The Macroeconomic Effects of Lockdown Policies

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Abstract

A tractable incomplete-market model with unemployment, sticky prices, and a fiscal side is used to quantify the macroeconomic effects of lockdown policies and the mitigating effects of raising government spending and implementing UI benefit extensions. We find that the effects of lockdown policies, although we are relatively conservative about the size of the lockdown, are huge: unemployment doubles on impact and almost triples even for relatively short lockdown durations. Output falls dramatically and debt-output ratios increase by several tens of percentage points. In addition, the surge in unemployment risk triggers a rise in precautionary savings that make such shocks Keynesian supply shocks: aggregate demand falls by more than aggregate supply, and lockdown policies are deflationary. Unfortunately, we find that raising public spending and extending UI benefits stimulate aggregate demand or improve risk-sharing but has little effects on output and unemployment, although they do alleviate the welfare losses of lockdown policies for the households.

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

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1 Introduction

This paper proposes a tractable heterogeneous-agent (HA) model based on Challe (2020) with unemployment risk to investigate the macroeconomic effects of lockdown policies implemented by most government in response to the spread of the Covid-19 epidemic in the spring of 2020. The model considers imperfect insurance, sticky prices and search and matching frictions. It also imbeds a set of fiscal policy instruments: government spending, unemployment insurance (UI) benefits and distortionary taxes, along with government bonds. The main interest of this framework is to offer 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 precautionary saving motive. In addition, the dynamics of desired savings and the equilibrium real interest rate have feedback general equilibrium effects through sticky prices and monetary policy.

The model consider three types of households: employed workers, unemployed workers and firm owners. Workers are heterogeneous in terms of their labor-market history and borrowing constrained as in all HA models, but we make simple assumptions that greatly simplify the model since they imply that the distribution of wealth is degenerate, as in Ravn and Sterk (2020) or Challe (2020). As a result, employed and unemployed workers consume exactly their income. Firm owners, who are more patient than workers, are the only type of households featuring positive assets in the form of government bonds and use them to smooth consumption. They would be willing to lend private assets to the workers, which implies that the expected real rate on this asset equates the expected real rate on bonds. However, workers are not allowed to hold negative assets but to borrowing constraints. Unemployed workers' Euler equation implies that they are borrowing constrained in terms of the amount of private asset, and employed workers' Euler equation implies that they hold zero private asset as an equilibrium outcome. This structure of financial markets implies that the Euler equation of employed households' Euler equation determines the equilibrium real interest rate. Its dynamics reflects two opposing forces: the consumption smoothing motive and the precautionary motive. The former implies that employed workers would like to borrow in the event of a shock that lowers their income temporarily to allow them to smooth their consumption, which, as in any representative-agent model would results in a rise of the real interest rate. The latter implies that, provided the negative shock raises their future probability of unemployment, they want to save to self-insure, which pushes the real interest rate down. Challe (2020) shows that the precautionary motive may dominate the smoothing motive for reasonable calibrations and if income is smooth enough compared to the dynamics of unemployment. As a result, negative productivity shocks may be deflationary, calling for an optimal *fall* in the nominal rate controlled by the Central rather than a *rise*, as usually seen in models with representative agents.

First, we propose a monthly calibration of our model that matches empirical facts about the labor markets of Euro Area countries. When driven by standard productivity shocks, the model predicts counter-cyclical and persistent fluctuations of the unemployment rate, and their relative size with respect to the fluctuations of output matches that observed in the data.

Second, we quantify the effects of lockdown policies by which a fraction of the labor force is kept out of job, and tailor the size of the shock to match the (scarce) existing evidence about the recent drop in economic activity, so as to lower output by 6 percents the first month. We consider it to last either 1, 2 or 3 months, and assume that exit from the lockdown is progressive. We find that, even in the case of a 1-month lockdown, output falls almost 10 percents below its steady-state value after a few month. Unemployment jumps from a steady-value of 7.6 percents to 13.2 percents on impact, and peaks at 16.7 percents in June 2020. These large negative effects result from the feedback loop between unemployment, consumption and output. The rise in unemployment depresses consumption and raises the desire to precautionary-save, which further lowers aggregate demand and output, and then further raises unemployment. In other words, aggregate demand is more depressed than supply, which is also reflected in the implied deflationary pressures: the inflation rate and the nominal interest rate both drop significantly. Hence, the model generates what Guerrieri, Lorenzoni, Straub, and Werning (2020) coin as Keynesian supply shocks. Longer lockdown shocks aggravate the fall in output and consumption, magnify the rise in unemployment. Last, even though the government keeps the level of its consumption expenditure and the level of UI benefits constant, the budget deficit explodes because the distribution of UI benefits surges and because the tax base shrinks. Given our assumption that taxes increase only mildly in the short and that most of the rise in deficits are financed by issuing bonds, the debt-GDP ratio rises by several percentage points: almost 12pp in the case of a 1-month lockdown and up to 21.3pp for a 3-months lockdown.

While these numbers are already huge, there are good reasons to think that they are rather conservative. Growth projections by the IMF, unemployment claim numbers suggest that the shock might be larger and trigger larger negative effects. In the above simulations, we assume that government spending and UI benefits remain constant while, in reality, both increased in most countries. For instance, in France, a 100 billion euros package was acted and UI benefits were extended to allow for partial unemployment (temporary unemployment where workers receive roughly 80 percents of the usual wage income). We thus also quantify the effects of these two types of policies on macroeconomic variables. While both measures could stimulate aggregate demand, they have basically no effects on aggregate output since supply is not there anyway. Government spending hikes generate inflationary effects but UI benefit extensions generate further deflationary pressures: since extensions are temporary, employed households are better insured against unemployment today but not tomorrow, which generates additional precautionary savings. While these policies are relatively ineffective in mitigating the aggregate dynamics of output and unemployment, they do have effects on the welfare of households. Calculating the optimized government spending and UI benefits in response to lockdown policies shows that a little more generous unemployment insurance and a little less public spending should be considered. None of the policies has a significant effect on unemployment or on GDP as clearly supply shocks can not be alleviated by demand stimulation measures. Economic policies can just mitigate the negative effects on the utility of agents by reducing deflation and temporarily improving risk sharing.

