. (2001) and Albuquerque (2006) findings. They concluded that bank transaction tax caused adverse allocation impact and even "significant financial disintermediation"(COELHO et al., 2001).

2.2 MODEL

We propose a DSGE model based on Gerali et al. (2010), augmented with a fiscal policy structure. The government can tax labor income, consumption, new loans and the profits of the banks; and spend it all in discretionary spending; no public investment is allowed.

As in Gerali et al. (2010) two types of households (patient and impatient household) consume and work, and one type of entrepreneur produces intermediate goods. The discount factors differ across agents - patient households save, while impatient households and entrepreneurs borrow.

The banking sector is monopolistically competitive for loans and deposits – the sector maximizes profits by adjusting loan and deposits' rates. Deposits and bank capital retained from previous years banks' profits finance loans. Loans are constraint by the presence of collaterals. In our model, banks also consider possible tax payments to define interest rates on loans and deposits.

We borrowed from Gerali et al. (2010) the other sectors in the economy. In the labor market, workers supply differentiated labor to different unions. The retailer

sector is monopolistically competitive, and the capital good production sector is perfectly competitive.

2.2.1 Banks

We modelled the banking sector as in Gerali et al. (2010), although opening the possibility for the government to charge tax on each new loan provided by the bank, as well as to charge a tax in the banking sector profit. In the model, banks receive all deposits and offer loans to entrepreneurs and households (no bond market, or securitization, is allowed). Each bank j must use deposits (D_t) and bank capital (K_t^b) to finance loans (B_t) – deposits and bank capital are perfectly substitute,

$$B_t = D_t + K_t^b \tag{34}$$

An exogenous capital-to-assets level defines the portion of deposits and bank capital in line with the international regulation (Basel regulations, for instance). Ceteris paribus, higher capital-to-asset level translates to smaller banking leverage, consequentially smaller steady-state overall national product. Gerali et al. (2010) assumes capital-to-asset at 9% compared to Germany (6.3%), France (6.6%) and Italy (6.6%) .

The model structures each bank j ($j \epsilon \ [0,1]$) in two parts: wholesales branch and the retailer bank. The wholesales branch is responsible for the bank's capital, while the retailer branch manages deposits and loans from households and entrepreneurs.

2.2.1.1 Wholesale branch

The wholesale branch works in a perfectly competitive market, where wholesale loans (B_t) equals bank capital (K_t^b) plus wholesale deposits (D_t). It accumulates bank

capital each period according to

$$\pi_t K_t^b = \left(1 - \delta^b\right) K_{t-1}^b + j_{t-1}^b \tag{35}$$

where j_t^b is the overall profit made by the wholesale branch and retailer branch of each bank, while δ^b is the spending needed to manage the bank capital.

The wholesale bank must solve the following problem to maximize the discounted sum of cash flows in real terms by choosing the volume of loans and deposits

$$\begin{aligned} Max\{B_t, D_t\} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \\ \Big[\left(1 + R_t^b\right) B_t - B_{t+1}\pi_{t+1} + D_{t+1}\pi_{t+1} \\ - \left(1 + R_t^d\right) D_t + (K_{t+1}^b \pi_{t+1} - K_t^b) - \frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{B_t} - \nu^b\right)^2 K_t^b\Big] \end{aligned} \tag{36}$$

subject to the identity

$$B_t = D_t + K_t^b$$

To assure a solution, banks have access to an unrestricted resource at the policy rate at the central bank. Finally, since the wholesale market is perfectly competitive, deposit rates and interbank market are equivalent ($R_t^d \equiv \; r_t$).

2.2.1.2 Retail Banking

The retail banks will differ from Gerali et al. (2010) when and if the government decides to tax its loans operations. The basic structure assumes loans and deposits markets as monopolistically competitive markets. The wholesale bank offers the loan amount $B_t\,(j)$ to the retail bank at rate R_t^b. The retail bank differentiates it at no cost and sells it to households and entrepreneurs, applying mark-ups and adjusting to tax costs when and if the government decided to tax loans. Changes in the loan rate imply a quadratic adjustment cost.

Retail loan bank solves the following maximization problem

$$\max\left\{r_t^{bH}(j), r_t^{bE}(j)\right\} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P$$
$$\left[r_t^{bH}(j)\, b_t^I(j) + r_t^{bE}(j)\, b_t^E(j) - R_t^b B_t(j) - \frac{\kappa_{bH}}{2}\left(\frac{r_t^{bH}(j)}{r_{t-1}^{bH}(j)} - 1\right)^2 r_t^{bH} b_t^I \right.$$
$$\left. - \frac{\kappa_{bE}}{2}\left(\frac{r_t^{bE}(j)}{r_{t-1}^{bE}(j)} - 1\right)^2 r_t^{bE} b_t^E - (taxloans) * (b_t^I + b_t^E) \right] \quad (37)$$

subject to both impatient households and entrepreneurs demand

$$b_t^E(j) = \left(\frac{r_t^{bE}(j)}{r_t^{bE}}\right)^{-\varepsilon_t^{bE}} b_t^E \quad (38)$$

and

$$b_t^I(j) = \left(\frac{r_t^{bH}(j)}{r_t^{bH}}\right)^{-\varepsilon_t^{bH}} b_t^I \quad (39)$$

where $B_t(j) = b_t(j) = b_t^I(j) + b_t^E(j)$.

The objective function can be written as:

$$MAX\left\{r_t^{bH}(j), r_t^{bE}(j)\right\} f\left(r_t^{bH}(j), r_t^{bE}(j)\right) = E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P$$
$$\left[(r_t^{bH}(j))^{1-\varepsilon_t^{bH}} \left(\frac{1}{r_t^{bH}}\right)^{-\varepsilon_t^{bH}} b_t^I + (r_t^{bE}(j))^{1-\varepsilon_t^{bE}} \left(\frac{1}{r_t^{bH}}\right)^{-\varepsilon_t^{bE}} b_t^E \right.$$
$$- R_t^b \left(\left(\frac{r_t^{bH}(j)}{r_t^{bH}}\right)^{-\varepsilon_t^{bH}} b_t^I + \left(\frac{r_t^{bE}(j)}{r_t^{bE}}\right)^{-\varepsilon_t^{bE}} b_t^E \right)$$
$$\left. - \frac{K_{bH}}{2}\left(\frac{r_t^{bH}(j)}{r_{t-1}^{bH}(j)} - 1\right)^2 r_t^{bH} b_t^I - \frac{K_{bE}}{2}\left(\frac{r_t^{bE}(j)}{r_{t-1}^{bE}(j)} - 1\right)^2 r_t^{bE} b_t^E - \left(tax^{loans}\right)(b_t^I + b_t^E) \right] \quad (40)$$

We get the following FOCs:

$$\frac{\left(r_t^{bH}(j), r_t^{bE}(j)\right)}{\partial r_t^{bH}(j)} = 0$$

$$\to E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{P}$$

$$\left[\left(\frac{r_t^{bH}(j)}{r_t^{bH}} \right)^{-\varepsilon_t^{bH}} b_t^I - R_t^b \left(r_t^{bH}(j)^{-1-\varepsilon_t^{bH}} \left(\frac{1}{r_t^{bH}} \right)^{-\varepsilon_t^{bH}} b_t^I \right) - K_{bH} \left(\frac{r_t^{bH}(j)}{r_{t-1}^{bH}(j)} - 1 \right) \right.$$

$$\left(\frac{r_t^{bH} b_t^I}{r_{t-1}^{bH}(j)} \right) + \left(tax^{loans} \right) \varepsilon_t^{bH} \left(\frac{1}{r_t^{bH}(j)} \right) b_t^I = 0 \quad (41)$$

$$\frac{\left(r_t^{bH}(j), r_t^{bE}(j) \right)}{\partial r_t^{bE}(j)} = 0$$

$$\to E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{P}$$

$$\left[\left(\frac{r_t^{bE}(j)}{r_t^{bH}} \right)^{-\varepsilon_t^{bE}} b_t^E - R_t^b \left(r_t^{bE}(j)^{-1-\varepsilon_t^{bE}} \left(\frac{1}{r_t^{bE}} \right)^{-\varepsilon_t^{bE}} b_t^E \right) \right.$$

$$- K_{bE} \left(\frac{r_t^{bE}(j)}{r_{t-1}^{bE}(j)} - 1 \right) \left(\frac{r_t^{bE} b_t^I}{r_{t-1}^{bE}(j)} \right) + \left(tax^{loans} \right) \varepsilon_t^{bE} \left(\frac{1}{r_t^{bE}(j)} \right) b_t^E = 0 \quad (42)$$

As in Gerali et al. (2010), the deposit retail branch of bank j receives deposits $d_t(j)$, and send them to the wholesale bank fund and receiving r_t.

