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Stéphane Auray Aurélien Eyquem

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The Macroeconomic Effects of Lockdown Policies*

Stéphane Auray[†] Aurélien Eyquem[‡]

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Abstract

A tractable incomplete-market model with endogenous unemployment risk, sticky prices, real wage rigidity and a fiscal side is calibrated to Euro Area countries and used to analyze the macroeconomic effects of lockdown policies. Modeling them as a shock to the extensive margin of labor adjustment – a rise in separations – produces large and persistent negative effects on output, unemployment and welfare, raises precautionary savings and lowers inflation, in line with early evidence about inflation dynamics. Modeling lockdowns as a shock to the intensive margin – a fall in labor utilization – produces small and short-lived macroeconomic and welfare effects, and implies a counterfactual rise in inflation. Conditional on a lockdown (separation) shock, raising public spending or extending UI benefits by large amounts is much more effective in stimulating the economy than during normal times. Quantitatively however, the ability of such policies to flatten the output and unemployment curves remains limited, even though these policies can alleviate a reasonable share of the aggregate welfare losses from the lockdown.

Keywords: Lockdown, Unemployment, Borrowing constraints, Incomplete markets, Government Spending, Unemployment Insurance.

JEL Class.: D52, E21, E62, J64, J65.

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[†]CREST-Ensai and ULCO; e-mail: stephane.auray@ensai.fr.

[‡]Univ Lyon, Université Lumière Lyon 2, GATE UMR 5824, F-69130 Ecully, France; Institut Universitaire de France; e-mail: aurelien.eyquem@univ-lyon2.fr.

1 Introduction

This paper proposes a tractable heterogeneous-agent (HA) model with endogenous uninsured unemployment risk to investigate the macroeconomic effects of lockdown policies implemented by most governments in response to the spread of the Covid-19 epidemic in the spring of 2020. In addition, it questions the ability of two policy measures, raising government spending or the level of unemployment insurance (UI) benefits, to alleviate the resulting negative macroeconomic and welfare effects.

Research on the macroeconomic effects of the Covid-19 epidemic has burgeoned in the recent weeks. Most contributions offer a mix of SIR (epidemiological) and macroeconomic models to analyze the joint dynamics of the pandemic and macroeconomic variables depending on lockdown policies, and/or derive optimal lockdown policies.[1] A less crowded literature, to which our paper belongs, is concerned with the macroeconomic consequences of lockdown policies and how traditional policy instruments might mitigate them (Bayer, Born, Luetticke, and Müller (2020), Fornaro and Wolf (2020) or Guerrieri, Lorenzoni, Straub, and Werning (2020) among others).

One of the key questions asked by these papers relates to the nature of the shock experienced by most economies around the world during the lockdown: is it a shock to aggregate supply or to aggregate demand? Most papers consider that the effects of lockdowns operate through a lower utilization of the labor used to produce goods, and that lockdown should be modeled as aggregate supply shocks.[2] However, if lockdowns were pure supply shocks, inflation would have risen significantly, which does not seem to have been the case according to the early evidence. Hence, are there mechanisms by which a negative supply shock can exhibit Keynesian features, *i.e.* generate more than proportional drop in aggregate demand, and therefore result in deflationary pressures? Guerrieri et al. (2020) show that models with sectoral heterogeneity can but that one-sector models even with heterogeneous agents can not.

We propose an alternative framework in which the source of households' heterogeneity is the (endogenous) labor-market status, and show that, contrary to Guerrieri et al. (2020)'s claim, one-

[1] See Eichenbaum, Rebelo, and Trabandt (2020a), Eichenbaum, Rebelo, and Trabandt (2020b), Glover, Heathcote, Krueger, and Rios-Rull (2020), Kaplan, Moll, and Violante (2020), Krueger, Uhlig, and Xie (2020) or Piguillem and Shi (2020) among many others.

[2] An exception is Eichenbaum, Rebelo, and Trabandt (2020a), who model lockdowns as a rise in the consumption tax rate. However, they consider a model with flexible prices in which the distinction between factors affecting aggregate and supply is irrelevant. This question is of first-order relevance in models with sticky prices, as suggested by the alternative approach used by the same authors in a more recent paper (Eichenbaum, Rebelo, and Trabandt (2020b)).

sector HA models *can* generate Keynesian supply shocks. The model is a variant of Ravn and Sterk (2017) and features incomplete markets, price and real wage rigidities, as well as search and matching frictions.[3] Three types of households are considered: employed workers, unemployed workers and firm owners. The structure of financial markets produces degenerate wealth distributions but fully preserves the endogenous effects of unemployment risk on precautionary savings. It offers an explicit relation between the dynamics of unemployment, unemployment risk and their effects on the real interest rate through the (usual) smoothing motive and through the (additional) precautionary saving motive.

We propose a monthly calibration of the model based on the average features of Euro Area countries, and feed the model with various shocks aimed at capturing the effects of lockdown policies. A fraction of the labor force is kept out of job, either through the intensive margin (labor utilization falls) or through the extensive margin (job separations rise). In the first case, the lockdown has relatively small and short-lived effects on output and unemployment, and generates small welfare losses. In addition, the inflation rate *rises*, as expected with standard supply shocks. Households face little unemployment risk, which mutes the precautionary motive, the smoothing motive dominates. Demand does not overshoot supply and inflation rises. In the second case, the lockdown has large and persistent negative effects on output and unemployment, and generates large welfare losses. Facing rising unemployment risk, households increase their demand for precautionary savings, which depresses aggregate demand more than supply, and the inflation rate *falls*. Modeled as large separation shocks, lockdowns qualify as Keynesian supply shocks in our model. This result echoes Ravn and Sterk (2017), who show the critical importance of separation shocks in accounting for the effects of the Great Recession on the level of unemployment. Our contribution is really to spell out how to use this kind of model to think about lockdown and fiscal policies.[4] Importantly, taking the perfect-insurance limit of our model reverses the result, as the very same separation shock has inflationary effects in this case, which highlights the critical contribution of imperfect insurance against unemployment risk to our main result.

In light of the early evidence about rising unemployment risk and negative inflation dynamics – discussed in the paper – we consider the second case – lockdown as separation shocks – as our baseline experiment. In this case, output falls by 6% on impact, by construction, and falls

[3]Ravn and Sterk (2020) or Challe (2020) are direct variants of Ravn and Sterk (2017), the former looking at optimal policy and the latter deriving new analytical results.

[4]Our model is very close to Ravn and Sterk (2017) even if they consider a perfectly rigid real wage, while we assume it is sticky.

almost 14% below its steady-state value at the trough. Unemployment jumps at 13.1% on impact – against 7.6% in the steady state – and reaches more than 20% at the trough; inflation falls by 2.8 percentage points in annual terms. Aggregate welfare losses peak at 6.59% of consumption equivalent and reach 0.8% from a lifetime perspective. As an interesting byproduct of our model, we perform a decomposition of the aggregate welfare losses. Less than 10% are endured by employed workers, and roughly 15% fall on newly unemployed households. The 75% remaining losses are born by firm owners.

Given the above results and the context, an additional and equivalently important question is the ability of government policies to reduce the adverse effects induced by lockdown shocks. Indeed, most governments of Euro Area countries have implemented large stimulus packages including more spending on goods and services and UI benefit extensions.[5] We analyze the effects of these two types of policies – raising government spending by 4 percentage points of GDP, and increasing the replacement rate of UI benefits by 10 percentage points – through the lens of our model. As a matter of fact, the introduction of a public sector differentiates our work from Ravn and Sterk (2020) or Challe (2020): government spending and UI benefits are financed by distortionary taxes in the steady state and public debt around the steady state. Raising government spending is almost five times more effective in stimulating output and reducing unemployment conditional on a lockdown shock than during normal times. Further, increasing the generosity of UI benefits has expansionary output effects and reduces unemployment, while it depresses activity and raises unemployment during normal times. Unfortunately, even though these policy shocks are large, the output or unemployment curves are not flattened much. However, the aggregate welfare losses from lockdown shocks are substantially reduced. In addition, we find that changes in policy instrument have potentially important redistributive effects. Raising government spending mostly favors workers (both employed and unemployed) at the expense of firm owners, while raising the UI benefits mostly benefits (newly and old) unemployed workers, and makes firm owners worse off.

In addition to Guerrieri et al. (2020), our paper also share its research questions with a couple of recent paper. Fornaro and Wolf (2020) propose a stylized model to understand the qualitative effects of lockdown and government policies, and stress that lockdowns might induce stagnation traps. Bayer et al. (2020) build a model with heterogeneous agents to quantify the effects of a lockdown and transfer policies in the U.S. While the first paper features walrasian labor markets, the second

[5]For instance, in France, a 100 billion euros package was acted and UI benefits were extended to allow for partial unemployment where workers receive roughly 80 percents of their usual wage income.

introduces an exogenous shock to the employed population to capture the effects of quarantine. Our framework features search and matching frictions and therefore endogenous dynamics of the unemployment rate. As such, it is better suited to understand the labor-market implications of lockdown shocks. In addition, we show that the margins of labor adjustment matter critically for the way lockdowns affect the economy. Our work can thus be seen as an important complement to these papers. More generally, our paper contributes to the recent literature on HANK models. Most of it so far focused on monetary policy.[6] Our interest is more clearly in fiscal policy, a dimension that received relatively less attention.[7] Finally, to the best of our knowledge, only Kekre (2019) investigates the effects of UI benefit extensions in a HANK model. He finds that UI benefit extensions can stimulate the economy, especially if monetary policy is accommodative or if the economy is inefficiently slack, as was the case during the 2008 Great Recession. Our results regarding the effects of UI benefits are clearly in line with his, although we focus on the more recent Covid-19 recession.

The paper is organized as follows. The model is described, discussed and calibrated in Section 2. Section 3 investigates the implications of lockdown policies depending on whether they affect the intensive margin of labor (utilization) or the extensive margin (separations). It also takes a look at the early evidence, that favors the latter assumption rather then the former. Section 4 analyzes the macroeconomic and welfare effects of government policies conditional on a lockdown modeled as a separation shock, and compares their effects with similar shocks hitting the economy at the steady state. Section 5 offers concluding remarks.

2 Model

The model structure borrows from Ravn and Sterk (2017) and features three types of households: employed workers, unemployed workers and firm owners. As will be clear, unemployed workers are financially constrained while employed workers hold zero assets as an equilibrium result. Firm owners receive profits, consume and hold government bonds. The rest of the model is a standard search and matching framework with (sticky) Nash-bargained wages. It sets the stage for the endogenous dynamics of unemployment, that affects the composition of the household sector and the extent of unemployment risk. Finally, a government sector is introduced, that levies distortionary

[6] See Gornemann, Kuester, and Nakajima (2016), Kaplan, Moll, and Violante (2018) or Auclert (2019) among many others, and Bilbiie (2019), Ravn and Sterk (2020), Challe (2020) in more tractable environments.

[7] A notable early exception is Challe and Ragot (2011). More recent contributions include Auclert, Rognlie, and Straub (2018), Hagedorn, Manovskii, and Mitman (2019), or Bayer, Born, and Luetticke (2020).

taxes on labor income and issues bonds to finance UI benefits and expenditure on goods and services.

2.1 Households

The economy is populated with a unit size continuum of households. A proportion $\chi \in [0,1]$ of workers that can either be employed or not, and a proportion $(1-\chi)$ of firm owners receives profits from intermediate-good producers and retailers.