Research on the macroeconomic effects of the Covid-19 epidemic have burgeoned in the recent weeks. Most contributions offer a mix of SIR (epidemiological) models and macroeconomic models to analyze the joint dynamics of the pandemic and macroeconomic variables depending on lockdown policies, and derive optimal lockdown policies (See Eichenbaum, Rebelo, and Trabandt (2020), Krueger, Uhlig, and Xie (2020), Piguillem and Shi (2020) among other). Another set of papers is concerned by the effects of lockdown policies and how traditional policy instrument might mitigate them (See Bayer, Born, Luetticke, and Müller (2020), Fornaro and Wolf (2020) or Guerrieri et al. (2020),). Our paper is closer to these contributions. Guerrieri et al. (2020) show the conditions under which supply shocks can have Keynesian features, *i.e.* generate excess demand fluctuations. They also show that government spending might be much less effective in stabilizing the economy and that risk-sharing considerations matter critically. Our contribution in regard to their paper is to show that Keynesian supply shocks can arise in one-sector models with sticky prices, incomplete markets and unemployment risk. Fornaro and Wolf (2020) propose a very stylized model to understand the potential effects of monetary and fiscal policies in the context of an epidemic that induces a lockdown. Their main point is to understand the qualitative effects as well as to underline that lockdown policies might induce stagnation traps. Our goal is more quantitative and our focus is exclusively on fiscal policy instruments, considering that monetary policy is conducted through a standard Taylor-type rule. Finally, our paper is arguably closest to Bayer et al. (2020), who build a model with heterogeneous agents to quantify the effects of a lockdown and the effects of transfer policies. Contrary to them, our model has a degenerate distribution of wealth and does not allow for such a granular analysis, in particular in terms of the effects of transfer policies on marginal propensities to consume. However, our model imbeds unemployment risk and equilibrium unemployment through search and matching frictions, two features that we believe are critical to understand the current situation, while both features are absent in Bayer et al. (2020). Our work can thus be seen as a complement to these existing studies.

The paper is organized as follows. The model is described and discussed in Section 2.

Section 3 calibrates the model. Section 4 discusses the implications of lockdown policies depending on their duration. Section 5 analyzes the effects of stimulus packages (a raise in government spending) and those of UI benefit extension programs. Finally, Section 6 derives the optimized government spending and UI benefit policies in response to the lockdown. Section 7 offers concluding remarks.

2 Model

The model structure borrows from Ravn and Sterk (2020) 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, because they are too impatient given market rates and have a restricted access to government bonds. Firm owners are more patient than workers, receive profits, consume and hold government bonds. The rest of the model is a standard search and matching framework with Nash bargained wages, that sets the stage for the endogenous dynamics of the unemployment rate, that affects the composition of the household sector and the extent of unemployment risk. Finally, a government sector is introduced, that levies distortionary taxes on labor income and issues bonds to finance unemployment insurance benefits and public spending.

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 that receive profits from production.

Firm owners. Firm owners receive the profits, hold assets and consume. They maximize their lifetime utility

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

where denotes their per-capita consumption and β^f their discount factor, subject to the following (aggregate) resource constraint

$$a_t^f + (1-\chi)\, c_t^f = (1 + r_{t-1})\, a_{t-1}^f + \Pi_t \tag{2}$$

where r_{t-1} is the return on assets between periods $t-1$ and t. The corresponding Euler equation on bonds yields

$$\mathrm{E}_t \left\{ \beta^f (1+r_t) \frac{u_c\left(c^f_{t+1}, g_{t+1}\right)}{u_c\left(c^f_t, g_t\right)} \right\} = 1 \tag{3}$$

Workers. Household $i \in [0, \chi]$ belongs to the category of workers maximizes the following welfare index

$$\mathrm{E}_t \left\{ \sum_{s=t}^{\infty} \beta^{s-t} u\left(c^i_s, g_s\right) \right\} \tag{4}$$

where $\beta < \beta^f$ is the subjective discount factor of workers, $c_{i,t} > 0$ is the consumption of household i and g_t is the aggregate amount of public spending. The budget constraint of household i is:

$$a^i_t + c^i_t = (1+r_{t-1})\, a^i_{t-1} + \varepsilon^i_t (1-\tau_t)\, w_t + \left(1-\varepsilon^i_t\right) b_t,\ a^i_t > 0 \tag{5}$$

where a^i_t is the household's wealth. Variable $\varepsilon^i_t = \{0, 1\}$ gives the employment status of the household: when $\varepsilon^i_t = 1$, the household is employed at the real wage w_t; when $\varepsilon^i_t = 0$, the household is unemployed and receives an unemployment insurance $b_t = b^r_t w$, where we denote b^r_t as the replacement rate of UI benefits. The wage income is taxed at the rate τ_t while UI benefits are exempted. The number of employed workers in the economy and the unemployment rate are tied by $n_t + u_t = 1$. At the beginning of period t, a proportion s of past employment relationships are exogenously destroyed and the pool of unemployed workers is $u_{t-1}+ sn_{t-1}$. Among these employed workers, a fraction f_t becomes employed before the end of period t. The number of employed workers is thus given by the following equation

$$n_t = (1-\sigma_t)\, n_{t-1} + f_t (1 - n_{t-1}) - \Lambda_t \tag{6}$$

where $\sigma_t = s(1-f_t)$ is net separation rate, and where the job-finding rate f_t and the worker-finding rate q_t are respectively defined as

$$f_t = \psi \left(\frac{v_t}{u_{t-1} + sn_{t-1}} \right)^{1-\gamma} \text{ and } q_t = \psi \left(\frac{u_{t-1} + sn_{t-1}}{v_t} \right)^{\gamma} \tag{7}$$