Retail deposit bank solves the following problem

$$\max \left\{ r_t^{bH}(j), r_t^{bE}(j) \right\} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{P} \left[r_t D_t(j) - r_t^d(j) d_t(j) - \frac{\kappa_d}{2} \left(\frac{r_t^d(j)}{r_{\kappa t-1}^d(j)} - 1 \right)^2 r_t^d d_t \right] \quad (43)$$

subject to

$$d_t^P(j) = \left(\frac{r_t^d(j)}{r_t^d} \right)^{-\varepsilon_t^d} d_t$$

assuming $D_t(j) = d_t(j)$.

Finally, the real banks' net profits are, then, the sum of net earnings from wholesale and retail branches minus the tax on banks' gross profits ($tax^{bprofits}$), when and if the government decides to tax the banks' profit.

$$j_t^b = (r_t^{bH} b_t^H + r_t^{bE} b_t^E - r_t^d d_t - \frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{B_t} - \nu^b\right)^2 K_t^b - Adj_t^B)(1 - tax^{bprofits}) \quad (44)$$

where Adj_t^B is the adjustment cost of changing interest rates on loans and deposits.

2.2.2 Households

Following Gerali et al. (2010), we assume two types of households: the patient households (P) and impatient households (I). While the patient household saves in every period, the impatient household borrows. The discount factor differentiates them. To compare the impact of different tax systems, we have modified the budget constraint as in Costa-Junior (2015) to incorporate tax in the households consumption and labor income.

2.2.2.1 Patient Households

As in Gerali et al. (2010), the patient household's expected utility is function of current and lagged consumption (c_t^P), housing (h_t^P) and hours worked (l_t^P):

$$E_o \sum_{t=0}^{\infty} \beta_P^t \left[\left(1 - a^P\right) \varepsilon_t^z \log\left(c_t^P(i) - a^P c_{t-1}^P\right) + \varepsilon_t^h \log\left(h_t^P(i)\right) - \frac{l_t^P(i)^{1+\phi}}{1+\phi}\right] \quad (45)$$

$\left(1 - a^P\right)$ is presented in the equation to offset external and group-specific habits in the steady-state marginal utility of consumption. The terms ε_t^z and ε_t^h represent shocks in consumption and housing. The budget constraint in real terms is given by

$$(1 + tax^c)\, c_t^P(i) + q_t^h{}_t^P(i) + d_t^P(i) \leq \left(1 - tax^{income}\right) w_t^P l_t^P(i) + \frac{\left(1 + r_{t-1}^d\right) d_{t-1}^P(i)}{\pi_t} + t_t^P(i) \quad (46)$$

Consumption ($c_t^P(i)$), accumulation of housing ($q_t^h h_t^P(i)$) and deposits ($d_t(i)$) give the expenses, while wage earning ($w_t^P l_t^P$), last period deposits ($\frac{\left(1+r_{t-1}^d\right)d_{t-1}(i)}{\pi_t}$) and lump-sum transfers (t_t^P) are the resources for each period. In line to Costa-Junior (2015), tax^c and tax^{income} will affect the households decision.

The objective function can be written as:

$$\begin{aligned} Max\ L = f\left(c_t^P, h_t^P, l_t^P\right) + \lambda[\left(1 - tax^{income}\right) w_t^P l_t^P(i) \\ + \frac{\left(1 + r_{t-1}^d\right) d_{t-1}(i)}{\pi_t} + t_t^P(i) - \left(1 + tax^c\right) c_t^P(i) - q_t^h \Delta h_t^P(i) - d_t^P(i)] \end{aligned} \tag{47}$$

We get the following FOCs:

$$\frac{\partial L}{\partial c_t^P} = 0 \rightarrow = E_0 \sum_{t=0}^{\infty} \beta_P^t \left[\left(1 - a^P\right) \varepsilon_t^z \frac{1}{(c_t^P(i) - a^P c_{t-1}^P)}\right] - \lambda\left(1 + tax^c\right) = 0 \tag{48}$$

$$\frac{\partial L}{\partial h_t^P} = 0 \rightarrow = E_0 \sum_{t=0}^{\infty} \beta_P^t \left[\varepsilon_t^h \frac{1}{h_t^P(i)}\right] - \lambda q_t^h = 0 \tag{49}$$

$$\frac{\partial L}{\partial l_t^P} = 0 \rightarrow = -E_0 \sum_{t=0}^{\infty} \beta_P^t [l_t^P(i)^{\phi}] + \lambda\ w_t^P(1 - tax^{income}) = 0 \tag{50}$$

$$\begin{aligned} \frac{\partial L}{\partial \lambda} = 0 \rightarrow (1 - tax^{income}) w_t^P l_t^P(i) + \left(1 + r_{t-1}^d\right) d_{t-1}^P(i) \pi_t + t_t^P(i) \\ - \left(1 + tax^c\right) c_t^P(i) - q_t^h \Delta h_t^P(i) - d_t^P(i) = 0 \end{aligned} \tag{51}$$

2.2.2.2 Impatient Households

Analogous to the patient household, the impatient household's expected utility is given by

$$E_o \sum_{t=0}^{\infty} \beta_I^t \left[\left(1 - a^I\right) \varepsilon_t^z \log\left(c_t^I(i) - a^I c_{t-1}^I\right) + \varepsilon_t^h \log\left(h_t^I(i)\right) - \frac{l_t^I(i)^{1+\phi}}{1+\phi} \right] \tag{52}$$

The parameter a^I is the habit consumption coefficient. The terms ε_t^z and ε_t^h represent the same shocks in consumption and housing as in the patient household.

The impatient household faces the following budget constraint

$$(1 + tax^c)\, c_t^I(i) + q_t^h{}_t^I(i) + \frac{\left(1 + r_{t-1}^{bH}\right) b_{t-1}^I(i)}{\pi_t} \leq \left(1 - tax^{income}\right) w_t^I l_t^I(i) + b_t^I(i) + t_t^I(i)$$

Consumption ($c_t^I(i)$), accumulation of housing ($q_t^h{}_t^P(i)$) and past debts payments ($\frac{\left(1+r_{t-1}^{bH}\right) b_{t-1}^I(i)}{\pi_t}$) give the expenses of the impatient household, while wage earning ($w_t^I\ l_t^I$), new loans (b_t^I) and lump-sum transfers (t_t^I) are the revenues.

The impatient household also faces borrowing constraints based on the expected value of its housing asset.

$$\left(1 + r_t^{bH}\right) b_t^I(i) \leq\ m_t^I E_t \left[\sum_{i=1}^{4} q_{t+i}^I h_{t+i}^I(i)\, \pi_{t+i} \right] \tag{53}$$

where m_t^I is the stochastic loan-to-value (LTV). The term m_t^I defines the amount of credit the impatient household potentially have in housing asset terms.

The objective function can be written as:

$$Max\ L = f\left(c_t^I, h_t^I, l_t^I\right)$$

$$+\lambda_1 \left[\left(1 - tax^{income}\right) w_t^I l_t^I\left(i\right) + b_t^I\left(i\right) + t_t^I\left(i\right) - \left(1 + tax^c\right) c_t^I\left(i\right) - q_t^h \Delta h_t^I\left(i\right) - \frac{\left(1 + r_{t-1}^{bH}\right) b_{t-1}^I\left(i\right)}{\pi_t}\right]$$

$$+ \lambda_2 \left[m_t^I E_t \left[\sum_{i=1}^{4} q_{t+i}^I h_{t+i}^I\left(i\right) \pi_{t+i}\right] - \left(1 + r_t^{bH}\right) b_t^I\left(i\right)\right]$$

We get the following FOCs:

$$\frac{\partial L}{\partial c_t^I} = 0 \rightarrow\ E_0 \sum_{t=0}^{\infty} \beta_I^t \left[\left(1 - a^I\right) \varepsilon_t^z \frac{1}{\left(c_t^I\left(i\right) - a^I c_{t-1}^I\right)}\right] - \lambda_1\left(1 + tax^c\right) = 0 \tag{54}$$

$$\frac{\partial L}{\partial h_t^I} = 0 \rightarrow\ E_0 \sum_{t=0}^{\infty} \beta_I^t \left[\varepsilon_t^h \frac{1}{h_t^I\left(i\right)}\right] - \lambda_1 q_t^h - \lambda_2 m_t^I E_t \left[\sum_{i=1}^{4} q_{t+i}^I \pi_{t+i}\right] = 0 \tag{55}$$

$$\frac{\partial L}{\partial l_t^I} = 0 \rightarrow -E_0 \sum_{t=0}^{\infty} \beta_I^t [l_t^I(i)^{\phi}] + \lambda_1 w_t^I \left(1 - tax^{income}\right) = 0 \tag{56}$$

$$\frac{\partial L}{\partial \lambda_1} = 0 \rightarrow \left(1 - tax^{income}\right) w_t^I l_t^I\left(i\right) + b_t^I\left(i\right) + t_t^I\left(i\right)$$

$$- \left(1 + tax^c\right) c_t^I\left(i\right) - q_t^h \Delta h_t^I\left(i\right) - \frac{\left(1 + r_{t-1}^{bH}\right) b_{t-1}^I\left(i\right)}{\pi_t} = 0 \tag{57}$$

$$\frac{\partial L}{\partial \lambda_2} = 0 \rightarrow\ m_t^I E_t \left[\sum_{i=1}^{4} q_{t+i}^I h_{t+i}^I\left(i\right) \pi_{t+i}\right] - \left(1 + r_t^{bH}\right) b_t^I\left(i\right) = 0 \tag{58}$$