Workers. Household $i \in [0,\chi]$ belongs to the category of workers and maximizes its lifetime utility:

$$\mathrm{E}_t \left\{ \sum_{s=t}^{\infty} \beta^{s-t} u\left(c_s^i, g_s\right) \right\} \tag{1}$$

where β is the subjective discount factor, $c_{i,t} > 0$ the individual level of private consumption and g_t is the aggregate amount of government spending. The budget constraint of worker i is:

$$a_t^i + c_t^i = (1+r_{t-1})\, a_{t-1}^i + \varepsilon_t^i (1-\tau)\, w_t + \left(1-\varepsilon_t^i\right) b_t,\ \ a_t^i \geq 0 \tag{2}$$

where a_t^i is the individual level of private wealth and r_{t-1} its return between period $t-1$ and t. Variable $\varepsilon_t^i = \{0,1\}$ defines the employment status of the worker: when $\varepsilon_t^i = 1$, the worker is employed at the real wage w_t; when $\varepsilon_t^i = 0$, the worker is unemployed and receives $b_t = b_t^r w$, where b_t^r is the replacement rate of UI benefits. The wage income is taxed at the constant rate τ while UI benefits are exempted. The proportion of employed workers among workers n_t and the rate of unemployment u_t are tied by $n_t + u_t = 1$. At the beginning of period t, an exogenous proportion s_t – following an AR1 process – of past employment relationships are destroyed and the pool of unemployed workers within the period is $u_{t-1}+ s_t n_{t-1}$. A fraction f_t of this pool becomes employed before the end of period t. The proportion of employed workers is thus given by:

$$n_t = (1-s_t)\, n_{t-1} + f_t\, (u_{t-1} + s_t n_{t-1}) = (1-\sigma_t)\, n_{t-1} + f_t\, (1-n_{t-1}) \tag{3}$$

where we have used $u_t = 1 - n_t$ and defined $\sigma_t = s_t\,(1-f_t)$ as the net separation rate – s_t being the gross separation rate. The matching function is:

$$m_t = \psi\, (u_{t-1} + s_t n_{t-1})^{\gamma}\, v_t^{1-\gamma} \tag{4}$$

where ψ is a matching-efficiency parameter. It implies that the job-finding rate $f_t \in [0,1]$ and the worker-finding rate $q_t \in [0,1]$ are respectively:[8]

$$f_t = \frac{m_t}{u_{t-1} + s_t n_{t-1}} = \psi \left(\frac{v_t}{u_{t-1} + s_t n_{t-1}} \right)^{1-\gamma} \text{ and } q_t = \frac{m_t}{v_t} = \psi \left(\frac{u_{t-1} + s_t n_{t-1}}{v_t} \right)^{\gamma} \tag{5}$$

From the perspective of a currently employed workers, the Euler equation on the private asset writes:

$$\mathrm{E}_t \left\{ \beta \left(1 + r_t\right) \frac{\left(1 - \sigma_{t+1}\right) u_c \left(c_{t+1}^{i=e}, g_{t+1}\right) + \sigma_{t+1} u_c \left(c_{t+1}^{i=u}, g_{t+1}\right)}{u_c \left(c_t^{i=e}, g_t\right)} \right\} \leq 1 \tag{6}$$

where $\sigma_t = s_t \left(1 - f_t\right)$ is the transition probability from employment to unemployment at the end of period t, $u_c(\cdot)$ is the marginal utility of private consumption and $c_t^{i=e}$ and $c_t^{i=u}$ respectively denote the individual consumption level if employed or not. The above equation holds with equality when employed worker i is not constrained financially, and with inequality when she is constrained. If the private asset is in zero-net supply – which is the case in general equilibrium – employed workers hold exactly zero private assets ($a_t^{i=e} = 0$) as an equilibrium result, and Equation (6) holds with equality. As a result, the distribution of wealth is degenerate, and all employed workers share the same per-capita level of consumption $c_t^{i=e} = c_t^e = (1 - \tau) w_t$. Further, given that $\sigma_t > 0$ and $u_c \left(c_{t+1}^e, g_t\right) < u_c \left(c_{t+1}^u, g_t\right)$ since the consumption of employed workers is larger on average than the consumption of unemployed workers, a precautionary motive arises due to the risk of unemployment. Employed workers face a potentially decreasing future consumption schedule that pushes them to save to self-insure. However, because they can not access private assets to actually precautionary-save, the excess asset demand is entirely reflected in a lower real interest rate. From the perspective of unemployed workers, the Euler equation holds with strict inequality and writes:

$$\mathrm{E}_t \left\{ \beta \left(1 + r_t\right) \frac{\left(1 - f_{t+1}\right) u_c \left(c_{t+1}^{i=u}, g_t\right) + f_{t+1} u_c \left(c_{t+1}^{i=e}, g_t\right)}{u_c \left(c_t^{i=u}, g_t\right)} \right\} < 1 \tag{7}$$

which means that they are constrained, and therefore share an identical level of per-capita consumption $c_t^{i=u} = c_t^u = b_t = b_t^r w$.

Firm owners. The household sector also comprises $(1 - \chi)$ firm owners. Since they are not exposed to idiosyncratic risk, they hold the same amount of private assets and government bonds. Firm owners invest in vacancies, own the retailers and receive the resulting profits. They maximize their lifetime utility:

[8] The bounds for f_t and q_t imply in particular that $v_t \geq 0$, a constraint that might become relevant in the case of very large shocks. See Petrosky-Nadeau and Zhang (2020) for a detailed discussion.

$$\mathrm{E}_t \left\{ \sum_{s=t}^{\infty} \beta^{s-t} \widetilde{u} \left(c_s^f, g_s \right) \right\} \tag{8}$$

where $\widetilde{u}(\cdot)$ differs from the utility function of workers, and c_t^f denotes their per-capita consumption level, subject to the following aggregate resource constraint:

$$a_t^f + d_t + (1-\chi) c_t^f + T_t = (1 + r_{t-1}) a_{t-1}^f + \left(1 + r_{t-1}^d\right) d_{t-1} + \Pi_t, \;\; a_t^f \geq 0, d_t \geq 0 \tag{9}$$

where r_{t-1}^d is the return on government bonds periods between period $t-1$ and t, d_t the aggregate amount of government bonds and T_t a lump-sum tax. The corresponding Euler equations are:

$$\mathrm{E}_t \left\{ \beta (1 + r_t) \Delta_{t,t+1} \right\} \leq 1 \tag{10}$$

$$\mathrm{E}_t \left\{ \beta \left(1 + r_t^d\right) \Delta_{t,t+1} \right\} \leq 1 \tag{11}$$

where $\Delta_{t,t+1} = \beta \widetilde{u}_c \left(c_{t+1}^f, g_{t+1} \right) / \widetilde{u}_c \left(c_t^f, g_t \right)$ is the stochastic discount factor of firm owners. Because firm owners invest in vacancies with a higher return than r_t, they would like to borrow in private assets but can not due to the borrowing constraint. Vacancies can not be arbitraged because the market to trade existing vacancies does not exist. Nevertheless, since firm owners take the return of all assets into account when choosing consumption optimally, the Euler equation on private assets holds with strict inequality:

$$\mathrm{E}_t \left\{ \beta (1 + r_t) \Delta_{t,t+1} \right\} < 1 \tag{12}$$

As a result, firm owners hold exactly zero private assets in equilibrium, $a_t^f = 0$, and the private asset is in zero-net supply in the economy. Firm owners hold government bonds, the corresponding Euler equation holds with equality and prices government bonds:

$$\mathrm{E}_t \left\{ \beta \left(1 + r_t^d\right) \Delta_{t,t+1} \right\} = 1 \tag{13}$$

2.2 Production and wage determination

As in the search and matching literature, each firm is a job. Firms invest in $v_t \geq 0$ vacancies, paying an exogenous unit vacancy cost κ_t – where κ_t follows an AR1 process – out of which a fraction q_t will be filled to produce goods with a linear technology. The aggregate production function is thus:

$$y_t = \chi n_t \xi_t z_t \tag{14}$$

where ξ_t is the rate of labor utilization and z_t the level of productivity. Both are exogenous and follow AR1 processes. Given that the intermediate good is sold on competitive markets at price φ_t, the marginal value of a filled position is:

$$J_t = \varphi_t z_t \xi_t - w_t + \mathrm{E}_t \left\{ \Delta_{t,t+1} \left((1 - s_t) J_{t+1} + s_t V_{t+1} \right) \right\} \tag{15}$$

where the first argument is the net contribution of the marginal worker, his marginal product less his wage bill, and the second argument is the continuation value. The marginal value of a position remaining vacant is:[9]

$$V_t = -\kappa_t + q_t J_t + \mathrm{E}_t \left\{ \Delta_{t,t+1} (1 - q_t) V_{t+1} \right\} \tag{16}$$

and we assume that the free entry condition $V_t = 0$ holds, which implies $q_t J_t = \kappa_t$.[10] The real wage is sticky in the sense that the effective wage is a geometric average of steady-state wage and the (notional) Nash-bargained wage:

$$w_t = w^{\alpha} \left(w_t^n \right)^{1-\alpha} \tag{17}$$

The notional wage w_t^n is determined as the solution to a Nash bargaining problem. It maximizes a geometric average of workers and firm job surpluses:

$$w_t^n = \max_{w_t} S_t^{\theta} J_t^{1-\theta} \tag{18}$$

where θ is the bargaining power of workers, and S_t expresses the marginal value of being employed:

$$S_t = u\left((1 - \tau) w_t, g_t \right) - u\left(b_t, g_t \right) + \beta \mathrm{E}_t \left\{ (1 - \sigma_{t+1} - f_{t+1}) S_{t+1} \right\} \tag{19}$$

where, remember, $\sigma_t = s_t (1 - f_t)$. The solution to this problem implies:

$$w_t^n = \varphi_t z_t \xi_t + \mathrm{E}_t \left\{ \Delta_{t,t+1} (1 - s_t) \kappa_{t+1} / q_{t+1} \right\} - \frac{(1 - \theta) S_t}{\theta (1 - \tau) u_c(c_t^e, g_t)} \tag{20}$$

Retailers buy the intermediate good y_t and then differentiate it into varieties ω to sell them at nominal price $p_t(\omega)$. Let y_t^d denote the total demand for final goods and $y_t^d(\omega)$ the demand for variety ω. Retailer ω sets its price $p_t(\omega)$ to maximize the discounted sum of its expected dividends:

[9]Since vacancies can be filled within the period, the current value of a vacancy depends on the current probability of the vacancy to be filled and the current value of a job filled.

[10]A shown in details by Petrosky-Nadeau and Zhang (2020), taking into account the positivity constraint on vacancies, $v_t \geq 0$, implies that the exact free-entry condition writes $\max(v_t, 0)(q_t J_t - \kappa_t) = 0$.

$$\mathrm{E}_t \left\{ \sum_{s=t}^{\infty} \Delta_{t,s} \left(\frac{p_s(\omega)}{p_s} - \varphi_t - \frac{\phi}{2} \left(\frac{p_s(\omega)}{p_{s-1}(\omega)} - 1 \right)^2 \right) y_s^d(\omega) \right\} \tag{21}$$

The demand for each variety depends on aggregate demand, on the relative price of good ω and the elasticity of substitution between varieties $\eta > 1$, *i.e.* $y_t^d(\omega) = (p_t(\omega)/p_t)^{-\eta} y_t^d$. We denote ϕ as the size of Rotemberg adjustment costs. Optimal pricing conditions are symmetric in equilibrium and imply the following New Keynesian Phillips Curve:

$$\eta - 1 = \eta\varphi_t - \phi\left(\pi_t(1+\pi_t) - \mathrm{E}_t\left\{\Delta_{t,t+1}\pi_{t+1}(1+\pi_{t+1})y_{t+1}/y_t\right\}\right) \tag{22}$$

where $\pi_t = p_t/p_{t-1} - 1$ is the net inflation rate. Finally, total (intermediate and final) profits distributed to firm owners are:

$$\Pi_t = y_t\left(1 - \phi\pi_t^2/2\right) - \chi n_t w_t - \kappa_t v_t \tag{23}$$

2.3 Government, monetary policy, aggregation and equilibrium

The government purchases goods and services g_t and provides unemployment insurance to the unemployed workers. This stream of expenditure is financed using the labor income tax, government bonds and a lump-sum tax paid by firm owners, so that the government's budget constraint writes:

$$\left(1 + r_{t-1}^d\right) d_{t-1} + g_t + \chi u_t b_t = d_t + \tau\chi n_t w_t + T_t \tag{24}$$

The lump-sum tax is used to ensure the sustainability of government debt in the long run using the following policy rule:

$$T_t = d_T\left(dy_{t-1} - dy\right) \tag{25}$$

where $dy_t = d_t/(12y)$ is the ratio of government debt to steady-state annual output. The Central Bank controls the nominal interest rate on private assets i_t^n and sets it according to the following simple Taylor-type rule subject to a zero lower bound (ZLB hereafter) constraint:

$$i_t^n = \max\left(r + \rho_i i_{t-1}^n + (1-\rho_i)\, d_\pi \pi_t, 0\right) \tag{26}$$

The real rate of return on private assets is determined according to the following Fisher equation:

$$1 + r_t = \mathrm{E}_t\left\{(1+i_t^n)/(1+\pi_{t+1})\right\} \tag{27}$$

Finally, the market clearing condition on the market for final goods and services is:

$$y_t \left(1 - \phi \pi_t^2/2\right) = \chi \left(n_t c_t^e + u_t c_t^u\right) + (1 - \chi)\, c_t^f + g_t + \kappa_t v_t \tag{28}$$

A competitive equilibrium in this economy is defined as a situation where, for a given path of fiscal policy instruments $\{g_t, b_t^r\}$: (i) for a given path of prices, households satisfy their optimality conditions and budget constraints, firms and retailers optimize, and the government budget constraint holds along with the lump-sum tax rule, and (ii) for a given path of quantities, prices adjust – subject to Rotemberg costs – so that all markets clear and the Nash bargaining solution for the notional real wage is verified.