Variable Λ_t is an exogenous shock that lowers employment, and captures the effects of the lockdown policies applied by governments to flatten the pandemic curve induced by the Covid-19 epidemic. From the perspective of a currently employed household, the Euler equation on asset writes

$$\mathrm{E}_t \left\{ \beta \left(1 + r_t\right) \frac{\left(1 - \sigma_{t+1}\right) u_c \left(c_{t+1}^{i=e}, g_{t+1}\right) + \sigma_{t+1} u_c \left(c_{t+1}^{i=u}, g_{t+1}\right)}{u_c \left(c_t^{i=e}, g_t\right)} \right\} \leq 1 \tag{8}$$

where $\sigma_t = s\left(1 - f_t\right)$ is the transition probability from employment to unemployment at the end of period t, and $c_t^{i=e}$ and $c_t^{i=u}$ respectively denote the individual consumption level of worker i if employed or unemployed. The above equation holds with equality when employed household i is not constrained, and with inequality when she is constrained. We assume (i) that workers are more impatient than firm owners and calibrate the steady-state value of β so that Equation (8) holds with equality, and (ii) that workers do not have access to the bond market.[1] As a consequence, they hold exactly zero assets ($a_t^{i=e} = 0$), implying a degenerate wealth distribution, and all employed households have the same per-capita level of consumption $c_t^{i=e} = c_t^e = \left(1 - \tau_t\right) w_t$. Further, given that $\sigma_t > 0$ and $u_c\left(c_{t+1}^e, g_t\right) < u_c\left(c_{t+1}^u, g_t\right)$, a precautionary motive arises due to the risk of unemployment. Employed workers face a potentially decreasing future consumption schedule, driven by the risk of income loss. It pushes them to save to self-insure through savings. However, because they can not access bonds markets, the excess asset demand translates into a lower real rate. From the perspective of unemployed households, the Euler equation holds with strict inequality and writes

$$\mathrm{E}_t \left\{ \beta \left(1 + r_t\right) \frac{\left(1 - f_{t+1}\right) u_c \left(c_{t+1}^{i=u}, g_t\right) + f_{t+1} u_c \left(c_{t+1}^{i=e}, g_t\right)}{u_c \left(c_t^{i=u}, g_t\right)} \right\} \leq 1 \tag{9}$$

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

2.2 Production and wage determination

As in the search and matching literature, each firm is a job. Firms post v_t vacancies, paying a unit vacancy cost κ, out of which a fraction q_t will be filled to produce goods with a linear technology. The aggregate production function is thus

$$y_t = \chi n_t z_t$$

Given that the intermediate good is sold on competitive markets at price φ_t, the marginal

[1] Imagine that agents can trade two types of assets, private and government bonds. Firm owners can access both types of assets provided there quantity is positive, and a no-arbitrage condition characterizes the returns on both assets. However, workers can only access private assets, at the same equilibrium rate than government bonds. Hence, in case of a shock that raises unemployment risk, (employed) workers would like to save in the form of private bonds but can not because the latter are in zero net supply, and are therefore constrained although they act as if they were not.

value of a filled position is:

$$J_t = \varphi_t z_t - w_t + \mathrm{E}_t \left\{ \Delta_{t,t+1} \left((1-s) J_{t+1} + sV_{t+1} \right) \right\} \tag{10}$$

where the first argument is the net contribution of the marginal worker, his marginal product less his wage bill, the second argument is the continuation value, and where

$$\Delta_{t,t+1} = \beta u_c \left(c_{t+1}^f, g_{t+1} \right) / u_c \left(c_t^f, g_t \right) \tag{11}$$

is the stochastic discount factor of firm owners. The value of a position remaining vacant is[2]

$$V_t = -\kappa + \mathrm{E}_t \left\{ q_t J_t + \Delta_{t,t+1} \left((1-q_t) V_{t+1} \right) \right\} \tag{12}$$

and we assume that the free entry condition $V_t = 0$ holds, which implies $q_t J_t = \kappa$. The total profits made by intermediate goods producers are

$$\Pi_{mt} = \varphi_t y_t - w_t \chi n_t - \kappa v_t \tag{13}$$

The real wage is sticky in the sense that the effective wage is a geometric average of the (notional) Nash-bargained wage:

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

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

$$w_t^n = \arg\max \left(S_t \right)^{\theta} J_t \left(w_t^n \right)^{1-\theta} \tag{14}$$

where θ is the bargaining power of workers, S_t is the surplus of being employed:

$$S_t = u \left((1-\tau_t) w_t, g_t \right) - u \left(b_t, g_t \right) + \beta \mathrm{E}_t \left\{ (1 - \sigma_{t+1} - f_{t+1}) S_{t+1} \right\} \tag{15}$$

where, remember, where $\sigma_t = s(1-f_t)$ is the transition probability from employment to unemployment at the end of period t. The Nash bargaining solution to this problem implies

$$w_t^n = \frac{\theta \left(\varphi_t z_t + \mathrm{E}_t \left\{ \Delta_{t,t+1} (1-s) \kappa / q_{t+1} \right\} \right)}{\theta + (1-\theta) S_t} \tag{16}$$

Retailers buy the intermediate good y_t and then differentiate it into varieties i to sell them at nominal price $p_t(i)$ on the market for final goods. Let y_t^d denote the total demand for

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

final goods and $y_t^d(i)$ the demand for variety i. Retailer i sets its price $p_t(i)$ to maximize the discounted sum of its expected dividends:

$$\mathrm{E}_t \left\{ \sum_{s=t}^{\infty} \Delta_{t,s} \Pi_{rs} \right\} \tag{17}$$

where

$$\Pi_{rt} = \left(\frac{p_t(i)}{p_t} - p_t^m - \frac{\phi}{2} \left(\frac{p_t(i)}{p_t} - 1 \right)^2 \right) y_t^d(i) \tag{18}$$

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

$$\eta - 1 = \eta \varphi_t - \phi \left(\pi_t(1+\pi_t) - \mathrm{E}_t \left\{ \Delta_{t,t+1} \pi_{t+1}(1+\pi_{t+1}) y_{t+1}/y_t \right\} \right) \tag{19}$$

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

$$\Pi_t = \Pi_{mt} + \Pi_{rt} = y_t \left(1 - \phi \pi_t^2/2\right) - \chi n_t w_t - \kappa v_t \tag{20}$$

2.3 Government, monetary policy, aggregation and equilibrium

The government purchases public goods g_t and provides unemployment insurance to the unemployed workers. It finances this stream of expenditure using the labor income tax and government bonds, so that its budget constraint writes:

$$(1 + r_{t-1}) d_{t-1} + g_t + \chi u_t b = d_t + \tau_t \chi n_t w_t \tag{21}$$