2.2.3 Entrepreneurs

Entrepreneurs look to maximize their objective function, minimizing the difference between individual consumption $c_t^E(i)$ and lagged aggregate consumption c_{t-1}^E. The entrepreneurs will maximize the following function

$$E_o \sum_{t=0}^{\infty} \beta_E^t log \left(c_t^E(i) - a^E c_{t-1}^E \right) \tag{59}$$

subject to the budget constraint

$$\begin{aligned} c_t^E(i) + w_t^P l_t^{E,P}(i) + w_t^I l_t^{E,I}(i) + \frac{1 + r_{t-1}^{bE}}{\pi_t} b_{t-1}^E(i) + q_t^k k_t^E(i) + \psi\left(u_t(i)\right) k_{t-1}^E(i) = \\ \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k (1-\delta) k_{t-1}^E(i) \end{aligned} \tag{60}$$

In the budget constraint, δ is the depreciation of capital; while the price of one unit of physical capital is q_t^k. The firm also defines the capacity utilization u_t at the cost $\psi(u_t) k_{t-1}^E$. Finally, $\frac{1}{x_t}$ is the relative competitive price $\left(\frac{P_t^w}{P}\right)$ of the wholesales good (y_t^E).

The production function of wholesales goods is given by

$$y_t^E(i) = a_t^E \left[k_{t-1}^E(i) u_t(i) \right]^{\alpha} \left[l_t^E(i) \right]^{1-\alpha} \tag{61}$$

where a_t^E (the total factor productivity) is a stochastic process, while the aggregated labor force is defined as

$$l_t^E = \left(l_t^{E,P} \right)^{\mu} \left(l_t^{E,I} \right)^{1-\mu}. \tag{62}$$

The entrepreneurs also face borrowing constraint based on a collateral, the expected value of their physical capital.

$$\left(1 + r_t^{bE} \right) b_t^E(i) \leq m_t^E E_t \left[q_{t+1}^k \pi_{t+1} (1-\delta) k_t^E(i) \right] \tag{63}$$

where m_t^E is the stochastic entrepreneurs' LTV ratio.

The objective function can be written as:

$$Max\ L = f\left(c_t^E\right) + \lambda_1\left[\frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k(1-\delta)k_{t-1}^E(i) - c_t^E(i) - w_t^P l_t^{E,P}(i) - w_t^I l_t^{E,I}(i) - \frac{1+r_{t-1}^{bE}}{\pi_t} b_{t-1}^E(i) - q_t^k k_t^E(i) - \psi(u_t(i))k_{t-1}^E(i)\right. + \lambda_2\left[m_t^E E_t\left[q_{t+1}^k \pi_{t+1}(1-\delta)k_t^E(i)\right] - \left(1+r_t^{bE}\right)b_t^E(i)\right] \tag{64}$$

We get the following FOCs:

$$\frac{\partial L}{\partial c_t^E} = 0 \rightarrow \frac{(c_t^E)}{\partial c_t^E} - \lambda = E_0 \sum_{t=0}^{\infty} \beta_E^t \left[\frac{1}{(c_t^E(i) - a^E c_{t-1}^E)}\right] - \lambda = 0 \tag{65}$$

$$\frac{\partial L}{\partial \lambda} = 0 \rightarrow \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k(1-\delta)k_{t-1}^E(i) - c_t^E(i) - w_t^P l_t^{E,P}(i) - w_t^I l_t^{E,I}(i) - \frac{1+r_{t-1}^{bE}}{\pi_t} b_{t-1}^E(i) - q_t^k k_t^E(i) - \psi(u_t(i))k_{t-1}^E(i) = 0 \tag{66}$$

$$\frac{\partial L}{\partial \lambda_2} = 0 \rightarrow\ m_t^E E_t\left[q_{t+1}^k \pi_{t+1}(1-\delta)k_t^E(i)\right] - \left(1+r_t^{bE}\right)b_t^E(i) = 0 \tag{67}$$

2.2.4 Loans and deposits demands

We used Gerali et al. (2010) 's modelling strategy for loans and deposits demand. The authors model the credit market based on Dixit e Stiglitz (1977) framework with CES baskets of differentiated products. Also, in the model, the elasticity of substitution is stochastic for deposits (ε_t^d) and loans - ε_t^{bH} for households and ε_t^{bE} for entrepreneurs, allowing the bank sector's mark-up shocks to affect the economy.

The demand function of household i for real loans $\bar{b}_t^I(i)$ is given by

$$\min\left\{b_t^I(i,j)\right\}\int_0^1 r_t^{bH}(j)\, b_t^I(i,j)\, dj \tag{68}$$

subject to

$$ \tag{69} $$

where $\varepsilon_t^{bH} > 1$. When aggregated, all impatient households' demand for loans is given by

$$b_t^I(j) = \left(\frac{r_t^{bH}(j)}{r_t^{bH}}\right)^{-\varepsilon_t^{bH}} b_t^I \tag{70}$$

where the interest rate on household's loans is

$$r_t^{bH} = \left[\int_0^1 r_t^{bH}(j)^{1-\varepsilon_t^{bH}} dj\right]^{\frac{1}{1-\varepsilon_t^{bH}}} \tag{71}$$

Likewise, entrepreneurs' demand for loans is

$$b_t^E(j) = \left(\frac{r_t^{bE}(j)}{r_t^{bE}}\right)^{-\varepsilon_t^{bE}} b_t^E \tag{72}$$

On deposit side, the demand for the patient household i deposits at bank j is given by

$$\max\left\{d_t^P(i,j)\right\}\int_0^1 r_t^d(j)\, d_t(i,j)\, dj \tag{73}$$

subject to

$$\left[\int_0^1 d_t^P(i,j)^{\frac{\varepsilon_t^d-1}{\varepsilon_t^d}} dj\right]^{\frac{\varepsilon_t^d}{\varepsilon_t^d-1}} \leq \bar{d}_t(i) \tag{74}$$

assuming $\varepsilon_t^d < -1$, where

$$d_t^P(j) = \left(\frac{r_t^d(j)}{r_t^d}\right)^{-\varepsilon_t^d} d_t \tag{75}$$

and the aggregate deposit rate is

$$r_t^d = \left[\int_0^1 r_t^d(j)^{1-\varepsilon_t^d} dj\right]^{\frac{1}{1-\varepsilon_t^d}} \tag{76}$$

2.2.5 Fiscal policy

We have added the fiscal policy in the original model, although in a simple form. In this economy, the government spends what is collected with tax – no public investment is allowed.

$$p_t g_t = t_t \tag{77}$$

The tax system is based on several tax possibilities embedded in the model, such as a tax on consumption, income, new loans and banks' profits.

$$t_t = tax^c P_t C_t + tax^{income} W_t L_t + tax^{loans}\left(b_t^H + b_t^E\right) + tax^{bprofits}(r_t^{bH} b_t^H + r_t^{bE} b_t^E$$
$$- r_t^d d_t - \frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{B_t} - \nu^b\right)^2 K_t^b - Adj_t^B) \quad (78)$$

where

$$C_t = c_t^P + c_t^I + c_t^E \quad (79)$$

and

$$W_t L_t = w_t^P l_t^P + w_t^I l_t^I \quad (80)$$

2.2.6 Capital production goods

The capital production sector follows the same structure as in Gerali et al. (2010). It is perfectly competitive, increasing the stock of effective capital $\overline{x}_t$ and then selling it to the entrepreneurs at price Q_t^k the end of the period. The capital production sector buys from entrepreneurs the capital after depreciation ($(1-\delta)\, k_{t-1}$) at price Q_t^k and buy final goods i_t from retailers at price P_t. Capital production sector maximization problem is

$$max\{\bar{x}, i_t\} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^E \left(q_t^k \Delta\bar{x}_t - i_t\right) \quad (81)$$

subject to

$$\bar{x}_t = \bar{x}_{t-1} + \left[1 - \frac{k_i}{2}\left(\frac{i_t \varepsilon_t^{qk}}{i_{t-1}} - 1\right)^2\right] i_t \quad (82)$$

The price of capital in real terms is represented by $q_t^k \equiv \frac{Q_t^k}{P_t}$, and the cost of adjustment is k_i. Finally, ε_t^{qk} is an exogenous "shock to the efficiency of investments" (GERALI et al., 2010).

