

The COVID19-Pandemic in the EU: Macroeconomic Transmission and Economic Policy Response*

Philipp Pfeiffer, Werner Roeger and Jan in 't Veld

Abstract

This paper uses a macroeconomic model to analyse the transmission of the COVID19-pandemic and its associated lockdown and quantify the stabilising effects of the economic policy response. Our simulations identify firm liquidity problems as crucial for shock propagation and amplification. We then quantify effects of short-term work allowances and liquidity guarantees - central policy strategies in the European Union. The measures reduce the output loss of COVID19 and its associated lockdown by about one fourth. However, they cannot prevent a sharp but temporary decline in production.

JEL Classification: E32, E6, F45, J08.

Keywords: Fiscal policy, COVID19, Monetary union, Short-work allowances, Liquidity constraints

* **Disclaimer:** The views expressed in this paper are those of the authors and should not be attributed to the European Commission.

Contacts: Philipp Pfeiffer, European Commission, Directorate-General for Economic and Financial Affairs, philipp.pfeiffer@ec.europa.eu; Werner Roeger, European Commission, Directorate-General for Economic and Financial Affairs, werner.roeger@ec.europa.eu; Jan in 't Veld, European Commission, Directorate-General for Economic and Financial Affairs, jan.intveld@ec.europa.eu.

Acknowledgements: We would like to thank Declan Costello, Björn Döhring, Robert Kuenzel, João Leal, José Leandro, Hauke Vierke, Lukas Vogel, Milan Vyskrabka and many colleagues involved in Directorate-General for Economic and Financial Affairs' forecast for useful comments and suggestions.

1. INTRODUCTION

COVID19 is a rare disaster requiring urgent and targeted policy action. The economic fallout of the pandemic has triggered an intense debate on effective policies. Governments have announced and implemented exceptional stabilisation efforts. Our paper contributes to this debate using a dynamic general equilibrium model and an up-to-date collection of fiscal policy measures in the EU. We assess the economic transmission of COVID-19 and quantify gains from stabilisation policies in the European Union (EU). Our model is two-region TANK model (two-agent New Keynesian) consisting of the EU-27 and the rest-of-the world (RoW). The framework is based on the European Commission's QUEST III model (Ratto et al., 2009). We extend the baseline model with a parsimonious model of heterogeneous firms and liquidity constraints.

Our analysis proceeds in two steps. First, a set of scenarios analyses the essential economic characteristics of the pandemic.¹ Stylised shocks capture the dynamic adjustment of the economy to (i) supply shocks through precautionary measures and (ii) shortfalls in consumer demand. Precautionary supply-side measures constrain labour input in production. The demand lockdown prevents consumers from undertaking certain consumption activities by either legal restrictions or voluntary protection. We quantify the impact of these shocks on the depth and duration of the recession. In addition, a simple financial accelerator mechanism via firm liquidity constraints amplifies the shocks. Without policy support, the simulations show an output contraction by more than 20% in the second quarter of 2020 compared to a no-pandemic baseline. Firm liquidity constraints almost double the depth of the recession and substantially prolong the slump. This amplification leads to a more U-shaped recovery. Output in 2021 remains markedly below a no-pandemic baseline (almost 40% of the 2020 impact remains in 2021). By contrast, a standard model without borrowing constraints does not generate a (large) fall investment based on the temporary lockdown shocks to demand and supply alone. As a result, the simulations without firm liquidity constraints (and in the absence of other shocks), show a V-shaped recovery.

In a second step, we turn to an early assessment of economic policy. The predicted collapse is unprecedented in post-war history. It warrants systematic comparison and quantification of the main policy strategies based on the identified transmission channels. Concretely, we focus on stabilisation gains from short-term work (STW) allowances and government guarantees. Besides automatic stabilisers, STW allowances and government guarantees are the dominant forms of fiscal response in the EU. Exploiting an up-to-date dataset of planned fiscal measures in the EU-27, we then show that together economic policies likely eliminate about one-fourth of the macroeconomic fallout of the pandemic.

At the heart of our policy analysis are two interacting adjustment inefficiencies, namely employment adjustment costs and liquidity constraints for firms. Measures targeted at reducing these distortions, such as STW allowances and loan guarantees, prevent a considerable revision of investment plans. Alleviating liquidity constraints supports spending in wages, intermediates, investment, and servicing of loans. STW allowances are particularly effective. Since workers stay in the firm, firms avoid matching frictions and hiring or firing costs. This cost-saving channel, in turn, improves the corporate liquidity position by stabilising the gross operating surplus. As a result, fewer firms become constrained, limiting the amplification arising from the occasionally binding constraint. Apart from short-run expansionary effects, these measures may avoid that temporary liquidity problems morph into insolvency issues. Together STW and guarantees reduce the output loss of COVID19 and its

¹ As discussed in Section 1.1, the scenarios are based on stylised versions of the simulations done in the context of the European Commission's Spring Forecast published on May 7, 2020: https://ec.europa.eu/info/business-economy-euro/economic-performance-and-forecasts/economic-forecasts/spring-2020-economic-forecast-deep-and-uneven-recession-uncertain-recovery_en

associated lockdown by around four percentage points: one fourth of the negative economic impact of the pandemic.