2.4 Lockdown policies

How do we account for the effects of lockdown policies in the model? Most contributions on the subject agree that the most likely effect goes through the utilization of labor used to produce goods. In our model, looking at the aggregate production function $y_t = \chi n_t \xi_t z_t$, a reduction in labor used to produce can either be achieved by firms through a fall in labor utilization ξ_t, as in Guerrieri et al. (2020) – the intensive margin – or through a fall in employment n_t – the extensive margin.[11] In the latter case, inspecting the law of motion of employment

$$n_t = (1 - s_t (1 - f_t))\, n_{t-1} + f_t (1 - n_{t-1}) \tag{29}$$

suggests that only a positive shock on s_t, a separation shock, is likely to have large effects on employment n_t. Indeed, an exogenous fall in the job-finding probability f_t – through lower match efficiency for example – can only have minor effects on n_t, since (i) the effect of f_t on $s_t (1 - f_t)$ is small, given the low value of f_t ($f = 0.0608$ in the steady state), and (ii) the effect of f_t on $f_t (1 - n_{t-1})$ is small since $1 - n_{t-1} = u_{t-1}$ is small ($u = 0.076$ in the steady state).

Hence, we consider lockdown policies as either lowering ξ_t (case 1), raising s_t (case 2, our baseline) or a half-half mix of both (case 3). However, the lockdown policies in many European countries were implemented in ways where the majority of employees are furloughed rather than fired, implying that they may return to their employer instead of starting a timely search process. We take this possibility into account by adding the possibility of a 75% drop in the cost of posting vacancies κ_t to the case of an adjustment through the extensive margin of labor (case 4). An

[11] A fall in output can also be achieved by lowering the level of productivity z_t but the effects are perfectly isomorphic to a shock on ξ_t, provided the persistence and size of the shocks are identical.

additional case with perfect insurance (case 5) is also investigated to contrast the implications of imperfect insurance.

What about the timing of the shocks? We consider the model to be in the steady state in February 2020, and assume a lockdown shock starting in March 2020. We calibrate the size of the lockdown shock to match the early evidence about the output costs of the lockdown and target a 6 percent fall of output below its steady-state value. The size of the lockdown shocks is adjusted so that all cases produce a similar drop in output on impact. We consider a duration of 2 months in all our experiments, with a constant lockdown shock size. After lockdown policies are lifted, we assume that their intensity decays by 50% each month. Given that the shocks are extremely large, linear approximations are likely unreliable, so we simulate the model non-linearly.[12]

2.5 Calibration

We calibrate the model based on key features of the average Euro Area economy.

Preferences. We start by specifying a utility function for workers and for firm owners. Government expenditure are introduced in the utility function of households to introduce potential interactions between public and private good dynamics. Let us define

$$\tilde{c}_t^i = \left((1-\Upsilon)\left(c_t^i\right)^{\nu} + \Upsilon g_t^{\nu}\right)^{\frac{1}{\nu}} \tag{30}$$

for $i = \{e, u, f\}$ as an aggregate consumption bundle that combines private and public consumption goods and services, and assume that both types of consumption are complement, *i.e.* $\nu < 0$. This assumption has already received strong empirical support in the literature (see Bouakez and Rebei (2007) or Auray and Eyquem (2019)), but is even more relevant in the context of a pandemic, especially if public consumption contains an important share of health expenditure. Further, the utility function of workers is $u(c_t^i, g_t) = \log(\tilde{c}_t^i)$ for $i = \{e, u\}$ and, following Challe (2020), the utility function of firm owners is $\tilde{u}(c_t^f, g_t) = (\tilde{c}_t^f)^{1-\rho_f}/(1-\rho_f)$, where firm owners are less risk-averse than workers, $\rho_f < 1$.

Calibration for the households. The model is monthly. The discount factor is $\beta = (0.993)^{1/3} = 0.9977$, which pins down the steady-state real rate in the baseline model to $r = 0.1654\%$

[12] The model is simulated under perfect foresight using a Newton-type algorithm. The algorithm is a built-in routine of Dynare (see Adjemian, Bastani, Juillard, Karamé, Mihoubi, Perendia, Pfeifer, Ratto, and Villemot (2011)). It is an application of the Newton-Raphson algorithm that takes advantage of the special structure of the Jacobian matrix in dynamic models with forward-looking variables. The details of the algorithm are explained in Juillard (1996).

monthly or 2% annually.[13] Given the precautionary motive implied by unemployment risk, employed workers would like to self-insure and therefore demand more private assets than in a perfect-insurance economy. Since private assets are in zero-net supply, the resulting excess demand of private assets is reflected in a lower equilibrium real interest rate than the interest rate implied by the subjective interest rate, that is $r < 1/\beta - 1$ ($0.1654\% < 0.2344\%$). The equilibrium real rate is obtained by setting the nominal rate at $i^n = r$, given that steady-state inflation is null.

In the steady state, unemployed households are 10.68% poorer on average than employed workers: $c^e = 0.5351 > c^u = 0.4780$. Put differently, the average drop in consumption upon job loss is roughly 10.5%. This is slightly lower than the number proposed by Ravn and Sterk (2017) for the U.S. (11.7%). As in Challe, Matheron, Ragot, and Rubio-Ramirez (2017), who propose a model with a comparable structure of the household sector, we set the share of firm owners to 10%, that is $\chi = 0.9$. In addition, following Challe (2020), we consider that firm owners are less risk-averse than workers with $\rho_f = 0.25$. This calibration, along with the calibrated real wage stickiness parameter, delivers a wage elasticity with respect to labor productivity of roughly 1/3. The parameter governing the elasticity of substitution between private and public goods is set to $\nu = -2/3$, implying an elasticity of 0.6, as estimated by Auray and Eyquem (2019). Last, the government spending utility weight Υ is calibrated in accordance with "Samuelson's principle "following Bilbiie, Monacelli, and Perotti (2019) or Auray, Eyquem, and Gomme (2018). For the given calibrated value of g (see below), Υ is set to equalize the households' weighted average marginal utility of the public good to the weighted average marginal utility of the private good. It gives $\Upsilon = 0.1150$.

Calibration for firms and monetary policy. We set the steady-state monopolistic competition markup of retailers to 25%, implying $\eta = 5$. This value belongs to the lower bound of recent mark-up estimations for a subset of European countries proposed by a study by the Bundesbank (2017). In addition, the Rotemberg parameter is set so as to equate the coefficients of the (linearized) Phllips Curves under Calvo and Rotemberg formulations of the NKPC. A 0.75 quarterly probability of not resetting prices in the Calvo set-up implies an equivalent 0.9 monthly probability. Hence, the equivalent Rotemberg parameter is given by $\phi = (\eta - 1)\, 0.9/\left((1 - 0.9)\,(1 - \beta 0.9)\right) = 443$. For the monetary policy rule, we follow Christoffel, Kuester, and Linzert (2009), who rely on the estimates of Smets and Wouters (2003), and set the elasticity of the nominal rate to inflation to $d_\pi = 1.5$, and the persistence parameter to $\rho_i = 0.85$.

[13] An alternative calibration is investigated in the Appendix, with a steady-state real rate that is very close to zero, so that the ZLB on the nominal rate binds when shocks lowering the nominal rate hit.

Calibration for the government. We calibrate $g/y = 0.1928$ based on Euro Area data at the end of 2019 provided by the Area Wide Model dataset.[14] Further, the steady-state replacement rate is $b^r = 0.6$ (see Esser, Ferrarini, Nelson, Palme, and Sjüberg (2013)) and the debt-to-annual GDP is set according to the last available data (2018) according to Eurostat for the Euro Area to $d/(12y) = 0.86$. These targets imply adjusting the steady-state labor income tax to $\tau = 0.3173$. The feedback parameter of the lump-sum tax rule is set to $d_\tau = 0.05$, the lowest possible value that is consistent with long-run debt sustainability.[15]

Calibration for the labor market. On the labor market, we also seek to replicate key features of a typical Euro Area country. The elasticity of matches with respect to unemployment is set to $\gamma = 2/3$, which is in the range of estimates proposed by Pissarides and Petrongolo (2001). Based on the labor-market transition probabilities estimated by Elsby, Hobijn, and Şahin (2013), we impose a monthly net separation rate of $\sigma = 0.005$ and adjust the job-finding rate to deliver a 7.6% unemployment rate,[16] implying $f = 0.0608$, which also lines up with the numbers reported by Elsby, Hobijn, and Şahin (2013). Along with Challe (2020), we consider a high degree of wage stickiness, $\alpha = 0.95$, to match the elasticity of the real wage to labor productivity. As suggested by Christoffel, Kuester, and Linzert (2009) and references therein, we target a steady-state worker-finding probability of $q = 0.7^3 = 0.3430$. This transition probability, together with the targeted unemployment rate, implies adjusting the matching efficiency parameter to $\psi = 0.1082$. Finally, the steady-state vacancy posting cost parameter κ remains to be pinned down. Along with the rest of the calibration – the worker-finding probability q in particular – it determines the bargaining power of workers θ. We target a relatively high bargaining power for workers, $\theta = 0.75$, so that the model produces a reasonable relative volatility of unemployment with respect to output when the model is driven by stochastic productivity shocks.[17] This implies setting $\kappa = 0.1215$, slightly above the values typically used to represent the U.S. economy (see Hagedorn and Manovskii (2008)).

3 The macroeconomic effects of lockdown policies

Figure 1 reports the effects of lockdown shocks on our model economy.[18] As explained above, we consider 4 sets of shocks: a negative shock to labor utilization (ξ_t), a positive shock to the separation

[14] See Fagan, Henry, and Mestre (2001) for details and `https://eabcn.org/page/area-wide-model` for the data.

[15] Lump-sum taxes serve no other purpose in our model economy.

[16] This number equates the unemployment rate reported by the AWM database in December 2019.

[17] Christoffel, Kuester, and Linzert (2009) find a relative volatility of 5.36 in euro area data. Our model delivers a 5.42 relative volatility when driven by productivity shocks with persistence $0.95^{1/3}$ and standard deviation 0.7%.

[18] A list of all the equations of the model is provided in the Appendix.

rate (s_t), a mix of both shocks, and a positive separation shock along with a negative shock on the vacancy posting cost (κ_t). In the second case, our baseline, we also compare the dynamics of the economy under perfect insurance among workers. As explained in Challe (2020), imposing $c_t^e = c_t^u$ brings the model as close as possible to a RANK economy.[19] Figure 1 tracks the dynamics of key macroeconomic aggregates, along with the welfare losses from the lockdown policies over various horizons T, denoted ζ_T. We adopt a utilitarian approach to the welfare criterion, and consider the Hicksian consumption equivalent that solves:

$$\sum_{s=0}^{s=T} \beta^s \left(\mathcal{U}\left(c_s^e, c_s^u, c_s^f, g_s\right) - \mathcal{U}\left(c^e\left(1-\zeta_T\right), c^u\left(1-\zeta_T\right), c^f\left(1-\zeta_T\right), g\right)\right) = 0 \tag{31}$$

where T is the horizon over which welfare losses are computed, given that the economy is in the steady state in period 0 and

$$\mathcal{U}\left(c_t^e, c_t^u, c_t^f, g_t\right) = \chi\left(n_t \log \tilde{c}_t^e + u_t \log \tilde{c}_t^u\right) + (1-\chi)\left(\tilde{c}_t^f\right)^{1-\rho_f}/(1-\rho_f) \tag{32}$$

where remember, $\tilde{c}$ refers to a bundle of private and public goods. We also compute the individual welfare losses of each of the three types of agents at various horizons T, respectively denoted ζ_T^e, ζ_T^u and ζ_T^f. Finally, since these losses do not account for the situation of workers that were previously employed and lost their jobs, we also compute the welfare losses ζ_T' using constant proportions of employed and unemployed households instead of time-varying ones in Equation (32). The difference between ζ_T and ζ_T' is therefore entirely driven by the changes in the composition of the labor force, and measures the losses from recently unemployed workers – diminished from the welfare gains from recently employed households. For the sake of readability, we only report the aggregate welfare losses on our Figures but display the decomposition of welfare losses in Table 1.