2.2.7 Goods retailers

The retail goods market also follows the same structure as Gerali et al. (2010), presented as a monopolistically competitive market. Retailers must choose the price that maximizes the following function

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{P} \left[P_t(j)\, y_t(j) - P_t^W y_t(j) - \frac{\kappa_p}{2} \left(\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{l_p} \pi^{1-l_p} \right)^2 P_t y_t \right] \tag{83}$$

subject to

$$y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon_t^y} y_t \tag{84}$$

Retailers buy goods at a price P_t^W, differentiate them at no cost and sell the new product adding the mark-up to it. The retailers' product demand derives from the consumer's maximization and is also subject to ε_t^y (a stochastic demand price-elasticity).

2.2.8 labor markets

Workers (patient and impatient) provide a differentiated labor force; two labor unions aggregate each labor force (patient households (s) and impatient households (m)) and sell to entrepreneurs. The unions maximize members' utilities selecting wages subject to "downward sloping demand curve and quadratic adjustment cost" (GERALI et al., 2010). The unions follow the objective function

$$E_0 \sum_{t=0}^{\infty} \beta_s^t \left\{ U_{c_t^s(i,m)} \left[\frac{W_t^s(m)}{P_t} l_t^s(i,m) - \frac{\kappa_w}{2} \left(\frac{W_t^s(m)}{W_{t-1}^s(m)} - \pi_{t-1}^{l_m} \pi^{1-l_w} \right)^2 \frac{W_t^s}{P_t} \right] - \frac{l_t^s(i,m)^{1+\phi}}{1+\phi} \right\} \tag{85}$$

subject to labor demand

$$l_t^s(i,m) = l_t^s(m) = \left(\frac{W_t^s(m)}{W_t^s} \right)^{\varepsilon_t^l} l_t^s \tag{86}$$

The household s (and m) supply labor following the wage-Phillips curve given by

$$\kappa_w \left(\pi_t^{w^s} - \pi_{t-1}^{l_w} \pi^{1-l_w} \right) \pi_t^{w^s} = \beta_s E_t \left[\frac{\lambda_{t+1}^s}{\lambda_t^s} \kappa_w \left(\pi_{t+1}^{w^s} - \pi_t^{l_w} \pi^{1-l_w} \right) \frac{\pi_{t+1}^{w^s\,2}}{\pi_{t+1}} \right] + \left(1 - \varepsilon_t^l\right) l_t^s + \frac{\varepsilon_t^l l_t^{s\,1+\phi}}{\omega_t^s \lambda_t^s} \tag{87}$$

where ω_t^s is real wage and $\pi_t^{w^s}$ is nominal wage inflation.

2.2.9 Monetary policy

As in Gerali et al. (2010), the central bank responds to the following Taylor rule

$$(1+r_t) = (1+r)^{(1-\phi_R)} (1+r_{t-1})^{\phi_R} \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi(1-\phi_R)} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y(1-\phi_R)} \varepsilon_t^r \tag{88}$$

where r_t is the base, interbank, interest rate; ϕ_π and ϕ_y are, respectively, the weights the central bank should give to the deviation of inflation from the target and the deviation of the product from previous period level. The term r refers to the nominal interest rate at steady state, y_t refers to the aggregated output and ε_t^r is the monetary policy shock.

2.2.10 Aggregation and market clearing

The equilibrium is given by

$$y_t = c_t + q_t^k \left[k_t - (1-\delta) k_{t-1}\right] + k_{t-1}\psi(u_t) + \delta^b \frac{K_{t-1}^b}{\pi_t} + g_t + Adj_t \tag{89}$$

The c_t is the aggregate consumption in t, k_t the aggregate stock of physical capital, k_t^b the aggregate bank capital, g_t is the government spending, and, finally, Adj_t represents the real adjustment cost for prices, wages and interest rates.

2.3 CALIBRATION

For the simulations, we used the parameters below (table 1, 2 and 3) from Gerali et al. (2010). For the structural parameters that the authors estimated, we used the mean of the posterior distribution; for others, we calibrated in line with the original paper.

Table 2.1 – Calibrated Parameters from Gerali et al. (2010)

Parameter	Description	Values
β_P	Patient household's discount factor	0.9943
β_I	Impatient household's discount factor	0.975
β_E	Entrepreneurs discount factor	0.975
ϕ	Inverse of the Frisch elasticity	1.00
μ	Share of unconstrained households	0.80
ε^h	Weight of housing in households' utility function	0.20
α	Capital share in the production function	0.25
δ	Depreciation rate of physical capital	0.025
ε^y	$\frac{\varepsilon^y}{\varepsilon^y - 1}$ is the markup in the good market	6
ε^l	$\frac{\varepsilon^l}{\varepsilon^l - 1}$ is the markup in the labour market	5
m^I	Households' LTV ratio	0.70
m^E	Entrepreneurs' LTV ratio	0.35
υ^b	Target to loans ratio	0.10
ε^d	$\frac{\varepsilon^d}{\varepsilon^d - 1}$ is the markdown on deposit rate	-1.46
ε^{bH}	$\frac{\varepsilon^{bH}}{\varepsilon^{bH} - 1}$ is the markup on rate on loans to householc	2.79
ε^{bE}	$\frac{\varepsilon^{bE}}{\varepsilon^{bE} - 1}$ is the markup on rate on loans to firms	3.12
δ^b	Cost for managing the bank's capital position	0.10
ξ_1	Parameter of adjustment cost for capacity utilisatior	0.478
ξ_2	Parameter of adjustment cost for capacity utilisatior	0.00478

Source: (GERALI et al., 2010). Produced by the author

Table 2.2 – Mean of the posterior distribution from Gerali et al. (2010)

Parameter	Description	Posterior distribution - mean
κ_p	p stickness	30.57
κ_w	w stickness	102.35
κ_i	Invest. adj. cost	10.26
κ_d	Dep. rate adj. cost	3.63
κ_{bE}	Firm rate adj. cost	9.51
κ_{bH}	HHs rate adj. cost	10.22
κ_{Kb}	Leverage dev. cost	11.49
ϕ_π	T.R. coeff. on π	2.01
ϕ_R	T.R. coeff. on R	0.77
ϕ_y	T.R. coeff. on y	0.35
l_p	p indexation	0.17
l_w	w indexation	0.28
a^h	Habit coefficient	0.85

Source: (GERALI et al., 2010). Produced by the author

Table 2.3 – Mean of the posterior distribution from Gerali et al. (2010)

Parameter	Description	Posterior distribution - mean
AR coefficient		
ρ_z	Consumpt. prefer.	0.394
ρ_h	Housing prefer.	0.917
ρ_{mE}	Firms' LTV	0.892
ρ_{mI}	HH's LTV	0.925
ρ_d	Dep. Markdown	0.830
ρ_{bH}	HH's loans markup	0.808
ρ_{bE}	Firms' loans markup	0.820
ρ_a	Technology	0.936
ρ_{qk}	Invest. Efficiency	0.543
ρ_y	p markup	0.306
ρ_l	w markup	0.636
ρ_{Kb}	Balance sheet	0.810
Standard deviation		
σ_z	Consumpt. prefer.	0.027
σ_h	Housing prefer.	0.076
σ_{mE}	Firms' LTV	0.007
σ_{mI}	HH's LTV	0.003
σ_d	Dep. Markdown	0.033
σ_{bH}	HH's loans markup	0.067
σ_{bE}	Firms' loans markup	0.063
σ_a	Technology	0.006
σ_{qk}	Invest. Efficiency	0.019
σ_R	Monetary policy	0.002
σ_y	p markup	0.634
σ_l	w markup	0.577
σ_{Kb}	Balance sheet	0.031

Source: (GERALI et al., 2010). Produced by the author

2.4 MAIN RESULTS

This section will focus on the model's long-term (steady-state) results and the model responses to selected shocks when facing different types of taxation.

2.4.1 Steady-state properties

We compared below the steady-state results assuming two taxations: first, a tax paid by the bank in each loan offered; second, a tax paid by the households on labor income. We calibrated the tax on labor income to produce the same amount of tax collection as 0.5% of tax on loans.

According to the result, and besides collecting the same amount of tax (about 1% of GDP), both tax systems generate different equilibrium. For instance, the tax on financial transactions applied on loans produced an overall steady-state stock of capital in steady-state lower under the financial sector tax system.

In the banking sector, the simulations indicate that the overall credit market spread increased by almost 70%, considering the impact of financial taxation on the steady-state loan rate for households and entrepreneurs. Also, the total outstanding credit to GDP is lower under the tax in financial transactions (171% of GDP, compared to 236% of GDP when compared to labor income taxation). Finally, the amount of credit to entrepreneurs represents a smaller share of the outstanding loans in the economy.