The labor income tax rate is used to ensure the sustainability of government debt in the long run using the following policy rule

$$\tau_t = \tau + d_\tau (dy_{t-1} - dy) \tag{22}$$

where $dy_t = d_t/(12y_t)$ is the debt to annual GDP ratio. The Central Bank controls the nominal interest rate i_t^n and sets it according to the following simple Taylor-type rule subject to a zero lower bound:

$$i_t^n = \max\left(r + \rho_r i_{t-1}^n + (1 - \rho_r) d_\pi \pi_t, 0\right) \tag{23}$$

where the real rate is then determined according to the following Fisher equation

$$1 + r_t = \mathrm{E}\left\{ (1 + i_t^n) \,/\, (1 + \pi_{t+1}) \right\} \tag{24}$$

The market clearing condition on the market for final goods and services is

$$y_t \left(1 - \phi \pi_t^2 / 2\right) = \chi \left(n_t c_t^e + u_t c_t^u\right) + (1 - \chi)\, c_t^f + g_t + \kappa_t v_t \tag{25}$$

and the government bonds market clearing condition is $d_t = a_t^f$. A competitive equilibrium in this economy is defined as a situation where, for a given path of fiscal policy instruments $\mathcal{F}_t = \{g_t, b_t^r, d_t\}$: (i) for a given path of prices, households satisfy their optimality conditions and budget constraints, the firm and retailers optimize and the government budget constraint holds, 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.

3 Calibration

In this section, public spending and UI benefits remain constant $\{g_t, b_t^r\} = \{g, b^r\}$. Before we derive quantitative results from our model, we calibrate it targeting targets the average Euro Area economy.

Preferences. Let us start by specifying a utility function for workers and for firm owners. Public expenditure are introduced in the utility function of agents to introduce meaningful policy trade-offs when allowing for variable public spending. More precisely, for all types of workers, we assume that utility stems from a bundle of private and public goods. Let us define

$$\tilde{c}_t^i = \left((1 - \Upsilon)\left(c_t^i\right)^{\nu} + \Upsilon g_t^{\nu}\right)^{\frac{1}{\nu}} \tag{26}$$

for $i = \{e, u, f\}$ as the consumption bundle combining private and public goods, and assume that both types of consumption are complement, *i.e.* $\nu < 0$. This assumption has already received quite some empirical support in the literature (see Bouakez and Rebei (2007) or Auray and Eyquem (2019)), but is even more relevant in a pandemic context: households' consumption is higher when (public health) spending is higher and vice-versa. Further, we assume that the utility function of workers is $u(c_t^i, h_t) = \log(\tilde{c}_t^i)$ for $i = \{e, u\}$ and, following Challe (2020), the utility function of firm owners is $u(c_t^f, g_t) = (\tilde{c}_t^f)^{1-\rho_f}/(1 - \rho_f)$.

Calibration for the households. The model is monthly. The discount factor is $\beta = (0.9925)^{1/3} = 0.9975$, which pins down the steady-state real rate in the baseline model to $r = 0.1761\%$ monthly or 2.1339% annually. Given the precautionary motive that is caused by unemployment risk, employed workers would like to self-insure and therefore demand more private assets than in a perfect insurance economy. Since they do not have access to private assets and that firm owners arbitrage between public and private assets, the excess demand of private assets is reflected in a lower equilibrium real interest rate on government bonds than the one implied by the subjective interest rate, given by $r = 0.1636\% < 1/\beta - 1 = 0.2513\%$. The equilibrium real rate is obtained by setting the nominal rate at $i^n = r$ and by imposing a zero inflation target to the Central Bank. In this steady state, unemployed households are 13.24% poorer on average than employed workers: $c^e = 0.5735 > c^u = 0.4976$. Put differently, the average drop in consumption when becoming unemployed is roughly 13%. As in Challe (2020), the share of firm owners to 10%, that is $\chi = 0.9$ and $\rho_f = 0.25$. The discount factor of firm owners is set to $\beta^f = 1/(1+r) = 0.9982$. 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), γ is set to equalize the weighted average marginal utility of public spending to the weighted average of marginal utilities of the consumption of private goods. It gives $\gamma = 0.1049$.

Calibration for firms and monetary policy. We set the steady-state monopolistic competition markup of retailers to 20%, implying $\eta = 6$. In addition, the Rotemberg parameter is set according the a first-order equivalence between Calvo and Rotemberg parameters. A 0.75 probability of keeping the price fixed in the quarterly Calvo set-up implies a 0.9 in the monthly set-up. Hence, the equivalent Rotemberg parameter is given by $\phi = (\eta - 1)\, 0.9/\left((1-0.9)\left(1-\beta^f 0.9\right)\right) = 443$. The elasticity of the nominal interest rate to inflation is given by $d_\pi = 1.5$ and the persistence parameter is $\rho_i = 0.85$.

Calibration for the government. We calibrate $g/y = 0.1928$ based on Euro Area data. Further, the replacement rate is $b^r = 0.6$ (see Esser, Ferrarini, Nelson, Palme, and Sjüberg (2013)) and we the debt-to-annual GDP is set according to the last available data (2018) for the Euro Area to $d/(12y) = 0.86$. We assume that the steady-state labor income tax is adjusted for the budget of the government to be balanced, which implies $\tau = 0.3084$. The feedback parameter of the tax rule is set to $d_\tau = 0.05$, the lowest value that is consistent with long-run debt sustainability.

Calibration for the labor market. On the labor market, we also seek to replicate key Euro Area data. In line with Challe (2020), we set the elasticity of matches with respect to unemployment to $\gamma = 2/3$, which is also in the range of estimates proposed by Pissarides and Petrongolo (2001). Using the labor-market transition probabilities estimated by Elsby, Hobijn, and Şahin (2013), we impose a net separation of $\sigma = 0.005$ and adjust the job-finding rate to deliver a $u = 0.076$ unemployment rate. We get $f = 0.00608$, which lines up pretty well with the numbers reported by Elsby, Hobijn, and Şahin (2013). Along with Challe (2020), the wage stickiness parameter is set to $\alpha = 0.946$. We also impose a steady-state worker-finding probability of $q = 0.7^3 = 0.3430$. Finally, the vacancy posting cost parameter κ remains to be pinned down. Along with the rest of the calibration, it determines the bargaining power of workers θ and the matching efficiency parameter ψ. We choose to target a $\theta = 0.75$ bargaining power, implying $\kappa = 0.1976$, and the matching efficiency parameter is $\psi = 0.1082$

When the model is fed with stochastic productivity shocks with a persistence of 0.95 and a 1 percent standard deviation, it predicts a 7.3 relative volatility of the unemployment rate with respect to output and unemployment is strongly counter-cyclical (the contemporaneous correlation is -0.93). These numbers suggest that our model produces reasonable unemployment fluctuations subject to standard productivity shocks, is in line with empirical evidence about the Euro Area. Parameter values are reported in Table 1.