– Figure 1 about here –

3.1 Baseline results

Let us first comment the effects of our baseline scenario (solid black line on Figure 1), where lockdown policies raise the separation rate. By construction, the response of GDP is -6 percents on impact. However, the overall drop in GDP is much larger because the lockdown is lifted gradually,

[19]Technically, the perfect insurance economy implies setting $b_t = b^r w_t$ with a value of b^r that yields $c^u = c^e$, so that the consumption levels *and* fluctuations of employed and unemployed workers are identical, *i.e.* $c_t^u = c_t^e$. In addition, the RANK model also requires adjusting the discount factor to deliver an identical steady-state level of the real interest rate.

which prevents some workers to going back on the labor market quickly. In addition, the law of motion of employment shows that employment evolves very persistently when, as in our calibration, the net separation rate σ_t is relatively small. The overall drop in GDP thus reaches 13.6%. Consumption falls as well, not so much because the consumption of workers remaining employed falls, but because many workers lose their job. This composition effect lowers consumption by 17.4 percents at the trough. The reason for the lower fall in GDP compared to consumption is that GDP includes the saved vacancy posting costs, since vacancies fall dramatically on impact before jumping after the lockdown is lifted. The unemployment rate rises at 13.1 percents on impact, and reaches a peak of 20.2 percents. The marginal profitability of matches falls, pushing down the bargained notional real wage and thus the effective real wage, although by less than 1.5 percents. Because the distribution of UI benefits explodes and because the labor income tax base shrinks, a large primary public deficit arises: from 2.5 percents of steady-state output on impact – a 4.9 pp increase with respect to it steady-state value – to 9 percents at the trough.

The dynamics of inflation is of the utmost interest. Indeed, within a standard RANK model, a fall in aggregate supply induces a *rise* in inflation and thus a *rise* in the nominal rate. The chief reason is that aggregate demand does not fall more than proportionally to aggregate supply. Indeed, given the fall in income and consumption, the RANK Euler equation only reflects the desire of the representative household to save or borrow to smooth consumption. In our HA model, this motive is present, but an additional motive determines the equilibrium real rate: the asset demand for a precautionary motive. When unemployment is expected to rise, workers face a potential decrease in their consumption path that depresses their consumption and raises their desired savings. The increase in precautionary savings depresses aggregate demand further, which leads the inflation rate, and the nominal interest rate to *fall*.

To see this more clearly, let us use the Euler equation of employed workers, which is the key equation of our model. On the one hand, imagine that consumption levels are both constant, for instance because the real wage is infinitely sticky and therefore constant, $c_t^e = c^e$ and $c_t^u = c^u$. Further, as in our baseline experiment, $g_t = g$. These assumptions mute the smoothing motive and the Euler equation writes:

$$\mathrm{E}_t \left\{ \beta \left(1 + r_t\right) \frac{\left(1 - \sigma_{t+1}\right) u_c\left(c^e, g\right) + \sigma_{t+1} u_c\left(c^u, g\right)}{u_c\left(c^e, g\right)} \right\} = 1 \tag{33}$$

Since $c^e > c^u$ in the steady state, $u_c\left(c^e, g\right) < u_c\left(c^u, g\right)$. As such, any shock that raises the expected separation rate $\sigma_{t+1} > \sigma$ raises the right term of the left-hand side, which then requires $1 + r_t$ to *fall* for the Euler equation to hold. On the other hand, imagine now that there is perfect insurance within our model, *i.e.* that $c_t^e = c_t^u$, then the probability of losing ones job σ_{t+1} disappears from the Euler equation, since this event is not attached to any consumption loss:

$$\mathrm{E}_t \left\{ \beta \left(1 + r_t\right) \frac{u_c\left(c_{t+1}^e, g\right)}{u_c\left(c_t^e, g\right)} \right\} = 1 \tag{34}$$

In this case, the precautionary motive is muted. A shock that lowers current consumption relative to future consumption raises $u_c\left(c_t^e, g\right)$ compared to $u_c\left(c_{t+1}^e, g\right)$, the right term of the left-hand side drops, which requires $1 + r_t$ to *rise* for the Euler equation to hold. If a shock produces an initial drop in consumption and then a monotonic return to the steady state, the real rate rises. If a shock produces a hump-shaped response of aggregate consumption, the real rate falls initially until the trough is reached, and then rises when aggregate consumption reverts.

The above thought experiment shows that, in the general case, a supply shock with adverse effects on unemployment and wages will trigger these two effects together. If the shock raises σ_t significantly and if the real wage is sticky enough, the precautionary motive is strong, which lowers r_t. Aggregate demand is more depressed than supply, expected inflation falls which implies a drop in current inflation π_t. The monetary policy rule then produces a fall in the nominal rate. On the contrary, if the shock has little impact on σ_t, if the real wage exhibits little stickiness, or if there is perfect insurance among workers, the precautionary motive is weak or muted, and the consumption smoothing motive is the main or the single driver of the real rate. In this case, aggregate demand does not exhibit excess fluctuations, and inflation rises along with the nominal interest rate.

In our baseline scenario (separation shock), the precautionary motive is strong. The model implies that aggregate demand is depressed more than supply, leading the shock to have even larger negative macroeconomic effects and generating deflationary pressures. These characteristics qualify the shock as a Keynesian supply shock. This result contrasts with the assertion of Guerrieri et al. (2020), who conclude that Keynesian supply shocks can not arise in one-sector models, even with incomplete markets. The key difference with Guerrieri et al. (2020) is that the source of income heterogeneity in our model stems from the (endogenous) labor-market status of households, which has important implications for the Euler equation that eventually determines the real rate of the economy. According to our simulations, inflation drops by 2.8pp in annual terms, before reverting slowly to its steady-state value.

3.2 Alternative shocks or model assumptions

Modeling lockdown policies as a shock to labor utilization (dotted blue line on Figure 1) as in Guerrieri et al. (2020) delivers very different results. An adjustment of the amount of labor through the intensive margin yields less persistent effects on virtually all variables – the 6% impact drop in output is also the trough of the recession – and destroys little jobs. The shock marginally raises unemployment and lowers the real wage, pushing employed households to increase their asset demand for the smoothing motive, as explained above. Since consumption falls on impact and reverts monotonically to the steady state, the real rate increases. Aggregate demand falls less than supply, making this type of shock a standard negative supply shock with inflationary consequences.

Unsurprisingly, a scenario in which lockdown policies push firms to adjust equally through the extensive and the intensive margin (dotted black line on Figure 1) roughly averages the effects of both shocks: the rise in unemployment is milder, peaking at 14%, output falls by 8% at the trough and the shock is mildly inflationary.

When lockdowns affect the extensive margin (through separations) but rematch is made less costly because the vacancy posting cost falls by 75% (dashed line on Figure 1), the effects of the lockdown are also attenuated, but less than in the case where both margins of labor adjustment are considered: output falls by 10% at the trough, unemployment peaks at 17% and the shock is initially deflationary before inflation overshoots is steady-state value and returns to its long-term value from above.

Last, when the baseline experiment (separation shock) is conducted in the perfect-insurance model, the effects on output and unemployment dynamics are roughly similar, but since the precautionary motive is muted, aggregate demand falls less than supply. The separation shock is thus *inflationary* rather than *deflationary*.

Last but not least, the welfare losses from the lockdown shocks are substantial. Table 1 (first column of each panel) reports the aggregate welfare losses resulting from each experiment, both at their (own) peak and from a lifetime perspective. They peak at 6.59 percents of consumption equivalent in the baseline experiment, and 2.61 percents if only the intensive margin of labor is adjusted. The half-half case produces welfare losses peaking at 3.85 percents. If the vacancy posting cost falls together with the rise in separations, the peak of welfare losses is 5.03 percents, more than 1.5pp below the peak in the baseline case. Finally, in the counterfactual model with perfect insurance, welfare losses peak at 6.40 percents.

Table 1 (other columns of each panel) also reports the welfare losses from each type of household and the welfare losses computed based on steady-state weights in the aggregate utility function. First, as long as government policies remain unchanged, the welfare losses from the typical unemployed worker are zero – except of course in the case of perfect insurance among workers – because UI benefits remain constant. The individual losses of employed workers are relatively small, peaking at 0.64% in the baseline case, and, once weighted using the proportion of employed workers in the total population, represent less than 10% of the aggregate welfare losses. Firm owners, on the contrary, bear the largest share of the total losses: once weighted by their proportion in the economy ($1-\chi = 10\%$), their losses peak at 4.97%. Second, neutralizing the weighting effect lowers the aggregate welfare losses by roughly 1pp in the baseline case, suggesting that the contribution of newly unemployed workers to the total welfare losses – net from the gains of newly employed workers – is around 15% of the aggregate losses. When the lockdown shock affects the intensive margin, since the unemployment effect is negligible, this last effect is basically nil. Combined with the fact that individual losses are roughly two times smaller in this case, the aggregate welfare losses are more than half those of the baseline case. Finally, in the case of a perfect insurance economy, the individual welfare losses of all workers (unemployed or not) are identical, the composition effect is neutralized ($\zeta_T' = \zeta_T$), and the welfare losses of firm owners are slightly magnified.

In the Appendix, we show that our results are either insensitive or strengthened by alternative assumptions about monetary policy, whether it is considering an alternative calibration that brings the economy closer to the ZLB or a more aggressive monetary policy.

3.3 Early evidence from the data

The above discussion suggests that the critical point to capture the effects of lockdown policies in our model lies in the adjustment margin of labor utilization by firms. If the lockdown affects the utilization of labor, the intensive margin, then the negative effects of lockdown policies on output, unemployment and welfare are moderate, and lockdowns have inflationary consequences. If the lockdown affects the number of employed workers, the extensive margin, then the negative effects are critically larger, and the shock induces deflationary pressures.

It is still early to be assertive about empirical evidence. First, available data are subject to large revisions and should therefore be read with caution. Second, a variety of measurement issues are present. For instance, lockdown policies push unemployed workers to declare themselves as being out of the labor force rather than as unemployed, because they are technically not available to take a job immediately – not because they do not want to but because the lockdown prevents them to. Another example is the accuracy of consumption price indices. During lockdown episodes, consumers are likely to shift consumption expenditure quite substantially and the computation of CPIs using usual weights might bias the measures of aggregate inflation. In addition, energy prices have fallen dramatically but for reasons that are orthogonal to lockdown policies. Nevertheless, early observations tend to support our claim that lockdown policies are deflationary, and best modeled as shocks to the extensive margin of labor.

Let us first focus on unemployment. In many countries, many jobs have already been destroyed – not just suspended or put on freeze. For instance, according to current numbers, Switzerland already counts more than 700 000 jobs destroyed, Spain more than 900 000, predictions of the Bank of Ireland – as of early April – suggest that a 3-months lockdown might bring the unemployment rate to more than 25 percents at the end of the second quarter of 2020.[20] A more recent and more conservative prediction by the Banque de France is that unemployment will jump to 11.5% in France by mid-2021.[21] Current OECD unemployment forecasts for the Euro Area for 2020Q4 range from 11.1% to 12.6%, while the unemployment rate was 7.6% at the end of 2019.[22] In any case, it is seriously doubtful that unemployment will remain unaffected at all, and more likely that a substantial fraction of the adjustment to lockdown policies has occurred (or will occur) through separations.

Regarding the dynamics of inflation, a recent blog post by IMF Chief Economist Gita Gopinath reports that inflation dynamics (reproduced in the top panel of Figure 2) has rather been negative around the world – except for food items – in spite of a large negative supply shock and large stimulus packages adopted by many countries, that both should have had inflationary effects. In particular, notice that the top panel of Figure 2 shows declining core CPI inflation rates, suggesting that the deflationary pressures were not (only) driven by the recent fall in commodity prices, and large enough to overturn the rise in food inflation. Focusing more specifically on the Euro Area, the bottom panel of Figure 2 shows that the HICP inflation fell from 1.3% in February 2020 to 0.1% in May 2020, its lowest value over the last 3 years. The core inflation CPI inflation rate also displays a clear decline, though less important quantitatively speaking.

Last but not least, Del Negro, Lenza, Primiceri, and Tambalotti (2020) track "the post-Covid

[20]See https://www.centralbank.ie/docs/default-source/publications/quarterly-bulletins/qb-archive/2020/quarterly-bulletin---q2-2020.pdf.

[21]See https://publications.banque-france.fr/en/macroeconomic-projections-june-2020.

[22]See https://data.oecd.org/unemp/unemployment-rate-forecast.htm.

evolution of key U.S. macroeconomic variables" and compare it "to their expected dynamics based on a VAR estimated on pre-Covid data" with a special focus on inflation dynamics, as they correctly claim that they are particularly informative about the relative importance of demand and supply effects at work. According to their conditional forecast exercise driven by an increase in the unemployment rate from less than 4% to more than 15%, the core CPI inflation rate in the U.S. could fall from slightly above 2% to close-to-negative values, around 0%, and the GDP deflator inflation rate from 2% to −2%.