In the labor market, the equilibrium also diverges. The results show lower total wage for both households (patient and impatient) with increasing inequality under financial taxation, with a more significant negative impact on the impatient household's payment per hour (the lower-income worker in the model).

Table 2.4 – Steady state result under different tax systems

	Tax of 0.5% on each loan paid by banks	Tax of 1.37% on wages paid by the households	(%)
Stock of capital (% of GDP)	2.95	4.44	-33.4%
Banking sector			
Deposit rate (%annual)	2.293	2.293	0.0%
Base rate (%annual)	3.863	3.863	0.0%
Loan rate for HH (%annual)	7.820	5.862	33.4%
Loan rate of Entrepreneurs (%annual)	8.842	5.862	50.8%
Spread between loans and deposit rate (%annual)	6.038	3.569	69.2%
Share of household borrowing (%)	42.439	36.731	15.5%
Share of entrepreneurs borrowing (%)	57.562	63.270	-9.0%
Outstanding loans (% of GDP)	1.713	2.359	-27.4%
Deposits (% of GDP)	1.537	2.147	-28.4%
Banks capital (% of outstanding loans)	0.103	0.090	14.3%
Banks'capital (% of GDP)	0.176	0.212	-17.0%
Labour market			
Impatient household total wage ($w^I l^I$)	0.163	0.164	-1.0%
Patient household total wage ($w^P l^P$)	0.650	0.656	-1.0%
Impatient household wage per hour (w^I)	0.171	0.174	-1.5%
Patient household wage per hour (w^P)	0.845	0.857	-1.4%
Hours worked impatient household (l^I)	0.950	0.944	0.6%
Hours worked patient household (l^P)	0.770	0.766	0.4%

Source: Produced by the author

2.4.2 Impulse response results

2.4.2.1 Technology shock

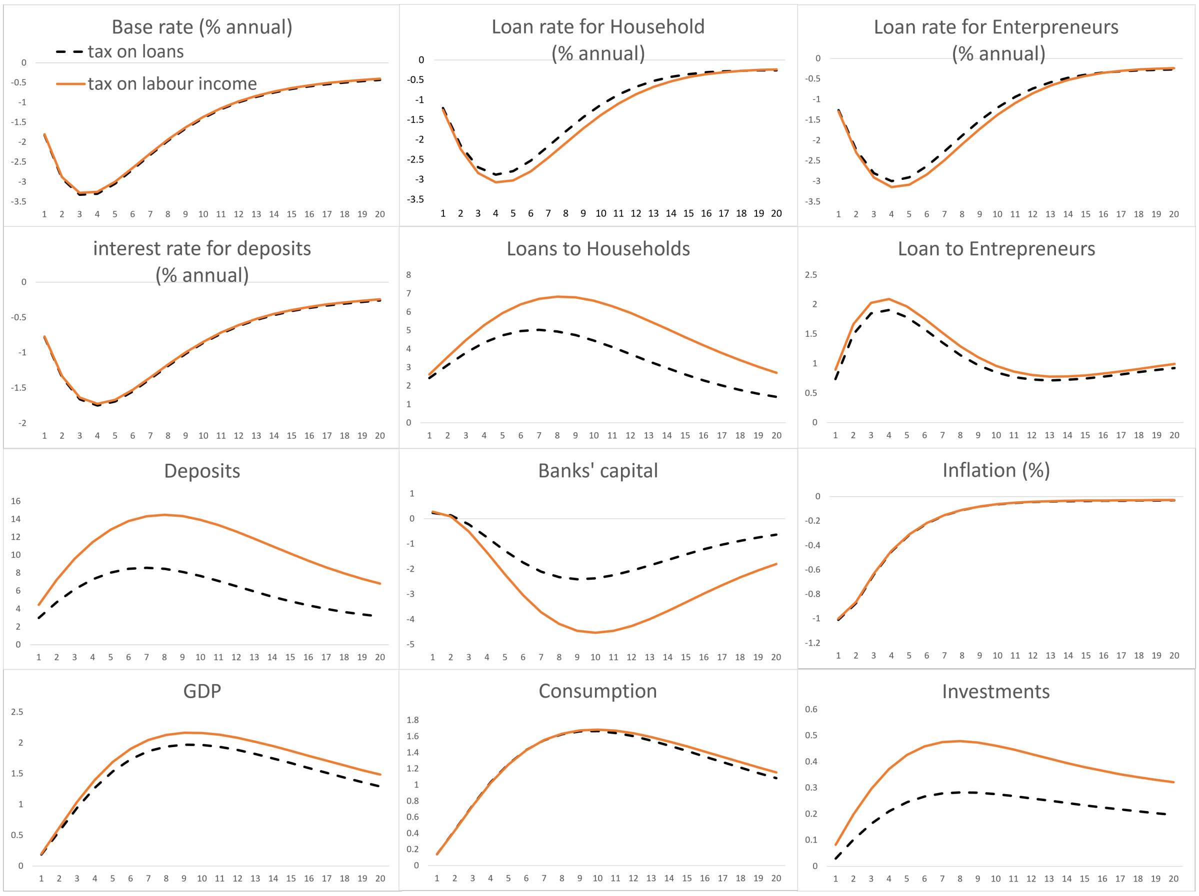
The propagation of a technology shock in the economy changes considering the tax system applied (figure). The economy under the financial tax system would benefit less from the positive technology shock, with loan rates falling less when compared to the tax on labor income, resulting in an economy that would grow less in response to the shock.

On interest rates, the base rate response proved similar under different taxation systems. However, the rates on household and entrepreneurs' loans show differences, with rates response under financial taxation being softer than the other case. These differences in rates also impact the response of loans to the positive technology shock. The exercise

shows a smaller reaction in the borrowing market for households and entrepreneurs in the financial tax system.

The overall product also differs depending on the type of taxation the economy faces. In the financial tax system, the economy would grow less in response to the technology shock. Within sectors, investments present the more significant discrepancy between the two simulations, although consumption also reflects the different taxation.

Figure 2.1 – Impulse response on positive technology shock



Source: Produced by the author

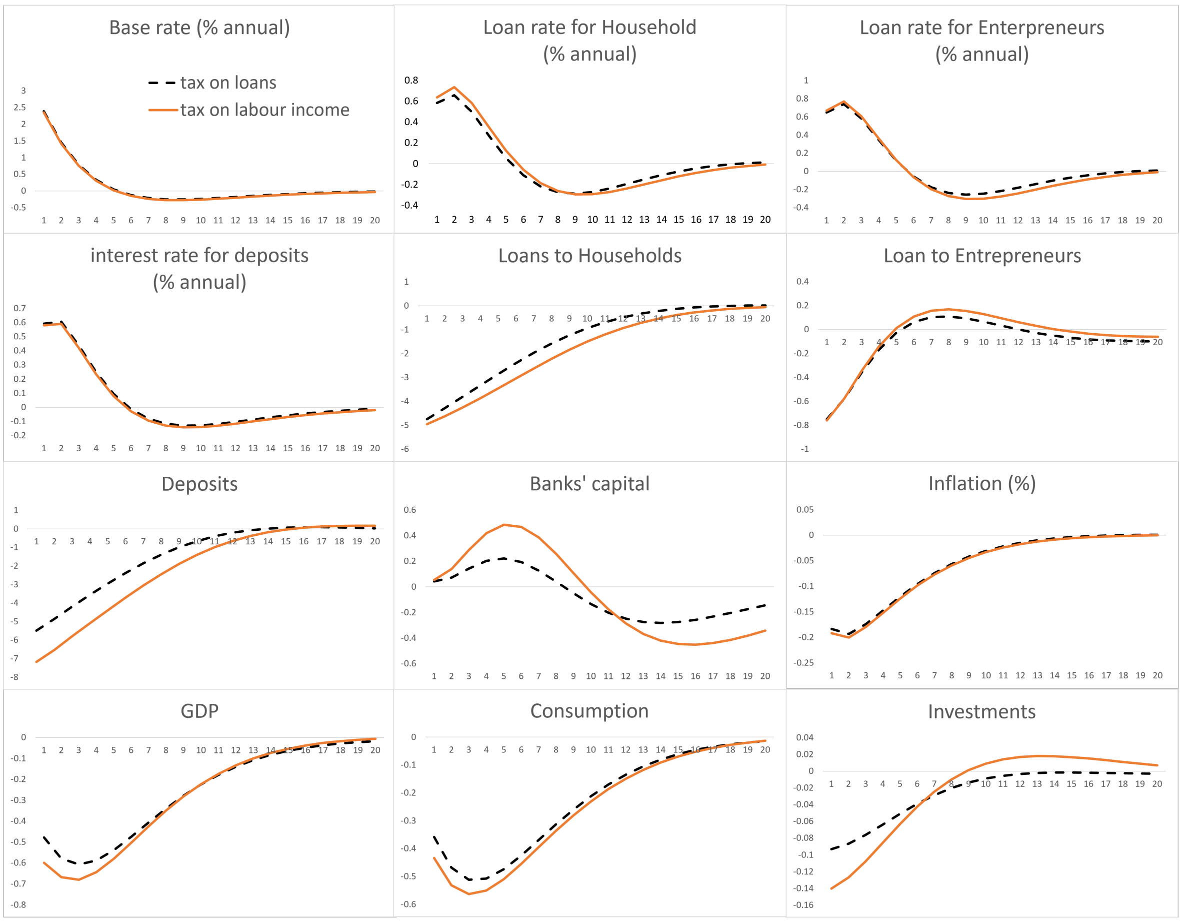
2.4.2.2 Monetary policy shock

In the case of a monetary policy shock, the financial tax system tends to slightly softens the impact of a monetary policy shock on growth, but less conclusive on inflation compared to the labor income tax. If anything, the monetary policy tend to become less effective under the financial tax system.