Table 1: Parameter values.

Discount factor workers	$\beta = 0.9975$
Discount factor firm owners	$\beta^f = 0.9982$
Private/public goods complementarity parameter	$\nu = -2/3$
Utility weight of public spending	$\Upsilon = 0.1049$
Share of firm owners	$1 - \chi = 0.1$
Firm owners risk-aversion parameter	$\rho_f = 0.25$
Steady-state retail mark-up	$1/(\eta - 1) = 0.2$
Rotemberg adjustment cost	$\phi = 443$
Nominal interest rate persistence	$\rho_i = 0.85$
Nominal interest rate response to inflation	$d_\pi = 1.5$
Steady-state public spending in GDP	$g/y = 0.1928$
Steady-state debt in annual GDP	$d/(12y) = 0.86$
Steady-state labor income tax rate	$\tau = 0.3084$
Tax rule feedback parameter	$d_\tau = 0.05$
Replacement rate	$b^r = 0.6$
Monthly net separation rate	$\sigma = 0.005$
Monthly job-finding rate	$f = 0.0608$
Monthly worker-finding rate	$q = 0.3430$
Elasticity matching function	$\gamma = 2/3$
Bargaining power of workers	$\theta = 0.75$
Matching efficiency	$\psi = 0.1082$
Vacancy posting cost	$\kappa = 0.1976$
Annual steady-state real rate	$100((1 + r)^{12} - 1) = 1.9804\%$
Implied consumption inequality among workers	$c^u/c^e = 0.8676$

4 The macroeconomic effects of lockdown policies

In the model, the steady-state value of Λ_t is zero. A lockdown policy consists in setting $\Lambda_t = \Lambda$ for a given duration.[3] After the lockdown is lifted, we assume that its exit rate is 0.5 per month.

We consider the model to be in the steady state in February 2020, and consider a lockdown shock starting in March 2020. We calibrate the size of the lockdown shock to match the (scarce) evidence about the output costs of the lockdown. In France, numbers have been released suggesting that output growth was −6 percent in the first quarter of 2020. Provided growth was close enough to zero in the first two quarters, we adjust the size of the lockdown shock so that it produces a 6 percent fall in output from its steady-state value. We consider three alternative durations: 1 month, 2 months or 3 months. Given that the shock is extremely large, linear approximations are likely unreliable, so we simulate the model non-linearly considering the shock as an MIT shock.[4] Figure 1 reports the effects of lockdown policies on our model economy. It tracks the dynamics of key macroeconomic aggregates, along with the welfare losses from the lockdown policies, denoted ζ. We adopt a utilitarian approach to the welfare criterion and attribute to each type of household an equal weight. As such, we consider the Hicksian consumption equivalent that solves:

$$\sum_{t=0}^{T} \tilde{\beta}^t \left(\mathcal{U}\left(c_t^e, c_t^u, c_t^f, g_t\right) - \mathcal{U}\left(c^e\left(1-\zeta_T\right)\right), c^u\left(1-\zeta_T\right)\right), c^f\left(1-\zeta_T\right)\right), g_t\right)\right) = 0 \tag{27}$$

where $\tilde{\beta} = \chi\beta + (1-\chi)\beta^f$, T is the horizon over which welfare losses are computed and

$$\mathcal{U}_t = \chi\left(n_t \log \tilde{c}_t^e + u_t \log \tilde{c}_t^u\right) + (1-\chi)\left(\tilde{c}_t^f\right)^{1-\rho_f}/(1-\rho_f) \tag{28}$$

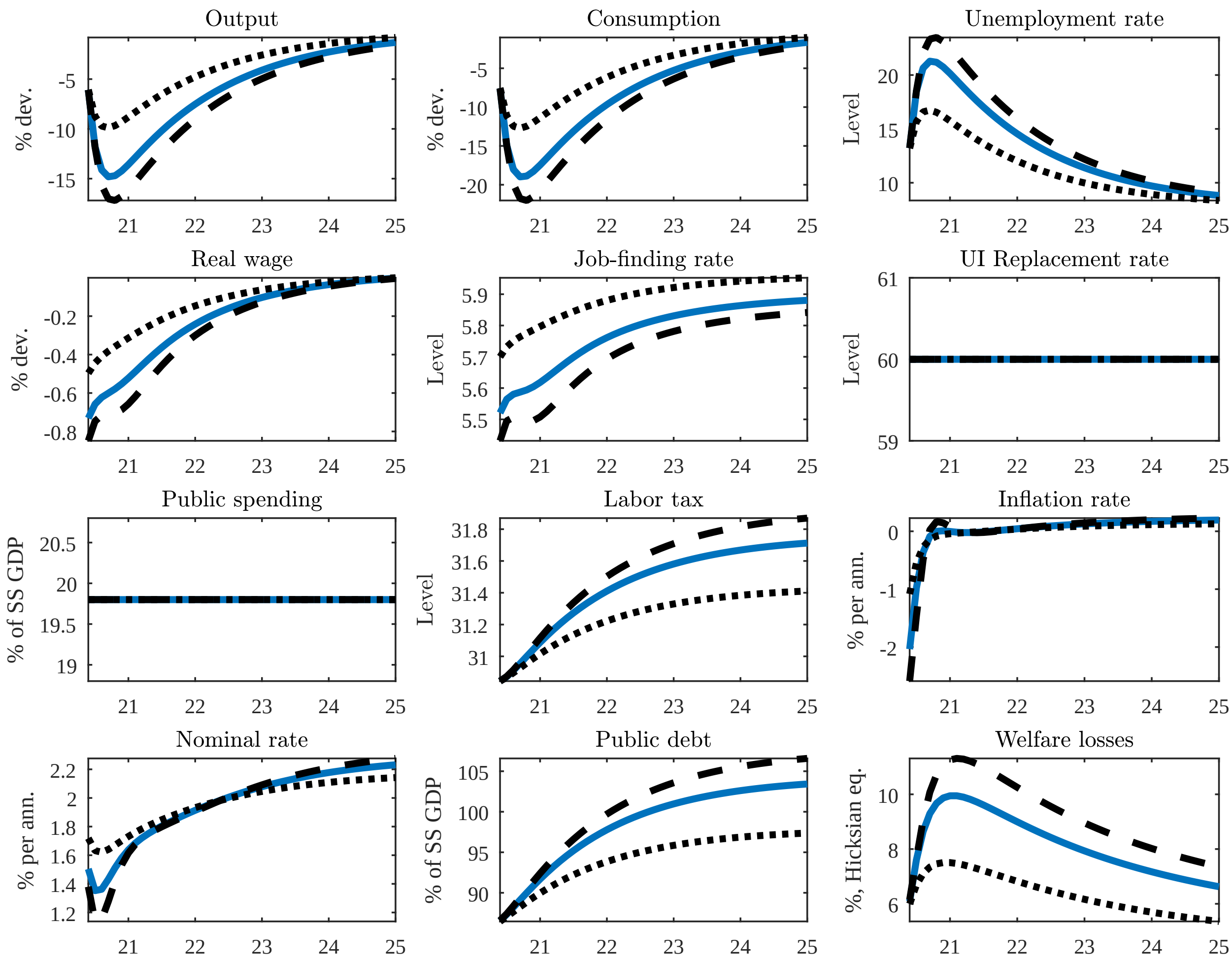
where remember, $\tilde{c}$ refers to a bundle of private and public goods.