As already mentioned, these early signs are not robust evidence. However, the model we propose, driven by a large separation shock, generates negative inflation dynamics and implies a large adjustment of the extensive margin of labor, in line with the above early signs.

4 Discretionary government policies

Figure 3 reports the dynamics of our economy when government policies are active. More precisely, in response to the lockdown shock, the government raises spending to steady-state GDP by 4pp (g_t/y from 0.198 to 0.238, dotted line) in response to the shock, or it raises the replacement rate of UI benefits by 10pp (b_t^r from 0.6 to 0.7, dashed line).[23] In both cases, the policy instrument is raised for the duration of the lockdown and decays at the same rate as the lockdown. Figure 3 also reports the baseline case with passive policies, *i.e.* $g_t = g$ and $b_t^r = b^r$, for a comparison.

– Figure 3 about here –

Panel (a) of Figure 3 reports the level effects of the lockdown shock combined or not with government policies, while Panel (b) reports the net effects of government policies conditional on the lockdown shock, against their effects when the same government policy shocks hit the economy at the steady state.

First, raising government spending conditional on the lockdown shock lowers the fall in output, as well as the rise in unemployment. In fact, Panel (b) of Figure 3 shows that government spending is much more effective in stimulating output and reducing unemployment conditional on a lockdown episode than when the spending shock hits at the steady state. The chief reason is that a lockdown

[23]The magnitude of both policy measures is realistic in light of the recent developments. For instance, France announced a total stimulus package of 100 billions of euros, representing approximately 4.25 percent of GDP. Other governments of countries within the Euro Area have announced similar packages. In addition, most Euro Area countries have implemented partial unemployment schemes by which workers that are temporarily locked down receive a substantially larger fraction of their labor income than during usual unemployment spells.

episode generates large amounts of slack on the labor market. In our model, the matching function implies that the job-finding probability is a concave function of labor-market tightness: a shock that raises tightness has larger effects on the job-finding probability – and thus on employment and output – when it occurs at a lower absolute value of tightness (see Michaillat (2014)). Hence, a government spending shock lowers unemployment more when conducted in a situation of slack labor markets, which raises output through the rise in employment. Employment contributes directly by allowing firms to produce more output, and indirectly through the fall in unemployment risk and the associated rise in consumption. Panel (b) of Figure 3 indeed shows that output increases much more when the shock hits conditional on a lockdown shock than at the steady state. In addition, private consumption is less crowded out because of the fall in unemployment risk and the associated reduction in precautionary savings. Quantitatively speaking, the present-value output government spending multiplier is 0.22 around the steady state and 1.01 conditional on a lockdown shock. However, the impact multiplier conditional on a lockdown is much lower, around 0.25, which explains why the increase in government spending has such a small effect on output in Panel (a) of Figure 3.

Further, the spending shock substantially reduces the resulting welfare losses, from 6.59% (at the peak) with constant spending to 5.13% with a 4pp rise in the spending ratio. On the one hand, both types of workers benefit from this policy through the rise of g_t in their utility function. At the peak of aggregate welfare losses, employed and unemployed workers respectively experience a 1.24% and 1.46% welfare *gain*. However, the welfare losses from newly unemployed workers (measured by $\zeta_T - \zeta'_T$) are only marginally lower than in the case of constant government spending. On the other hand, firm owners experience larger individual welfare losses, explained by the inflationary impact of the spending shock – and the associated adjustment costs – and by the lower fall in the real wage. Both effects contribute to depress aggregate profits and thus the consumption of firm owners more than under a passive policy.

Second, the results regarding UI benefits are even more striking, as the shock has different *qualitative* implications depending on whether the shock hits conditional on a lockdown shock or at the steady state. At the steady state, a rise in UI benefits raises the outside option of workers, the real wage increases, vacancy creations are depressed, as well as employment and output. Conditional on a lockdown shock that lowers the level of the real wage, the increase in UI benefits attenuates this dynamics. As such, it helps workers sustain larger levels of consumption: directly through higher UI benefits for unemployed workers, and indirectly through lower wage losses for employed workers.

It therefore stimulates output instead of depressing it, as it is the case when rise in UI benefits hits at the steady state. Implementing the UI benefit policy conditional on a lockdown shock lowers the resulting peak of welfare losses from 6.59% to 5.89%. Not surprisingly, this policy strongly favors the unemployed workers, experiencing a welfare gain of 5.86% at the peak of aggregate welfare losses. The effects of rising UI benefits on the real wage also reduce the welfare losses from employed workers, as their losses drop from 0.64% to 0.42%, at the peak of aggregate welfare losses. The welfare losses of newly unemployed workers, proxied by $\zeta_T - \zeta'_T$, are much more reduced by this policy, as the consumption loss upon unemployment spells is temporarily much lower. Last, firm owners experience larger welfare losses, because of the impact of (less negative) wage dynamics on profits.

Our results suggest that both types of policies may stimulate the economy more conditional on a lockdown shock than during normal times. Nevertheless, from a quantitative perspective and even though these are large swings in policy instruments, the amount of output and employment stimulation they produce remains too modest to significantly flatten the negative output curve and the positive unemployment curve. But it does not necessarily mean that these policies are useless. Indeed, our results indicate that both policies attenuate the aggregate welfare losses resulting from the lockdown shock. Finally, we show that both policies convey different redistributive effects: a rise in government spending favors workers (unemployed and employed) against firm owners while a rise in UI benefits mostly favors unemployed workers, and slightly improves the situation of employed workers against firm owners.

– Table 1 about here –

In the Appendix, we show that the effects of government policies are either not affected by the ZLB, because the ZLB episode is relatively short-lived, or magnified by an aggressive monetary policy. These results suggest that, in our model, the interaction between a more aggressive monetary policy and active government policies is the most effective combination to flatten the output and unemployment curves resulting from the lockdown shock – albeit by a limited amount, and to reduce the resulting welfare losses.

5 Conclusion

This paper developed a tractable HA model with uninsured unemployment risk and borrowing constraints. Our assumptions produced a degenerate wealth distribution that greatly simplified the model. Calibrated to represent an average Euro Area economy and hit with a combination of shocks that aimed at reproducing the effects of the lockdown on the economy, it helped us clarify the differentiated macroeconomic effects of lockdowns depending on whether they imply an adjustment of labor through the intensive margin (relatively small output effects, little if any unemployment effects, small welfare losses along with inflationary pressures) and through the extensive margin (large output, unemployment, welfare losses along with deflationary pressures). In the latter case, the expected rise in unemployment led households to demand more assets to precautionary-save. Aggregate demand fell more than supply, lowering the inflation rate as well as the nominal interest rate, making the lockdown shock a Keynesian supply shock. We also discussed early evidence about unemployment and inflation dynamics. Both suggested that, within the scope of our model, the transmission mechanism implied by an adjustment of the extensive margin was a more plausible representation of lockdown policies.

Finally, we discussed the effects of raising government spending and extending UI benefits, a quite novel exercise in the literature of HANK models. These policies were more effective in stimulating output conditional on a lockdown shock than at the steady state, and conveyed potentially different distributional consequences. Quantitatively speaking, the effects of these (large-scale) policies was however not large enough to significantly flatten the output and unemployment curves, in spite of their ability to flatten the aggregate welfare loss curve.

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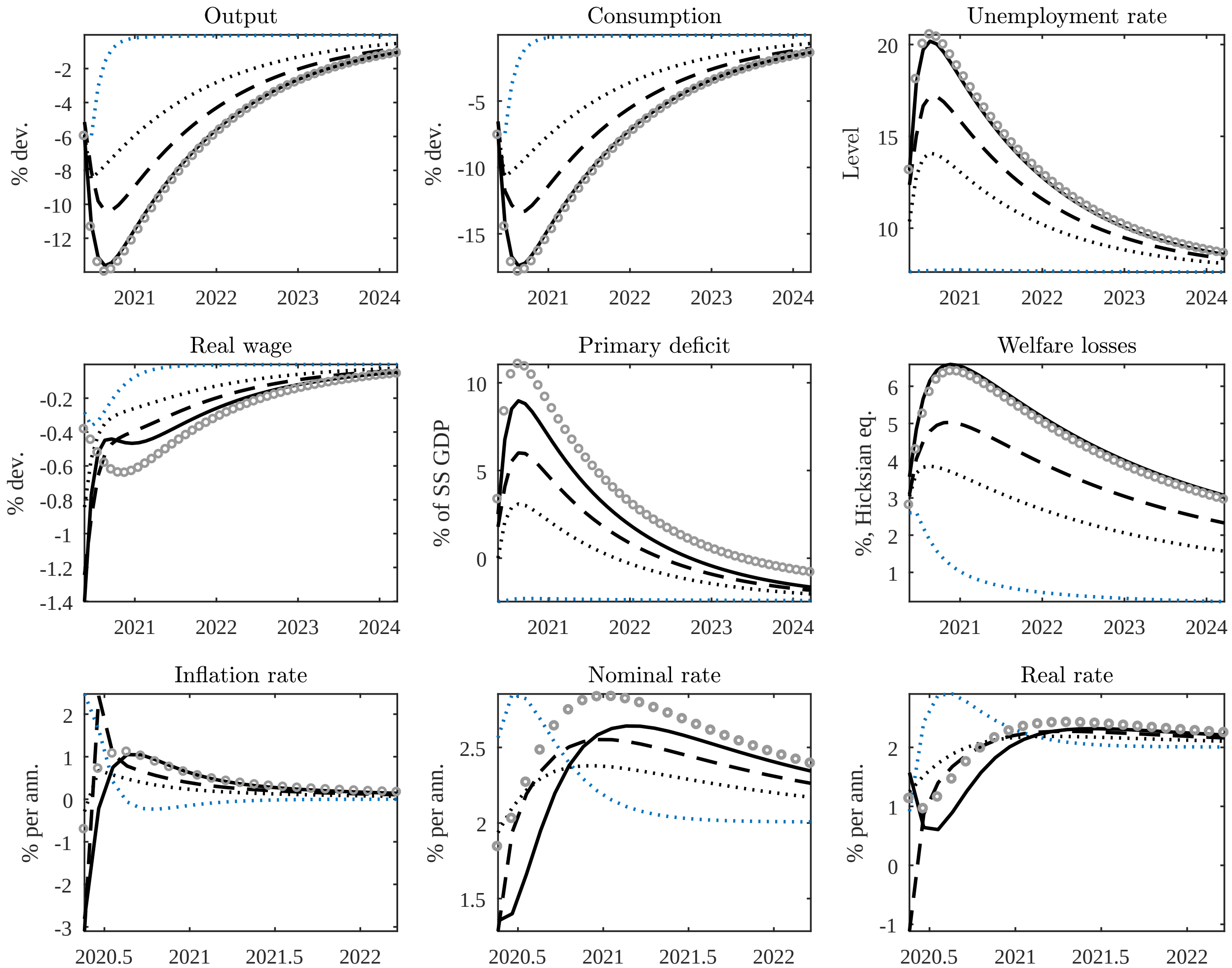
Figures and Tables

Table 1: Welfare losses, in percents

	Peak ($p = \arg\max\{\zeta_t\}_{t=0}^{t=\infty}$)					Lifetime (∞)				
	ζ_p	ζ_p^e	ζ_p^u	ζ_p^f	ζ_p'	ζ_∞	ζ_∞^e	ζ_∞^u	ζ_∞^f	ζ_∞'
Passive gvt policies										
$\uparrow s_t$ - baseline	6.59	0.64	0.00	49.73	5.58	0.79	0.07	0.00	7.07	0.66
$\uparrow s_t$ - perf. insurance	6.40	0.55	0.55	56.16	6.40	0.72	0.07	0.07	7.64	0.72
$\downarrow \xi_t$	2.61	0.33	0.00	25.78	2.61	0.05	0.01	0.00	0.50	0.05
half $\uparrow s_t$+ half $\downarrow \xi_t$	3.85	0.54	0.00	31.29	3.36	0.40	0.04	0.00	3.57	0.33
$\uparrow s_t$+ $\downarrow \kappa_t$	5.03	0.67	0.00	38.50	4.25	0.60	0.06	0.00	5.27	0.49
Raise g_t										
$\uparrow s_t$ - baseline	5.13	−1.24	−1.46	51.08	4.16	0.70	−0.03	−0.08	7.11	0.57
Raise b_t^r										
$\uparrow s_t$ - baseline	5.90	0.42	−5.36	51.63	5.30	0.76	0.06	−0.25	7.26	0.65

Note: the horizon of the peak, p, is case-specific.