On interest rates, the loan rates for households and entrepreneurs respond differently under each tax system, with rates move proving to be, in general, slightly softer again in the tax system example. These differences in rates also tend to impact the demand for loans. In the financial tax system, the exercise shows a smaller response in the households' demand for loans. For entrepreneurs, the differences between the two taxation models are less relevant.

Finally, the dynamic of the GDP differs after facing a monetary policy shock under different taxation hypotheses. In the financial tax system, the economy would be less sensitive to the rate increase shock. Within sectors, investments show different paces between the two simulations, although consumption is also marginally affected by the different taxation.

Figure 2.2 – Impulse response function on positive monetary policy shock



Source: Produced by the author

2.5 CONCLUSION

We proposed an augmented Gerali et al. (2010) model intended to assess the impact of different taxation in the economy's steady-state, as well as in the variables response to specific shocks. Our contributions were to implement a government structure with discretionary spending in the model allowing the government to fund itself by taxing the households labor income or taxing banks based on their loans to the impatient household and the Entrepreneurs.

According to our results, the economies where the government funding comes from tax in the financial transactions have higher banking spreads and lower level of stock of capital at the steady-state compared to a government that is funded by a tax on labor income. Also, the labor market in steady-state shows the impatient households been more negatively affected by working more and receiving less per hour when compared to the economies with labor income tax system. Finally, when facing technology or monetary policy shocks, the economy under the financial tax system tends to have softer cycles.

Our results, under our assumptions, suggest that the financial taxation system is a sub-optimum option to fund governments when compared to labor income tax, given the negative impact it has for the long run and the response of the economy to technology shocks. This is in line to Coelho et al. (2001) and Albuquerque (2006) . We believe more value can be added to the discussion by adding other types of taxation in the model, opening room for a broader analysis of different tax systems and analysis of a diverse system with several taxes being used simultaneously.

BIBLIOGRAPHY

ALBUQUERQUE, P. Bad taxation: Disintermediation and illiquidity in a bank account debits tax model. **International Tax and Public Finance**, v. 13, n. 5, p. 601–624, 2006. Disponível em: <https://EconPapers.repec.org/RePEc:kap:itaxpf:v:13:y:2006:i:5:p:601-624>.

ALVAREZ, F. E.; ARGENTE, D.; LIPPI, F. A simple planning problem for covid-19 lockdown. **National Bureau of Economic Research**, n. w26981, 2020.

ANSAH, J.; EPSTEIN, N.; NALBAN, V. COVID-19 Impact and Mitigation Policies. **IMF Working Papers**, International Monetary Fund, v. 20, n. 233, nov 2020. ISSN 1018-5941. Disponível em: <https://www.elibrary.imf.org/view/journals/001/2020/233/article-A001-en.xml>.

ANTHONY, J.; BIJLSMA, M.; ELBOURNE, A.; LEVER, M.; ZWART, G. Financial transaction tax: review and assessment. 2012.

ATKESON, A. G.; KOPECKY, K.; ZHA, T. Behavior and the transmission of covid-19. In: **AEA Papers and Proceedings**. [S.l.: s.n.], 2021. v. 111, p. 356–60.

BERNANKE, B. S. **The Courage to Act**. [S.l.]: New York: WW Norton, 2015. 624 p. ISBN 039324721X.

BERNANKE, B. S.; GERTLER, M.; GILCHRIST, S. The financial accelerator in a quantitative business cycle framework. **Handbook of macroeconomics**, Elsevier, v. 1, p. 1341–1393, 1999.

BLANCHARD, O.; LEANDRO, A.; ZETTELMEYER, J. Redesigning eu fiscal rules: From rules to standards. **Economic Policy**, 2021.

CAMPBELL, J. Y.; MANKIW, N. G. Consumption, income, and interest rates: Reinterpreting the time series evidence. **NBER macroeconomics annual**, MIT Press, v. 4, p. 185–216, 1989.

CARRILLO, J. A.; MENDOZA, E. G.; NUGUER, V.; ROLDAN-PEñA, J. Tight money-tight credit: Coordination failure in the conduct of monetary and financial policies. **American Economic Journal: Macroeconomics**, v. 13, n. 3, p. 37–73, 2021.

CASTO, M. R. d.; GOUVEA, S. N.; MINELLA, A.; SANTOS, R. C.; SOUZA-SOBRINHO, N. F. Samba: Stochastic analytical model with a bayesian approach. **Central Bank of Brazil**, n. Wps239, 2011.

CHRISTIANO, L. J.; EICHENBAUM, M.; EVANS, C. L. Nominal rigidities and the dynamic effects of a shock to monetary policy. **Journal of political Economy**, The University of Chicago Press, v. 113, n. 1, p. 1–45, 2005.

CHRISTIANO, L. J.; MOTTO, R.; ROSTAGNO, M. Risk shocks. **American Economic Review**, v. 104, n. 1, p. 27–65, 2014.

COELHO, I.; SUMMERS, V. P.; EBRILL, L. P. Bank Debit Taxes in Latin America: An Analysis of Recent Trends. 2001.

COENEN, G.; STRAUB, R. Does government spending crowd in private consumption? theory and empirical evidence for the euro area. **International Finance**, Wiley Online Library, v. 8, n. 3, p. 435–470, 2005.

COENEN, G.; STRAUB, R.; TRABANDT, M. Fiscal policy and the great recession in the euro area. **American Economic Review**, v. 102, n. 3, p. 71–76, 2012.

COIBION, O.; GORODNICHENKO, Y.; WEBER, M. Labor markets during the covid-19 crisis: A preliminary view. **National Bureau of Economic Research**, n. w27017, 2020.

COSTA-JUNIOR, C. J. **Entendendo os Modelos de Equilíbrio Geral Dinâmico Estocástico (DSGE)**. São Paulo: [s.n.], 2015. 339 p. ISBN 978-85-91-919671-0-0.

DIXIT, A.; STIGLITZ, J. Monopolistic competition and optimum product diversity. **The American Economic Review**, v. 67, n. 3, p. 297–308, 1977. Disponível em: <http://www.jstor.org/stable/10.2307/1831401>.

EICHENBAUM, M. S.; REBELO, S.; TRABANDT, M. Epidemics in the neoclassical and new keynesian models. **National Bureau of Economic Research**, n. w27430, 2020.

EICHENBAUM, M. S.; REBELO, S.; TRABANDT, M. The macroeconomics of epidemics. **National Bureau of Economic Research**, n. w26882, 2020.

FERGUSON, N. M.; CUMMINGS, D. A.; FRASER, C.; CAJKA, J. C.; COOLEY, P. C.; BURKE, D. S. Strategies for mitigating an influenza pandemic. **Nature**, Nature Publishing Group, v. 442, n. 7101, p. 448–452, 2006.

GALÍ, J.; LÓPEZ-SALIDO, J. D.; VALLÉS, J. Understanding the effects of government spending on consumption. **Journal of the european economic association**, Oxford University Press, v. 5, n. 1, p. 227–270, 2007.

GERALI, A.; NERI, S.; SESSA, L.; SIGNORETTI, F. M. Credit and banking in a DSGE model of the euro area. **Journal of Money, Credit and Banking**, v. 42, n. 6, p. 107–141, 2010. Disponível em: <http://ideas.repec.org/p/bdi/wptemi/td{_}740{_}1>.

GLOVER, A.; HEATHCOTE, J.; KRUEGER, D.; RÍOS-RULL, J.-V. Health versus wealth: On the distributional effects of controlling a pandemic. **National Bureau of Economic Research**, n. w27046, 2020.

GOURINCHAS, P.-O. Flattening the pandemic and recession curves. **Mitigating the COVID Economic Crisis: Act Fast and Do Whatever**, CEPR press London, UK, v. 31, p. 57–62, 2020.