Let us start with the effects of a 1-month lockdown. Figure 1 shows that, 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, which prevent some workers to going back on the labor market quickly. The overall drop in GDP thus reaches almost 10 percents (-9.89). Consumption falls as well, not so much because the consumption of workers remaining

[3] Lockdown in the Chinese province of Wuhan lasted 2.5 months. Most countries that engaged in such policies will set a minimal duration of one month.

[4] The model is simulated under perfect foresight using a Newton-type algorithm to account for the potential non-linear effects of the shocks. 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).

Figure 1: Macroeconomic effects of lockdown policies.



Dotted: One month. Solid: 2 months (baseline). Dashed: 3 months.

employed falls, but because many workers are now unemployed. This composition effect lowers consumption by almost 13 percent (12.72) 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. The unemployment rate jumps at 13.2 percents on impact and reaches a peak of 16.7 percents, at the end of June 2020. The profitability of a match falls substantially, which lowers the bargained notional real wage and thus the effective real wage, although by less than 0.6 percent.

The dynamics of inflation is of the utmost interest. Indeed, when facing a negative supply shock, a standard RANK economy would predict a rise in the real interest rate, and rise in inflation and a rise in the nominal rate. The chief reason is that the Euler equation would imply that the marginal utility of consumption is lower in the future than in the present, since consumption is lower today and higher tomorrow. The equilibrium real rate should thus rise, reflecting the demand of the representative household to borrow to smooth the consequences of the negative supply shock. In our model, this motive is present, but an additional motive determines the equilibrium real rate: the demand for a precautionary motive. When future unemployment rises, workers face a potential decrease in their consumption path that depresses their consumption and raises their desired savings. The real rate thus falls, aggregate demand falls along with inflation, and the nominal rate falls. This is the case here, as the model implies that aggregate demand is depressed more than supply, leading the shock to have even larger negative macroeconomic consequences. Hence, our model predicts that the current lockdown policies have a current deflationary effect. After unemployment reaches its peak, the logic inverts, precautionary savings fall, raising the real rate, leading to inflationary effects. However, in our case, the subsequent inflationary effects are much smaller than the initial deflation effects: inflation drops by 1.08pp in annual terms and then jumps at 0.43pp when unemployment starts falling.

The dynamics of inflation implies a negative response of the nominal rate controlled by the Central Bank. In our model, the drop in inflation is not large enough to push the nominal rate at the ZLB. In addition, because the distribution of UI benefits explodes and because the (labor income) tax base shrinks, a large public deficit arises: from -3 percents of steady-state output on impact to 5.8 percents at the trough. Hence, the debt ratio rises slowly and eventually reaches more than 97.7 percents of steady-state GDP, a 11.7pp increase. The labor income tax rate rises gradually to help finance the deficit, by more than 0.58pp.

When the lockdown lasts for more than one month, the impact responses of output, consumption and unemployment are the same but the subsequent movements are much larger. Output falls by 14.8 percents when lockdown lasts 2 months and 17.2 percents when it lasts 3 months. The fall in consumption shows a similar pattern (-19 and -22 percents respectively), unemployment rises to much higher levels (21.3 and 23.5 percents respectively), which magnifies the precautionary motive and leads to much greater deflationary effects: inflation falls by 2pp in the 2-month case and by 2.6pp in the 3-month case, which triggers much larger drops in the nominal rate of the Central Bank. Finally, the debt ratio increases by more 18pp and 21.3pp respectively.