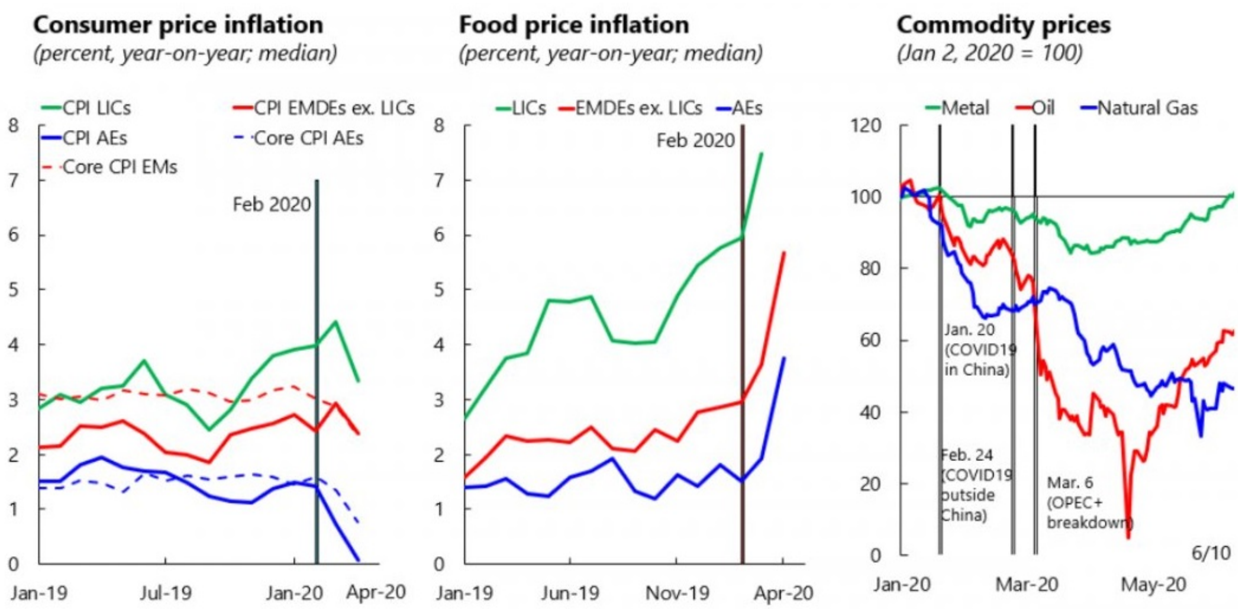
Figure 1: Macroeconomic effects of lockdown policies



Solid black: separation shock (baseline). Dotted black: mix of separation and labor utilization shock. Dotted blue: labor utilization shock. Dashed black: separation and vacancy cost shock. Circled grey: separation shock under perfect insurance. The horizon is shorter for inflation, the nominal and the real interest rate.

Figure 2: Recent trends in inflation

(a) A global perspective



Note: Taken from https://blogs.imf.org/2020/06/16/the-great-lockdown-through-a-global-lens/?utm_medium=email&utm_source=govdelivery. See the original picture for details and sources.

(b) Inflation in the Euro Area

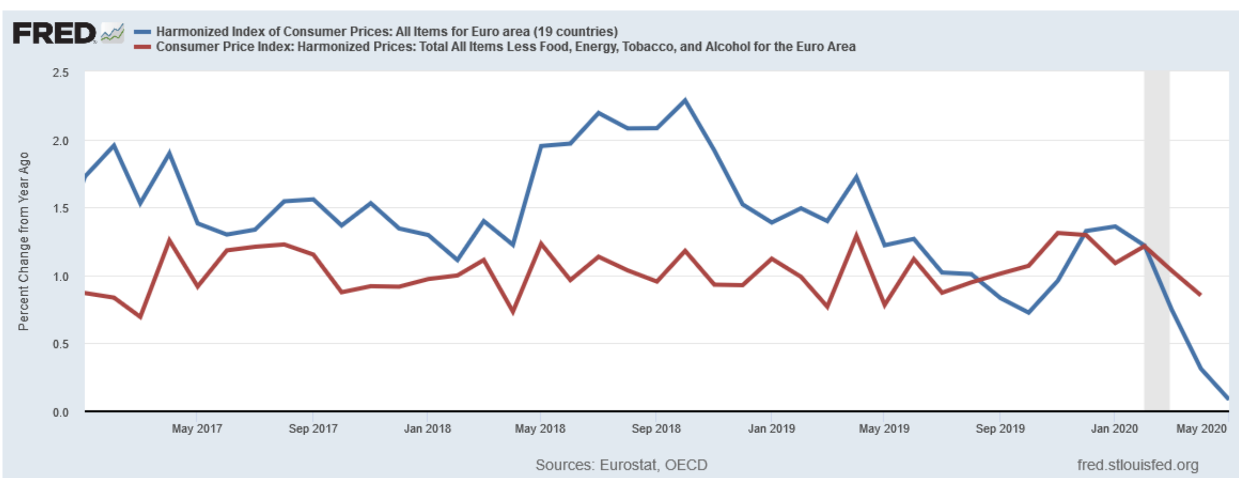
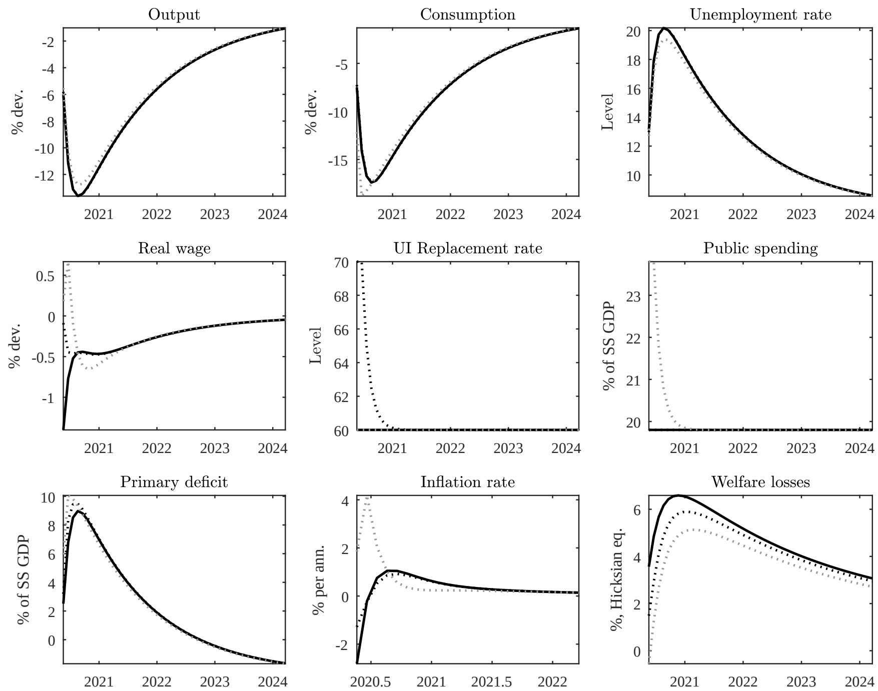


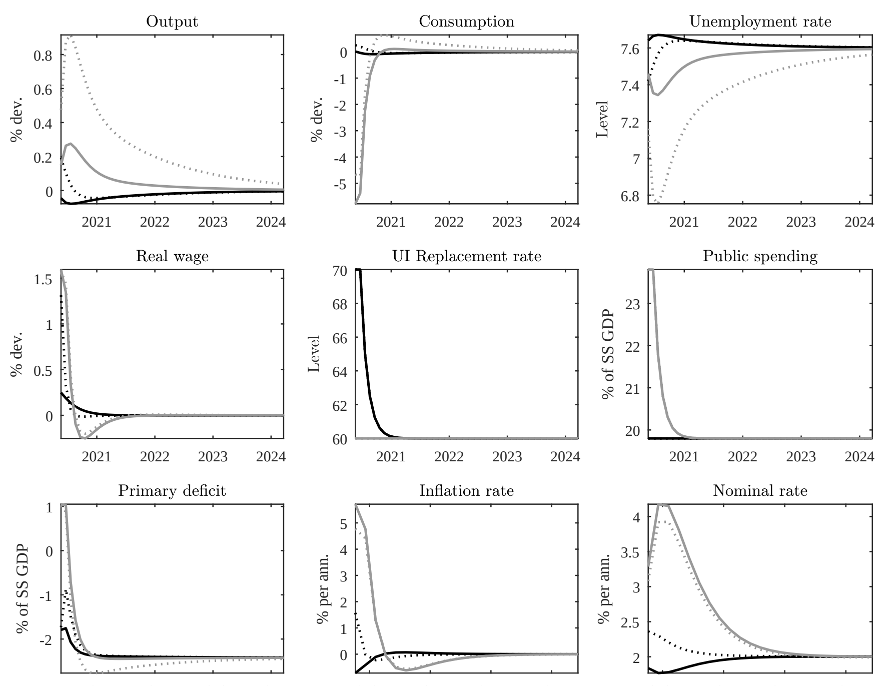
Figure 3: The effects of spending and UI benefit policies.

(a) Level effects



Solid black: Baseline lockdown shock alone. Dotted black: lockdown + increase in UI benefit replacement rate. Dotted grey: lockdown + increase in government spending. The horizon is shorter for inflation.

(b) Net effects



Black: UI replacement rate shock. Grey: government spending shock. Solid: around the steady state. Dotted: conditional on lockdown. The horizon is shorter for inflation and the nominal interest rate.

Appendix to "The Macroeconomic Effects of Lockdown Policies"
Not Intended For Publication