HASELL, J.; MATHIEU, E.; BELTEKIAN, D.; MACDONALD, B.; GIATTINO, C.; ORTIZ-OSPINA, E.; ROSER, M.; RITCHIE, H. A cross-country database of covid-19 testing. **Scientific Data**, Nature Research Journals, v. 7, n. 345, 2020.

IMF. Policy responses to covid-19. 2021. (accessed: 04.05.2021). Disponível em: <https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19>.

JONES, C. J.; PHILIPPON, T.; VENKATESWARAN, V. Optimal mitigation policies in a pandemic: Social distancing and working from home. **National Bureau of Economic Research**, n. w26984, 2020.

KAPLAN, G.; VIOLANTE, G. L.; WEIDNER, J. The wealthy hand-to-mouth. **Brookings Papers on Economic Activity**, Brookings Institution Press, p. 77–138, 2014. ISSN 00072303, 15334465. Disponível em: <http://www.jstor.org/stable/23936272>.

KEYNES, J. M. **The General Theory of Employment, Interest and Money**. [S.l.]: Macmillan, 1936. 14th edition, 1973.

MATHESON, T. Taxing Financial Transactions: Issues and Evidence. 2011.

MENKVELD, A. J. Financial Transaction Tax. **DSF Policy Briefs**, n. 8, p. 1–3, 2011. Disponível em: <https://ec.europa.eu/taxation{_}customs/financial-transaction-tax{_}pthttp://personal.vu.nl/a.j.menkveld/media/ds>.

OECD. Covid-19 government financing support programmes for businesses. 2020. Disponível em: <https://www.oecd.org/finance/COVID-19-Government-Financing-Support-Programmes-for-Businesses.pdf>.

OECD. One year of sme and entrepreneurship policy responses to covid-19: Lessons learned to “build back better”. **Trackling Coronavirus (COVID-19): Contributing to a Global Effort**, 2021. Disponível em: <https://www.oecd.org/coronavirus>.

TOBIN, J. A proposal for international monetary reform. **Eastern Economic Journal**, v. 4, n. 3-4, p. 153–159, 1978. Disponível em: <https://EconPapers.repec.org/RePEc:eej:eeconj:v:4:y:1978:i:3-4:p:153-159>.

APPENDIX A – EQUATIONS CHAPTER 1

A.0.1 EPIDEMIC DYNAMICS

New infection weighted average

$$\tau_t^h = \tau_t^{hR}\left(1-\lambda^{NR}\right) + \tau_t^{hNR}\,\lambda^{NR}$$

New infection Ricardian HH

$$\tau_t^{hR} = \pi_1^R\, s_t^R\, c_t^{sR}\left(i_t\, c_t^i\right) + \pi_2^R s_t^R\, n_t^{sR}\,(1-\theta_t)\left(i_t n_t^i\,(1-\theta_t)\right) + \pi_3^R\, s_t^R\, i_t$$

New infection Non-Ricardian HH

$$\tau_t^{hNR} = \pi_1^{NR}\, s_t^{NR}\, c_t^{sNR}\left(i_t\, c_t^i\right) + \pi_2^{NR} s_t^{NR}\, n_t^{sNR}\,(1-\theta_t)\left(i_t n_t^i\,(1-\theta_t)\right) + \pi_3^{NR}\, s_t^{NR}\, i_t$$

Total susceptibles (weighted average)

$$s_t = s_t^R\left(1-\lambda^{NR}\right) + s_t^{NR}\lambda^{NR}$$

Susceptibles Ricardian HH

$$s_{t+1}^R = s_t^R - \tau_t^{hR} + \omega\, r_{t-26}^R$$

Susceptibles Non-Ricardian HH

$$s_{t+1}^{NR} = s_t^{NR} - \tau_t^{hNR} + \omega\, r_{t-26}^{NR}$$

Total infected (weighted average)

$$i_t = i_t^R\left(1-\lambda^{NR}\right) + i_t^{NR}\lambda^{NR}$$

Infected Ricardian HH

$$i_{t+1}^{R} = i_t^{R} + \tau_t^{hR} - (\pi_r + \pi_d)\, i_t^{R}$$

Infected Non-Ricardian HH

$$i_{t+1}^{NR} = i_t^{NR} + \tau_t^{hNR} - (\pi_r + \pi_d)\, i_t^{NR}$$

Total recovered (weighted average)

$$r_t = r_t^{R}\left(1 - \lambda^{NR}\right) + r_t^{NR}\lambda^{NR}$$

Recovered Ricardian HH

$$r_{t+1}^{R} = r_t^{R} + \pi_r\, i_t^{R} - \omega\, r_{t-26}^{R}$$

Recovered Non-Ricardian HH

$$r_{t+1}^{NR} = r_t^{NR} + \pi_r\, i_t^{NR} - \omega\, r_{t-26}^{NR}$$

Total deaths

$$d_{t+1} = d_t + \pi_d i_t$$

Total population

$$pop_{t+1} = pop_t - \pi_d i_t$$

A.0.2 INTERMEDIATE GOODS PRODUCERS

Production function

$$y_t = \breve{p}_t\, A\, k_t^{G} k_t^{1-\alpha}\, \left((1-\theta_t)\; n_t\right)^{\alpha}$$

Marginal cost

$$mc_t = \frac{\left(w_t - T_t^N\right)^{\alpha} r_t^{k\,1-\alpha}}{A\; k_t^G \alpha^{\alpha}\; (1-\alpha)^{1-\alpha}\, (1-\theta_t)^{\alpha}}$$

Wages

$$w_t = mc_t\, \alpha\, A\, k_t^G n_t^{\alpha-1} k_t^{1-\alpha}\; (1-\theta_t)^{\alpha}\; + T_t^N$$

Law of motion of capital Capital

$$k_t = \left(\chi^g\; (\bar{s^e}) + (1-\chi^g)\; {s^e}_t\, \frac{1+{r^k}_{t+1}}{1+(rr+\delta)}\right) \frac{1}{\psi_s} - k_{t-1}\,\delta + x_t\; \left(1 - \frac{\psi}{2}\left(\frac{x_t}{x_{t-1}} - 1\right)^2\right)$$

Law of motion of public owned capital

$$k_t^g = x_t^g + (1-\delta)\; k_{t-1}^g$$

A.0.3 CAPITAL GOODS PRODUCERS

FOC with respect to capital

$$Q_t = E_t\left[\left(\frac{1}{1+rr_{t+1}}\right)\left(Q_{t+1}(1-\delta) + (1-\alpha)\frac{y_{t+1}}{k_{t+1}}\right)\right]$$

FOC with respect to investment

$$Q_t\psi\left(\frac{x_t}{x_{t-1}} - 1\right)\frac{x_t}{x_{t-1}} - E_t\left[Q_{t+1}\left(\frac{1}{1+R_{t+1}^k}\right)\psi\left(\frac{x_{t+1}}{x_t} - 1\right)\left(\frac{x_{t+1}}{x_t}\right)^2\right] + 1 = Q_t\left(1 - \frac{\psi}{2}\left(\frac{x_t}{x_{t-1}} - 1\right)^2\right)$$

A.0.4 BANKING SECTOR

Net wealth

$${s^e}_t = \psi_s\; k_{t-1}\, q_{t-1}\; + k_{t-1}\, q_{t-1}\; \left({r^k}_{t-1}\right) - (1-\psi_s)\; q_{t-1}\, k_{t-1}\; (rr_{t-1} - 1 + EFP_{t-1})$$

External finance premium

$$EFP_t = \frac{{r^k}_{t-1}}{1-\psi_s} - (\bar{rr} - 1)$$

A.0.5 HOUSEHOLDS

A.0.5.1 Total consumption

Total susceptibles consumption (weighted average)

$$c_t^s = c_t^{sR}\left(1-\lambda^{NR}\right) + c_t^{sNR}\,\lambda^{NR}$$

Total infected consumption (weighted average)

$$c_t^i = c_t^{iR}\left(1-\lambda^{NR}\right) + c_t^{iNR}\,\lambda^{NR}$$

Total recovered consumption (weighted average)

$$c_t^r = c_t^{rR}\left(1-\lambda^{NR}\right) + c_t^{rNR}\lambda^{NR}$$

A.0.5.2 Non-Ricardian consumption

Total Non-Ricardian Consumption

$$c_t^{NR} = s_t^{NR}\,c_t^{sNR} + i_t^{NR}\,c_t^{iNR} + r_t^{NR}\,c_t^{rNR}$$

Non-Ricardian susceptible consumption

$$c_t^{sNR} = w_t\,n_t^s + T_t^h + T_t^{h-covid}$$

Non-Ricardian infected consumption

$$c_t^{iNR} = w_t\,n_t^i + T_t^h + T_t^{h-covid}$$

Non-Ricardian recovered consumption

$$c_t^{rNR} = w_t\, n_t^r + T_t^h + T_t^{h-covid}$$

A.0.5.3 Ricardian consumption

Consumption Ricardian

$$c_t^R = s_t^R\, c_t^{sR} + i_t^R\, c_t^{iR} + r_t^R\, c_t^{rR}$$

$$\tilde{c^{sR}}_t = \left(\alpha_g^{\frac{1}{\nu_g}}\; {c^{sR}}^{\frac{\nu_g - 1}{\nu_g}} + (1 - \alpha_g)^{\frac{1}{\nu_g}}\; {g_t}^{\frac{\nu_g - 1}{\nu_g}} \right)$$