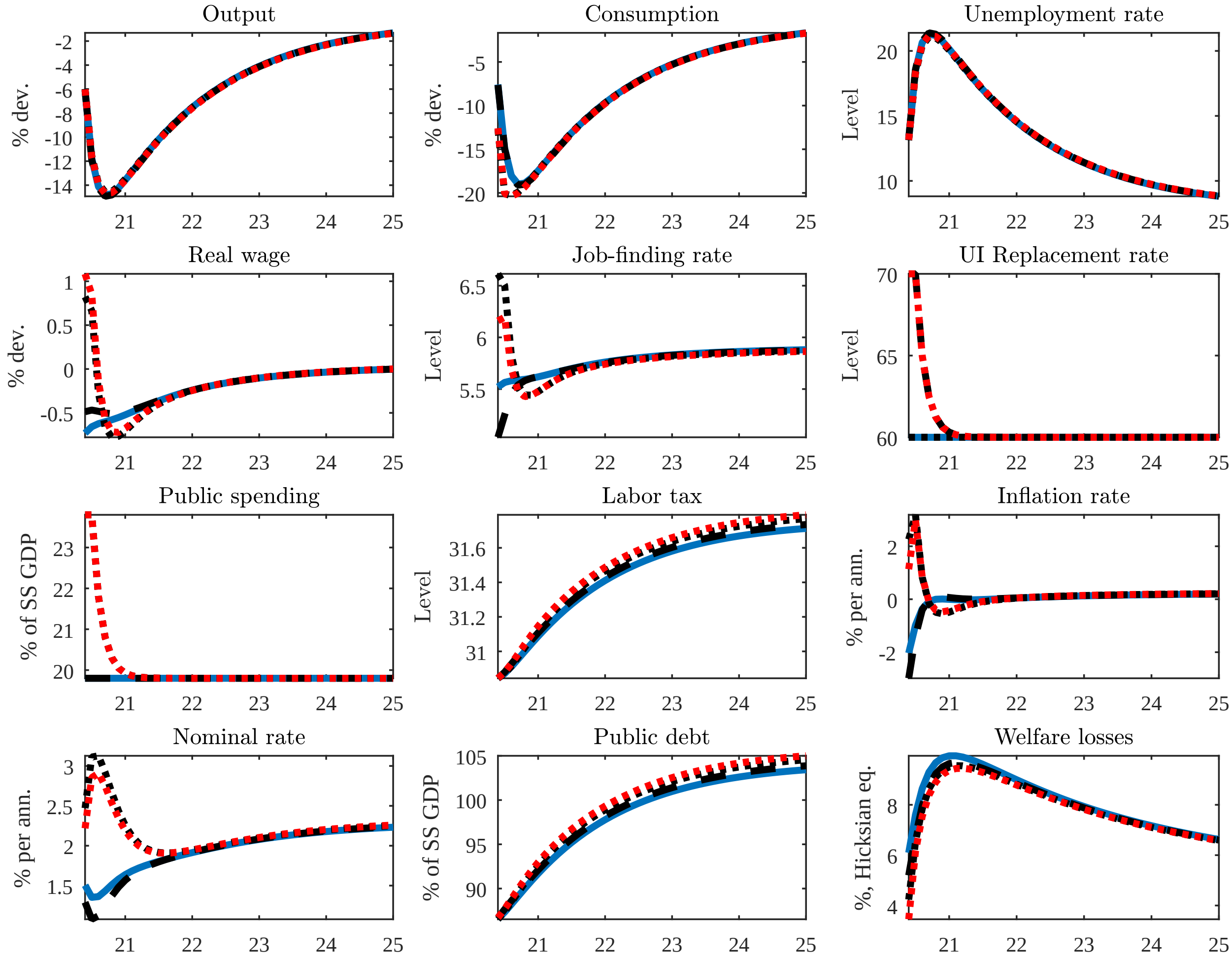
Last but not least, the welfare losses from the lockdown policy are substantially large. They peak at 7.5 percents of consumption equivalent in the case of a 1-month lockdown, almost 10 percents for a 2-months lockdown and 11.3 percents if the lockdown lasts 3 months. In particular, the maximum welfare losses in the case of a 2-months lockdown arise at the horizon of 8 months, in October 2020.

5 Raising government spending and UI benefits

Figure 2 now reports the dynamics of our economy in the baseline case of a 2-months lockdown when the government adopts passive policies by which government spending and the UI replacement rate remain constant (solid) with a case where the government raises spending to steady-state GDP by 4pp (*i.e.* from 0.198 to 0.238, dotted line) and with a case where the government raises the UI replacement rate by 10pp (*i.e.* from 0.6 to 0.7, dashed line). In each case, the policy instrument is raised for the duration of the lockdown and decays at the same rate as the lockdown. A last case combines both spending and UI benefit policies. The first active policy case is realistic given that, for example, France recently announced a total stimulus package of 100 billions of euros, representing approximately 4.25 percent of GDP. The second is also realistic, given that in most Euro Area countries, a partial unemployment system allows workers that are temporarily locked down to get a substantial fraction of their usual labor income.

Figure 2 draws quite a pessimistic picture: neither the rise in government spending or the increase in UI benefits are able to flatten the output curve. While somehow surprising, the chief reason is relatively simple: an exogenous increase in aggregate demand relative to the case of passive policies does not alleviate the constraint on supply. Even if the government could stimulate demand, supply is simply not there. As a consequence, the unemployment rate is almost not affected either. Aggregate consumption is only marginally affected by the UI benefit policy, and lowered by the spending policy because of crowding out effects. The crowding out effect is reflected in a lower fall of inflation when government spending is raised. On the contrary, when the UI rate is raised, the deflationary effect of the lockdown policy is magnified: employed workers understand that they are almost fully insured today but that it will not last, therefore raising the precautionary motive. For instance, inflation falls by 2pp in annual terms in the baseline case with passive policies, by 0.55pp when public spending

Figure 2: The effects of spending and UI benefit policies.



Dotted: public spending. Solid: passive. Dashed: UI replacement rate. Red dotted: both policies. Note: The time range for the plot of inflation has been shortened for to better illustrate the (short-run) effects of policies on inflation.

are increased and by 3pp when the UI replacement is raised. Nevertheless the consequences of these policies are mainly reflected in nominal variables rather than in real variables, as already mentioned. Finally, Table 2 below reports the welfare losses from the 4 cases at the 8-months horizon. Both discretionary policies reduce the welfare losses although not by much. The public spending policy cuts the welfare losses by roughly 0.5pp while the UI benefit policy lower them by 0.35pp. The combination of both policies reduces the welfare losses by 0.6pp.

6 Optimized government spending and UI benefits

So government policies are almost ineffective in reducing the fall in output or the increase in unemployment. Does it mean that the government should not intervene in this context? This is clearly not the case because these policies can still affect welfare while having relatively little effects on output and unemployment. Hence, we now analyze the optimized responses of spending and the UI replacement rate to the lockdown shock. To do this, let us consider the two simple policy rules for government spending and the UI replacement rate:

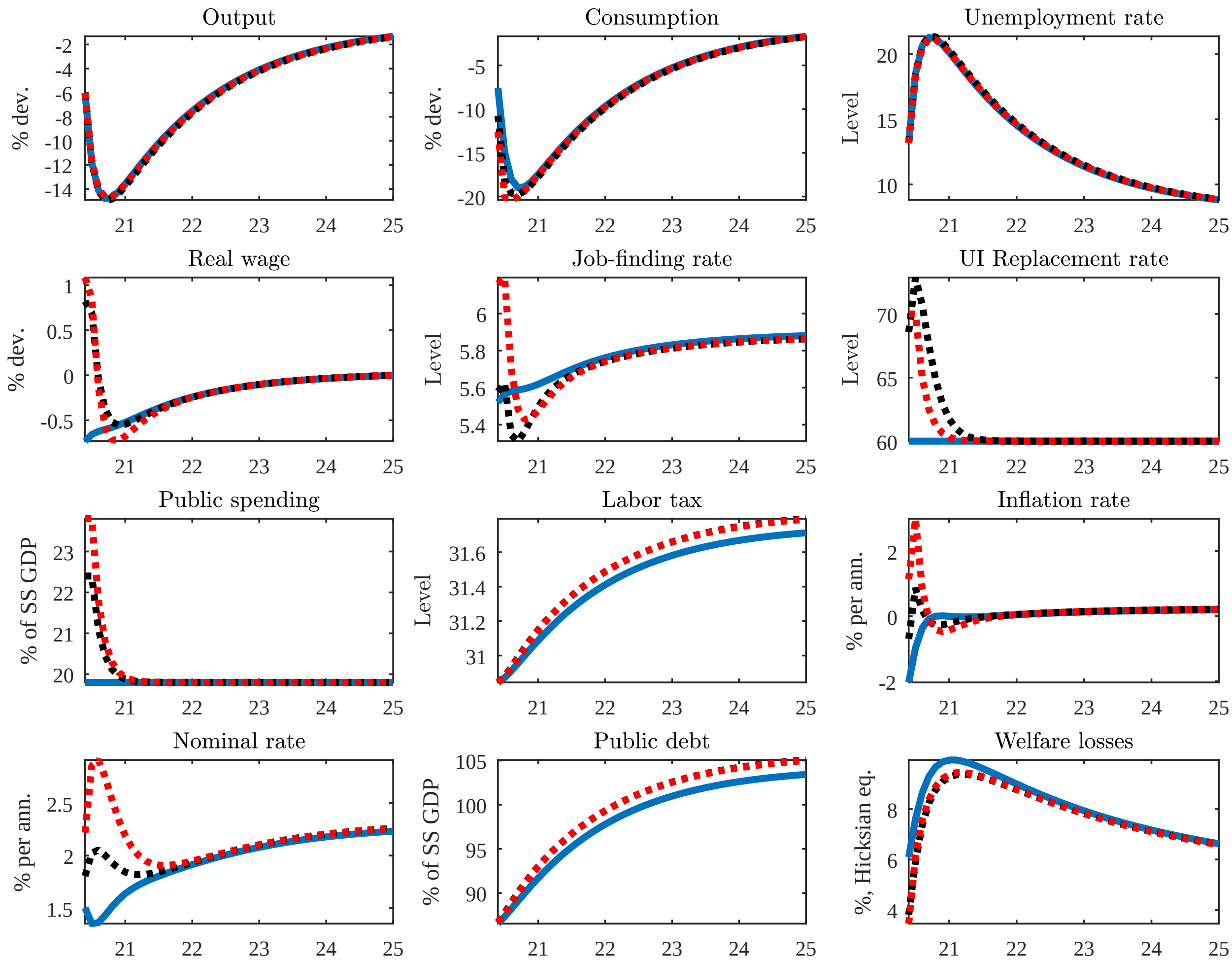
$$g_t - g = (1 - \rho_g)(g_{t-1} - g) + d_g \Lambda_t \tag{29}$$

$$b_t^r - b^r = (1 - \rho_b)(b_{t-1}^r - b^r) + d_b \Lambda_t \tag{30}$$

where ρ_g and ρ_b are now allowed to differ from the autoregressive parameter of the lockdown shock, and d_g and d_b are the feedback parameters to the lockdown policy. The idea of our optimized policies is to find the set of parameters $\mathcal{P} = \{\rho_g, \rho_b, d_g, d_b\}$ that minimizes the welfare losses from the household sector that result from the lockdown policy ζ. Given that our baseline scenario is a 2-months lockdown shock, and that welfare losses peak 8 months after the lockdown shock hits, we consider policies that seek to minimize the welfare losses at the 8-months horizon, that is ζ_8. Figure 3 reports the dynamics implied by optimized policies, along with those under discretionary policies investigated in the previous section and the passive case, for a comparison.

Figure 3 shows that the optimized policies are actually very close to the discretionary policies undertaken by government since the beginning of the lockdown: raise public expenditure substantially and raise UI benefits (which, given the simplicity of our model, could mean in reality an extension in duration or a rise in the amount of UI benefits). The quantitative results of our optimized policies imply however that public spending should rise less (2.5pp of steady-state GDP) than under discretionary policies (4pp of steady-state GDP), and that the replacement rate of UI benefits should rise more (12.9pp) than under discretionary policies (10pp). In any case, as shown by Table 2, the welfare gains from optimized policies with

Figure 3: Optimized spending and UI benefit policies.



Dotted: optimized policies. Solid: passive. Red dotted: discretionary policies.

respect to discretionary policies are very small (around 0.1pp of consumption equivalent) compared to the global welfare losses from the lockdown shock (almost 10pp).

Table 2: Welfare losses at 8 months (ζ_8), in percents

Passive policies $\Delta g = 0, \Delta b^r = 0$	9.95
Raising g $\Delta g = 0.04, \Delta b^r = 0$	9.50
Raising b^r $\Delta g = 0, \Delta b^r = 0.1$	9.63
Raising both $\Delta g = 0.04, \Delta b^r = 0.1$	9.36
Optimized rules $d_g = 0.3881, d_b = 1.5404$	9.26

7 Conclusion

This paper developed a tractable HA model with unemployment risk, imperfect insurance and borrowing constraints. Our assumptions produced a degenerate distribution of households that greatly simplified the model. Hit with a shock that lowers employment for a few months, the model produced very large numbers for the drop in economic activity and the rise in unemployment. The rise in present and expected unemployment led households to precautionary save, making the lockdown shock a Keynesian supply shock. It also predicted an important deterioration of the state of public finances. The longer the lockdown the larger the resulting depression. In addition, because European labor markets are relatively sluggish, the recovery was slow and the effects of the shock lasted at least until 2025. Finally, we analyzed the effects of raising public spending and extending UI benefits, and found that those policies had little effect on output and unemployment dynamics, but were able to mitigate the welfare losses from lockdown policies by sustaining aggregate demand and fostering risk-sharing among households. Optimized policies were found to be close enough to the actual policies chosen by most European governments.

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