A List of model equations

Euler on private assets (employed)	$\mathrm{E}_t \left\{ \beta \left(1+r_t\right) \frac{(1-\sigma_{t+1}) u_c\left(c_{t+1}^e, g_{t+1}\right) + \sigma_{t+1} u_c\left(c_{t+1}^u, g_{t+1}\right)}{u_c\left(c_t^e, g_t\right)} \right\} = 1$
Euler on gov. bonds (firm owners)	$\mathrm{E}_t \left\{ \beta \left(1+r_t^d\right) \Delta_{t,t+1} \right\} = 1$
Subjective discount factor (firm owners)	$\Delta_{t,t+1} = \beta \widetilde{u}_c(c_{t+1}^f, g_{t+1}) / \widetilde{u}_c(c_t^f, g_t)$
Individual consumption (unemployed)	$c_t^u = b_t$
Individual consumption (employed)	$c_t^e = (1-\tau) w_t$
Aggregate production function	$y_t = \chi n_t \xi_t z_t$
Aggregate profits	$\Pi_t = y_t \left(1 - \phi \pi_t^2 / 2\right) - \chi n_t w_t - \kappa_t v_t$
Marginal value of a job filled	$J_t = \varphi_t z_t \xi_t - w_t + \mathrm{E}_t \left\{ \Delta_{t,t+1} \left(1 - s_t\right) J_{t+1} \right\}$
New Keynesian Phillips Curve	$\eta - 1 = \eta \varphi_t - \phi \left(\pi_t (1+\pi_t) - \mathrm{E}_t \left\{ \Delta_{t,t+1} \pi_{t+1} (1+\pi_{t+1}) y_{t+1} / y_t \right\} \right)$
Free-entry condition	$\max\left(v_t, 0\right) \left(q_t J_t - \kappa_t\right) = 0$
Law of motion of employment	$n_t = \left(1 - \sigma_t\right) n_{t-1} + f_t \left(1 - n_{t-1}\right)$
Matching function	$m_t = \psi \left(u_{t-1} + s_t n_{t-1}\right)^{\gamma} v_t^{1-\gamma}$
Job finding probability	$f_t = \min \left(\max \left(\psi \left(\frac{v_t}{u_{t-1} + s_t n_{t-1}} \right)^{1-\gamma}, 0 \right), 1 \right)$
Worker-finding probability	$q_t = \max \left(\min \left(\psi \left(\frac{u_{t-1} + s_t n_{t-1}}{v_t} \right)^{\gamma}, 1 \right), 0 \right)$
Accounting on labor market	$n_t + u_t = 1$
Net separation rate	$\sigma_t = s_t \left(1 - f_t\right)$
Marginal value of being employed	$S_t = \log \widetilde{c}_t^e - \log \widetilde{c}_t^u + \beta \mathrm{E}_t \left\{ \left(1 - \sigma_{t+1} - f_{t+1}\right) S_{t+1} \right\}$
Notional real wage	$w_t^n = \varphi_t z_t \xi_t + \mathrm{E}_t \left\{ \Delta_{t,t+1} \left(1 - s_t\right) \kappa_{t+1} / q_{t+1} \right\} - \frac{(1-\theta) S_t}{\theta (1-\tau) u_c(c_t^e, g_t)}$
Effective real wage	$w_t = w^{\alpha} \left(w_t^n\right)^{1-\alpha}$
Individual consumption	$c_t^f = \left(\left(1 + r_{t-1}^d\right) d_{t-1} - d_t + \Pi_t - T_t \right) / \left(1 - \chi\right)$
Goods market clearing condition	$y_t \left(1 - \phi \pi_t^2 / 2\right) = \chi \left(n_t c_t^e + u_t c_t^u\right) + \left(1 - \chi\right) c_t^f + g_t + \kappa_t v_t$
Taylor-type rule	$i_t^n = \max \left(r + \rho_i i_{t-1}^n + \left(1 - \rho_i\right) d_{\pi} \pi_t, 0\right)$
Fisher equation	$1 + r_t = \mathrm{E}_t \left\{ \left(1 + i_t^n\right) / \left(1 + \pi_{t+1}\right) \right\}$
Public debt dynamics	$\left(1 + r_{t-1}^d\right) d_{t-1} + def_t = d_t$
Primary government deficit	$def_t = g_t + \chi u_t b_t - \tau \chi n_t w_t - T_t$
Lump-sum tax rule	$T_t = d_T \left(d_{t-1} - d\right) / (12 y)$
Marg. utility of cons. (employed)	$u_c\left(c_t^e, g_t\right) = \left(1 - \Upsilon\right) \left(c_t^e / \widetilde{c}_t^e\right)^{\nu} / c_t^e$
Marg. utility of cons. (unemployed)	$u_c\left(c_t^u, g_t\right) = \left(1 - \Upsilon\right) \left(c_t^u / \widetilde{c}_t^u\right)^{\nu} / c_t^u$
Marg. utility of cons. (firm owners)	$\widetilde{u}_c\left(c_t^f, g_t\right) = \left(1 - \Upsilon\right) \left(c_t^f / \widetilde{c}_t^f\right)^{\nu} \left(\widetilde{c}_t^f\right)^{1-\rho_f} / c_t^f$
Consumption bundle (employed)	$\tilde{c}_t^e = \left(\left(1 - \Upsilon\right) \left(c_t^e\right)^{\nu} + \Upsilon g_t^{\nu} \right)^{\frac{1}{\nu}}$
Consumption bundle (unemployed)	$\tilde{c}_t^u = \left(\left(1 - \Upsilon\right) \left(c_t^u\right)^{\nu} + \Upsilon g_t^{\nu} \right)^{\frac{1}{\nu}}$
Consumption bundle (firm owners)	$\tilde{c}_t^f = \left(\left(1 - \Upsilon\right) \left(c_t^f\right)^{\nu} + \Upsilon g_t^{\nu} \right)^{\frac{1}{\nu}}$
Aggregate welfare	$\mathcal{W}_t = \mathcal{U}_t + \beta \mathrm{E}_t \left\{ \mathcal{W}_{t+1} \right\}$
Aggregate utility	$\mathcal{U}_t = \chi \left(n_t \log \tilde{c}_t^e + u_t \log \tilde{c}_t^u\right) + \left(1 - \chi\right) \left(\tilde{c}_t^f\right)^{1-\rho_f} / \left(1 - \rho_f\right)$
Unemployment benefits	$b_t = b_t^r w$
Public spending shock	$g_t = \left(1 - \rho_L\right) g + \rho_L g_{t-1} + \epsilon_t^g$
Replacement rate shock	$b_t^r = \left(1 - \rho_L\right) b^r + \rho_L b_{t-1}^r + \epsilon_t^b$
Separation shock	$s_t = \left(1 - \rho_L\right) s + \rho_L s_{t-1} + \epsilon_t^s$
Labor utilization shock	$\xi_t = \left(1 - \rho_L\right) + \rho_L \xi_{t-1} + \epsilon_t^{\xi}$
Vacancy posting cost shock	$\kappa_t = \left(1 - \rho_L\right) \kappa + \rho_L \kappa_{t-1} + \epsilon_t^{\kappa}$
Productivity shock	$z_t = \left(1 - \rho_z\right) z + \rho_z z_{t-1} + \epsilon_t^z$

Note: ρ_L is the common persistence parameter of lockdown (s_t, ξ_t and κ_t) and policy (g_t and b_t^r) shocks.

B Sensitivity analysis

B.1 Lockdown shock

We report the impulse responses after a (separation) lockdown shock under alternative calibrations of interest.

First, since the Euro Area was already very close to the ZLB on the nominal interest rate before the Covid-19 outbreak, it is natural to investigate the effects of lockdown policies for a calibration where the nominal rate is closer to the ZLB. We recalibrate the model so that it produces a steady-state nominal rate that is slightly above zero. The lockdown shock, pushing the desired real rate down, makes the nominal rate hit the ZLB instantly. Technically, we increase the discount factor to $0.99739^{1/3}$ (against $0.993^{1/3}$ in the baseline calibration) to obtain a close-to-zero steady-state nominal rate, and adjust $\kappa = 0.2442$ (instead of $\kappa = 0.1915$ in the baseline) to keep on hitting the target value of bargaining power of workers ($\theta = 0.75$). A lower steady-state real rate is associated with a larger precautionary motive, a larger consumption loss upon unemployment and larger consumption inequality among workers (15% against 10.5% in the baseline). Figure 4 shows that the ZLB is hit immediately, which magnifies the negative output, unemployment and welfare effects of the lockdown shock. Deflationary pressures are also amplified. Aggregate welfare losses peak at 7.5%, against 6.58% in the baseline experiment, in part because of the larger effects of the shock, but also because utility losses are discounted using a much higher discount factor. Table 2 also shows that hitting the ZLB essentially magnifies the individual welfare losses from employed workers (1.03% against 0.64% in the baseline), and the losses from newly unemployed workers ($\zeta_T - \zeta_T' = 1.25\%$ against 1% in the baseline).

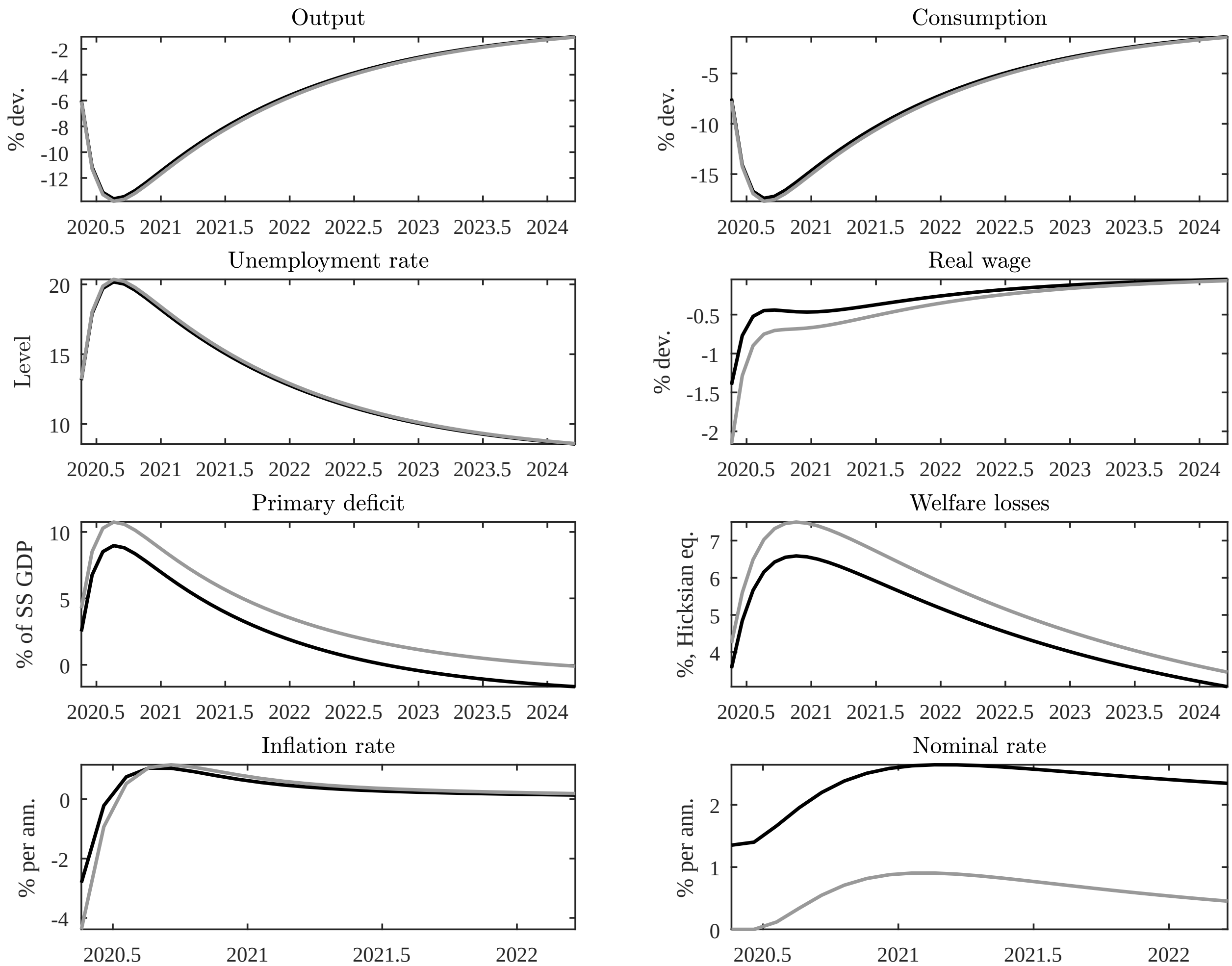
Second, Figure 5 compares the effects of a lockdown (separation) shock under the baseline calibration with and a calibration that implies a more aggressive monetary policy ($\rho_i = 0$). When monetary policy is more aggressive, the macroeconomic effects and the welfare losses are amplified, because the nominal rate hits the ZLB on impact, which results in further deflationary pressures, with depressing effects on output and employment.

B.2 Government policies

Figure 6 and 7 respectively report the net effects of the two policy measures conditional on the lockdown shock under the two alternative calibrations: one that brings the steady-state nominal rate closer to the ZLB, and one that makes monetary policy respond more aggressively to inflation ($\rho_i = 0$).

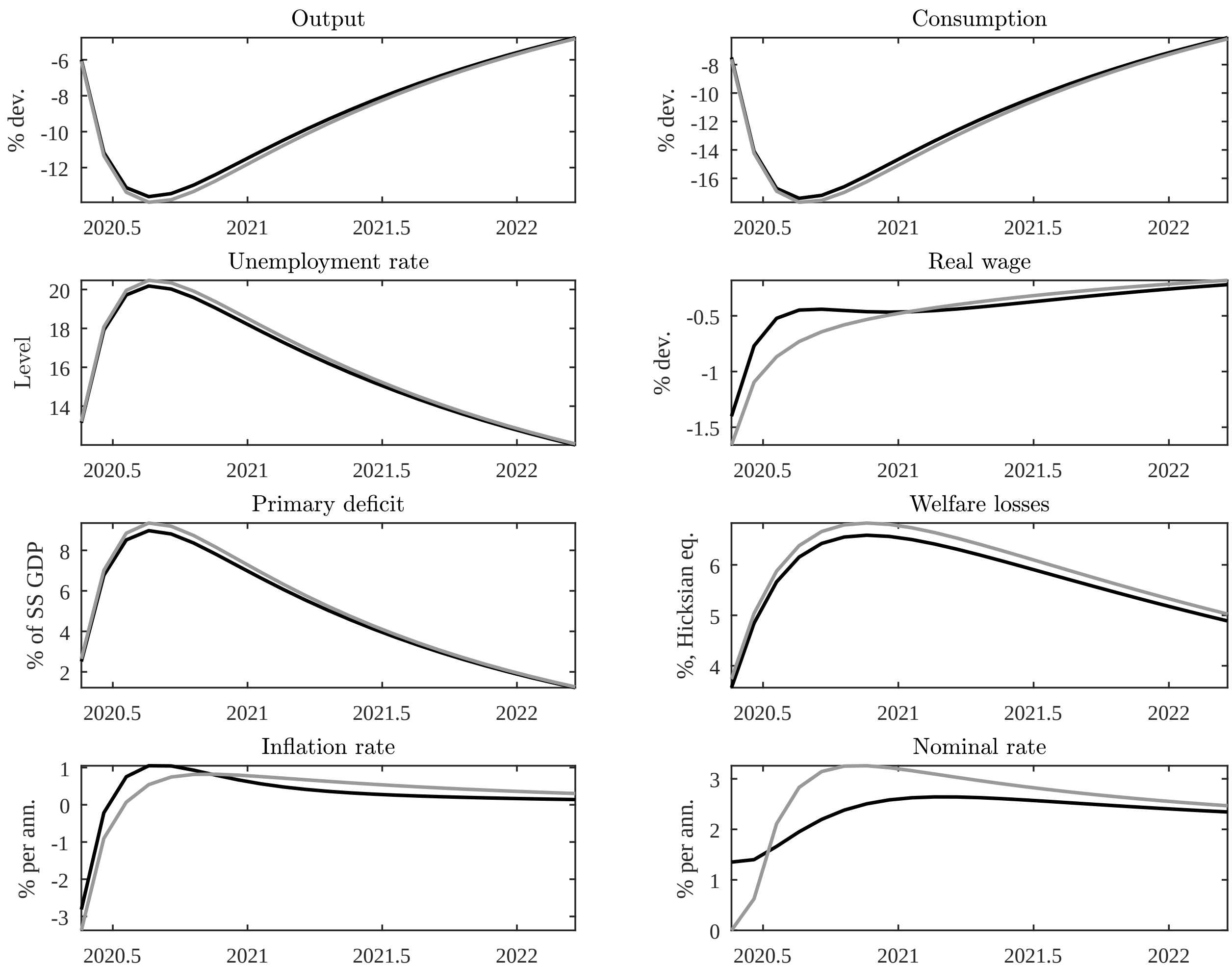
Figure 6 the effects of government policies are not very different from those implied by the baseline calibration. The chief reason is the short duration of the ZLB episode (3 to 4 months), because the lockdown shock is not very persistent. If anything, the net effects of government policies are more persistent. Table 2 shows that the structure of welfare losses is broadly unchanged, all agents experiencing larger losses or smaller gains, mostly because utility flow are discounted using a larger discount factor.