$$\tilde{c^{iR}}_t = \left(\alpha_g^{\frac{1}{\nu_g}}\; {c^{iR}}^{\frac{\nu_g - 1}{\nu_g}} + (1 - \alpha_g)^{\frac{1}{\nu_g}}\; {g_t}^{\frac{\nu_g - 1}{\nu_g}} \right)$$

$$\tilde{c^{rR}}_t = \left(\alpha_g^{\frac{1}{\nu_g}}\; {c^{rR}}^{\frac{\nu_g - 1}{\nu_g}} + (1 - \alpha_g)^{\frac{1}{\nu_g}}\; {g_t}^{\frac{\nu_g - 1}{\nu_g}} \right)$$

FOC for consumption susceptible

$$\frac{\alpha_g^{\frac{1}{\nu_g}}\; (\nu_g - 1)}{\nu_g\, {c^{sR}}^{\frac{1}{\nu_g}}\; \left(\tilde{c^{sR}}_t\right)} = \tilde{\lambda}_t^b - \lambda_t^\tau \pi_1^R \left(i_t c_t^i \right)$$

FOC for consumption infected

$$\frac{\alpha_g^{\frac{1}{\nu_g}}\; (\nu_g - 1)}{\nu_g\, {c^{iR}}^{\frac{1}{\nu_g}}\; \left(\tilde{c^{iR}}_t\right)} = \tilde{\lambda}_t^b$$

FOC for consumption recovered

$$\frac{\alpha_g^{\frac{1}{\nu_g}}\; (\nu_g - 1)}{\nu_g\, {c^{rR}}^{\frac{1}{\nu_g}}\; \left(\tilde{c^{rR}}_t\right)} = \tilde{\lambda}_t^b$$

FOC hours-worked

$$Bn_t^s \ = \tilde{\lambda_t^b} w_t \left(1-\tau\right)\left(1-\theta_t\right) + \lambda_t^\tau \pi_2^R \, \left(i_t \, n_t^i \left(1-\theta_t\right)\right)$$

FOC hours-worked

$$Bn_t^i \ = \tilde{\lambda_t^b} w_t \left(1-\tau\right)\left(1-\theta_t\right)$$

FOC hours-worked

$$Bn_t^r \ = \tilde{\lambda_t^b} w_t \left(1-\tau\right)\left(1-\theta_t\right)$$

FOC for new infected

$$\lambda_t^i = \lambda_t^\tau + \lambda_t^s$$

FOC susceptibles

$$\begin{aligned} 0 = log\left(\tilde{c_{t+1}^{sR}}\right) - \frac{B}{2}\, \left(n_{t+1}^s\right)^2 + \lambda_{t+1}^\tau \left(\pi_1^R c_{t+1}^{sR}\left(i_{t+1}\, ci_{t+1}\right)\right. \\ + \pi_2^R, \left(n_{t+1}^s \ \left(1-\theta_{t+1}\right)\right)\left(i_{t+1}\ n_{t+1}^i \ \left(1-\theta_{t+1}\right)\right) + \pi_3^R \, i_t \\ + \lambda_{t+1}^{\tilde{b}}\left(\left(1-\tau\right)\ w_{t+1}\, n_{t+1}^s \ \left(1-\theta_t\right) - c_{t+1}^{sR} - T_t^{adj}\right) - \frac{\lambda_t^s}{\beta} + \lambda_{t+1}^s \end{aligned}$$

FOC infected

$$\begin{aligned} 0 = log\left(\tilde{c_{t+1}^{iR}}\right) - \frac{B}{2}\, \left(n_{t+1}^i\right)^2 \\ + \lambda_{t+1}^{\tilde{b}}\left(\left(1-\tau\right)\ w_{t+1}\, ni_{t+1}\ \left(1-\theta_t\right) - c_{t+1}^{iR}\ - T_t^{adj}\right) \\ - \frac{\lambda_{t+1}^i}{\beta} + \lambda_{t+1}^i\ \left(1-\pi_r-\pi_d\right) + \lambda_{t+1}^r \pi_r \end{aligned}$$

FOC recovered

$$0 = log\left(\tilde{c^{rR}_{t+1}}\right) - \frac{B}{2}\,\left(n^{r}_{t+1}\right)^{2}$$
$$+\lambda^{\tilde{b}}_{t+1}\left((1-\tau)\; w_{t+1}\, n^{r}_{t+1},(1-\theta_t) - c^{rR}_{t+1}\; - T^{adj}_{t}\right) - \frac{\lambda^{r}_{t}}{\beta} + \lambda^{r}_{t+1}$$

A.0.6 MONETARY POLICY

Taylor rule

$$log(Rb_t/Rb) + r_{\pi}\, log\left(\frac{\pi_t}{\pi}\right) + r_x\, log\left(\frac{y_t}{y^{f}_{t}}\right)$$

A.0.7 LOCKDOWN

Lockdown rule

$$(1-\theta_t) = 1 - \kappa\; ((1+i_{t-1})^{\kappa\_pw} - 1)$$

A.0.8 FISCAL POLICY

Debt dynamics

$$D_t = D_{t-1}(rr_{t-1} - 1) + G^{T}_{t} + X^{G}_{t} - R_t$$

Primary spending

$$G^{T}_{t} = G^{A}_{t} + G^{S}_{t}$$

Autonomous spending

$$G^{A}_{t} = (T_t + \tau^{t} w_t n_t)\alpha^{GX} - \rho(D_{t-1} - \bar{D})\varphi^{G^{A}}$$

Social spending

$$G^{S}_{t} = T^{h}_{t} + T^{h-covid}_{t} + T^{N}_{t} N,$$

Permanent cash transfer program to HH Non-Ricardian

$$T_t^h = \bar{T^h} - \rho(D_{t-1} - \bar{D})\varphi^{Th}$$

Covid cash transfer program to HH Non-Ricardian

$$T_t^{h-covid} = i_{t-1}\zeta^h$$

Covid cash transfer program to Intermediate goods producer

$$T_t^N = i_{t-1}\,\zeta^N$$

Public investment

$$X_t^G = (T_t + \tau^t w_t n_t)(1 - \alpha^{GX}) - \rho(D_{t-1} - \bar{D})\varphi^X$$

Total revenues

$$R_t = T_t + \tau^t w_t n_t + T_t^{adj}$$

Lump sum tax to fund social spending, interest burden and austerity policy

$$T_t^{adj} = D_{t-1}(rr_{t-1} - 1) + T_t^h + \rho(D_{t-1} - \bar{D})(1 - \varphi^{Th} - \varphi^{GA} - \varphi^X)$$

A.0.9 EQUILIBRIUM CONDITIONS

Aggregated demand

$$y_t = \tilde{x}_t + c_t + g_t$$

Aggregated investments

$$\tilde{x}_t = x_t + xg_t$$

Aggregated hours

$$n_t = s_t\, n_t^s + i_t\, n_t^i + r_t\, n_t^r$$

Aggregated consumption

$$c_t = s_t\, c_t^s + i_t\, c_t^i + r_t\, c_t^r$$

Real interest rate

$$rr_t = \frac{R_t^b}{\pi_{t+1}}$$

GOODS

Nonlinear price setting 1

$$K_t^f = \gamma mc_t \tilde{\lambda}_t^b y_t \ + \beta\, \xi\, \pi_{t+1}^{\frac{\gamma}{\gamma-1}}\, K_{t+1}^f$$

Nonlinear price setting 2

$$F_t = \tilde{\lambda}_t^b y_t + \beta\, \xi\, \left(\pi_t\right)^{\frac{1}{\gamma-1}}\, F_{t+1}$$

Nonlinear price setting 3

$$Kf_t = F_t\, \left(\frac{1-\xi\, \pi_t^{\frac{1}{\gamma-1}}}{1-\xi}\right)^{-(\gamma-1)}$$

Inverse price dispersion

$$\breve{p}_t = \left((1-\xi)\, \left(\frac{1-\xi\, \pi_t^{\frac{1}{\gamma-1}}}{1-\xi}\right)^{\gamma} + \frac{\xi\, \pi_t^{\frac{\gamma}{\gamma-1}}}{\breve{p}_{t-1}}\right)^{-1}$$