Figure 4: Lockdown policies close to the ZLB.



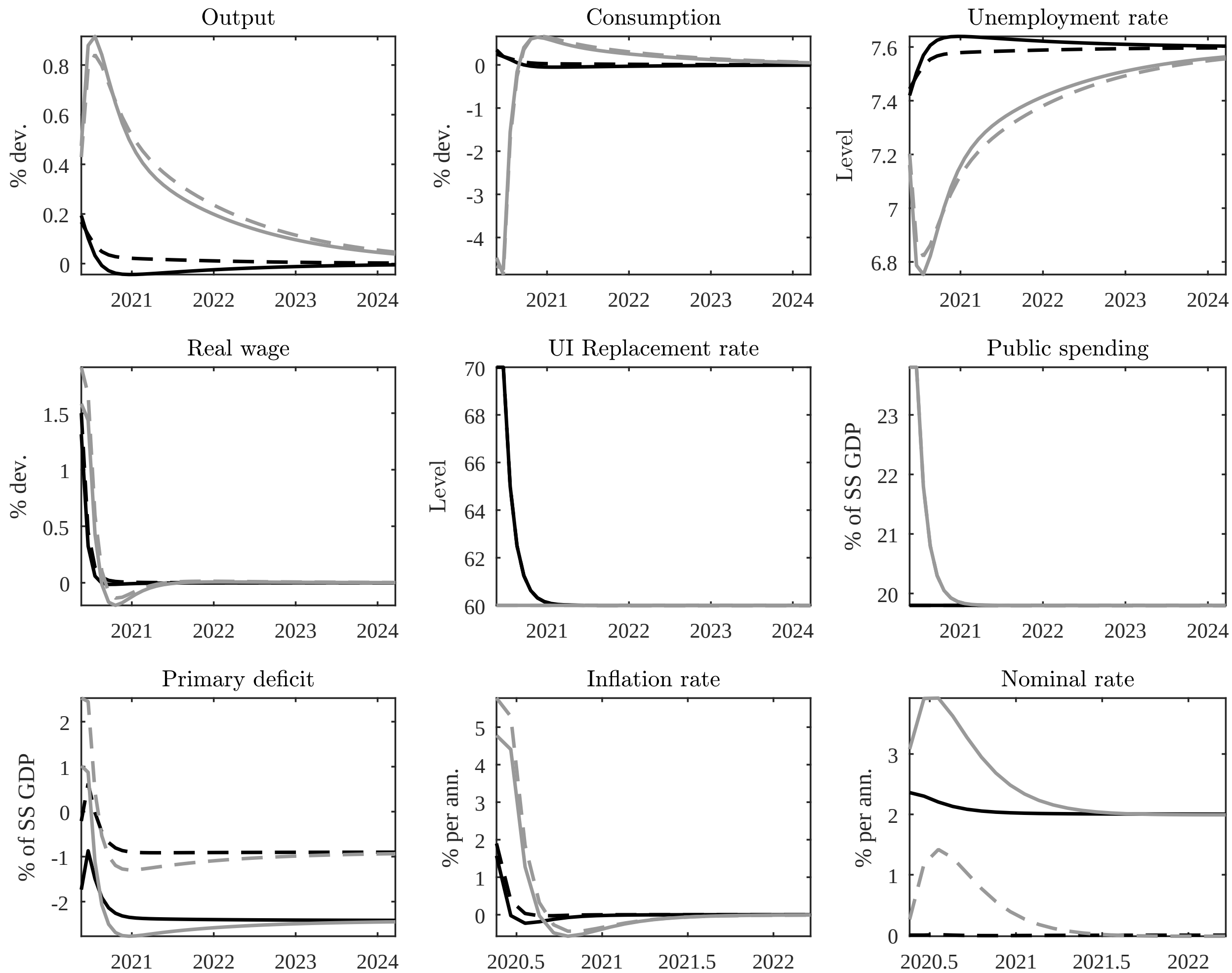
Solid black: Baseline calibration. Grey: Close to the ZLB. The horizon is shorter for inflation and the nominal rate.

Figure 5: Effects of lockdown policies under aggressive monetary policy.



Black: Baseline. Grey: Aggressive monetary policy ($\rho_i = 0$). The horizon is shorter for inflation and the nominal interest rate.

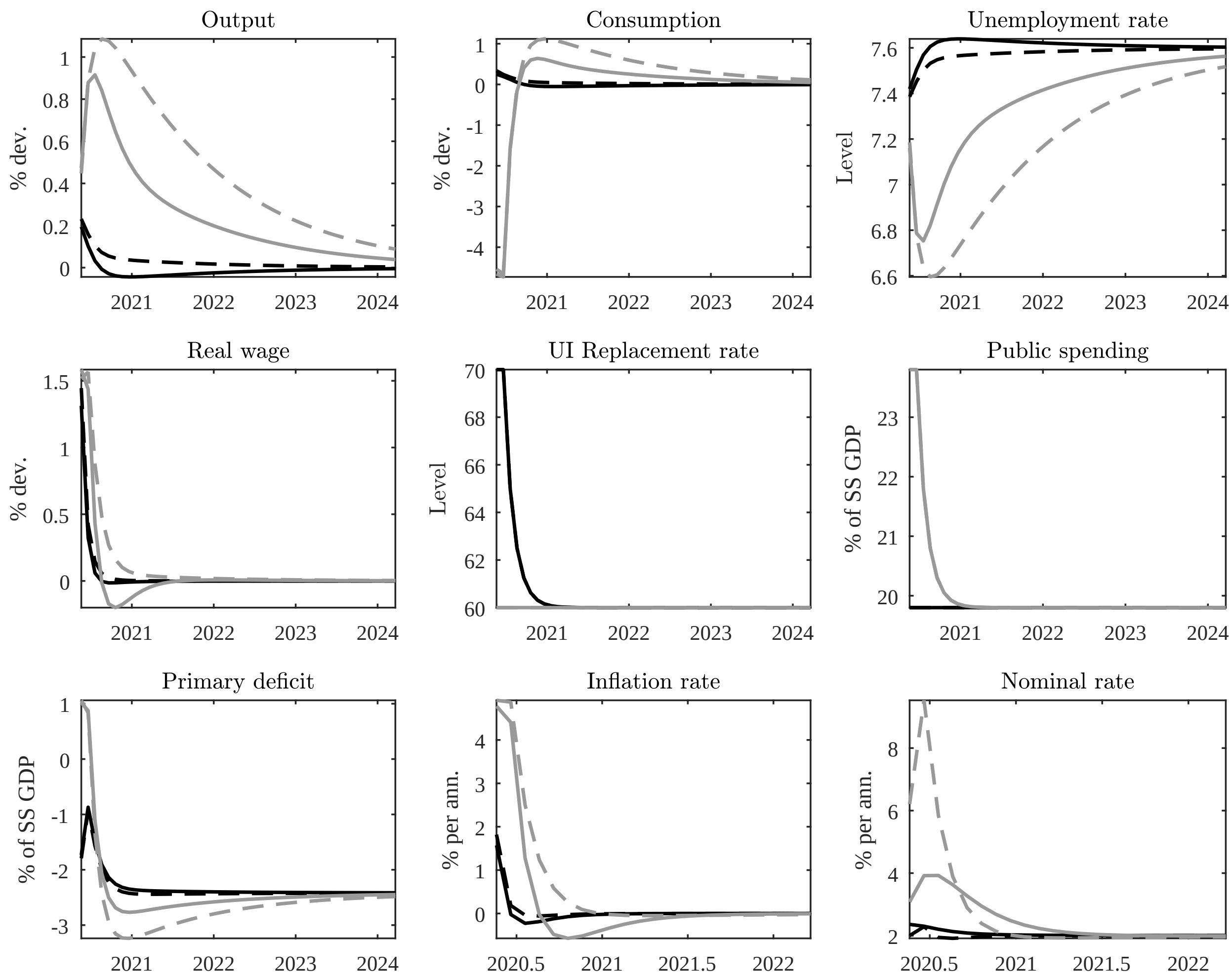
Figure 6: Net effects of government policies conditional on lockdown close to the ZLB.



Black: UI replacement rate shock. Grey: government spending shock. Solid: conditional on lockdown, baseline calibration. Dashed: conditional on lockdown, close to the ZLB. The horizon is shorter for inflation and the nominal interest rate.

Under a more aggressive monetary policy, Figure 7 (dashed lines) shows that raising the level of UI benefits is slightly more effective in raising output and lowering unemployment than in the baseline calibration. Further, the effects of government spending are much larger. The main explanation is that the Central Bank offers a more efficient stabilization of the rise in inflation implied by the spending shock, which contributes to attenuate the fall in the consumption of employed workers and reduces the crowding-out effect. This case actually yields the lowest aggregate welfare losses from the lockdown shock (5.11% against 6.59% in the baseline case with passive policies and 5.13% in the baseline case with rising government spending).

Figure 7: Net effects of government policies conditional on lockdown under aggressive monetary policy.



Solid: Baseline. Dashed: aggressive monetary policy ($\rho_i = 0$). Black: UI replacement rate shock. Grey: government spending shock. The horizon is shorter for inflation and the nominal interest rate.

Table 2: Welfare losses under alternative calibrations, in percents

	Peak ($p = \arg\max \{\zeta_t\}_{t=0}^{t=\infty}$)					Lifetime (∞)				
	ζ_p	ζ_p^e	ζ_p^u	ζ_p^f	ζ_p'	ζ_∞	ζ_∞^e	ζ_∞^u	ζ_∞^f	ζ_∞'
Passive gvt policies										
$\uparrow s_t$ - ZLB	7.50	1.03	0.00	52.68	6.25	0.79	0.09	0.00	6.65	0.64
$\uparrow s_t$ - $\rho_i = 0$	6.83	0.88	0.00	50.19	5.82	0.81	0.07	0.00	7.20	0.67
Raise g_t										
$\uparrow s_t$ - ZLB	6.10	-1.16	-1.55	56.02	4.86	0.71	0.00	-0.06	6.71	0.56
$\uparrow s_t$ - $\rho_i = 0$	5.11	-1.33	-1.46	51.39	4.12	0.68	-0.04	-0.08	7.02	0.55
Raise b_t^r										
$\uparrow s_t$ - ZLB	6.77	0.70	-5.34	54.81	5.93	0.76	0.08	-0.22	6.80	0.63
$\uparrow s_t$ - $\rho_i = 0$	6.06	0.55	-5.36	52.12	5.47	0.77	0.06	-0.25	7.35	0.65

Note: the peak p is case-specific.