The policies, however, cannot prevent a temporary decline in production because of sickness, restrictions on the mobility of workers or supply chain interruptions. Moreover, additional consumption from transfers can only (fully) materialise after the lockdown period. It cannot prevent a sharp drop in consumer spending during the pandemic.

We analyse our results for a given short-lived pandemic. This optimistic simplification is designed to transparently distill essential model features, in particular the internal propagation mechanism in response to the exogenous pandemic shocks. An additional longer pandemic scenario relaxes this assumption to show the sensitivity in a stylised way.

1.1. RELATED LITERATURE

There have been widespread calls for policies to mitigate the impact of the COVID-19 shock (e.g., Brunnermeier et al., 2020; Gopinath, 2020; and papers in Baldwin and Weder di Mauro, 2020). While monetary policy plays a crucial role in safeguarding liquidity conditions in the banking system and protecting the continued flow of credit to the real economy, the space of central banks is largely constrained. It is generally recognised that the ECB should not be expected to do all the heavy lifting. Economists have therefore emphasised that governments must step in with generous loans and other support programs to prevent mass bankruptcies, and direct fiscal measures to support demand when the lockdowns are lifted (e.g. Bénassy-Quéré et al. (2020), Lane (2020), Claes and Wolff (2020), and others).

In an assessment of the efficacy of fiscal policies in the financial crisis, Coenen et al. (2012) compare transfer multipliers in seven large-scale DSGE models. In these models, spending multipliers are typically largest, often exceeding unity when the zero lower bound (ZLB) constrains monetary policy. By contrast, tax multipliers remain lower. Typically, transfer multipliers are also lower than government consumption and investment shocks. However, targeted transfers to constrained households entail multipliers closer to those of spending shocks. Guerrieri et al. (2020) emphasise that when some sectors are shut down, a traditional fiscal stimulus is less effective, as any money spent cannot go to “closed” sectors, whose workers have the greater marginal propensity to consume. As long as there are sectors shut down, there is a unit government spending multiplier and a transfer multiplier equal to the average marginal propensity to consume. Faria e Castro (2020) analyses different types of fiscal policies and finds that unemployment insurance benefits are the most effective tool to stabilise income for borrowers, who are the hardest hit, while savers may favour unconditional transfers. Liquidity assistance programs are effective if the policy objective is to stabilise employment in the affected sector. Bayer et al. (2020) also emphasise the importance of conditional transfers. Fornano and Wolf (2020) emphasise the role expectations and the risks of demand-induced growth slowdowns.

Our paper considers firm and household heterogeneity. Yet, the model remains parsimonious. Important related work complements our analysis by considering a more granular economic structure. Hagedorn and Mitman (2020) apply a HANK model to study the interaction of fiscal and monetary policy. Guerrieri et al. (2020) as well as Baqaee and Farhi (2020) use multi-sector models to show amplification effects through complementarities and incomplete markets. Bigio et al. (2020) compare transfers to credit policy and highlight the role of debt.

The economic literature on COVID19 is growing rapidly. Important contributions also link economic models with epidemiological frameworks (e.g., Acemoglu et al., 2020; Eichenbaum et al., 2020; Glover et al., 2020; and Jones et al., 2020; and references therein).

We contribute to this literature by implementing a lockdown shock in a standard macro model and highlighting the role of liquidity constraints. Exploiting information about size and composition of EU fiscal measures, our paper then shows the depth of the recession and the shape of the recovery with and without fiscal measures.

The paper is closely related to the scenario analysis published in the Spring Forecast of the European Commission (2020). Compared to the present paper, the simulations reported in the forecast document consider a richer modelling environment with deeper regional and sectoral disaggregation and more transmissions channels (e.g. uncertainty shocks) and time patterns of the pandemic. By contrast, here we stress the role of inefficiencies arising from employment adjustment and liquidity constraints in a more stylised way.

1.2. ROAD MAP

The next two sections present the model, its calibration, and the underlying assumptions of the pandemic shock. Section 4 shows simulations results absent policy intervention, while Section 5 summarises announced policy measures and the mapping into the model. Section 6 conducts robustness analysis and Section 7 concludes.

2. MODEL

We conduct our analysis in a two-region TANK model (two-agent New Keynesian) consisting of the EU-27 and the RoW. The framework is based on the European Commission’s QUEST III model suite (see, e.g., Ratto et al., 2009). Our discussion, therefore, focusses on the main model elements and refers for standard features to Ratto et al. (2009). We extend the baseline model with a parsimonious model of firm liquidity constraints.

The model structure of all regions is symmetric. It includes nominal price and wage rigidities as well as adjustment costs associated with employment and investment. Households provide labour services to domestic firms. A share of households is liquidity constrained. Monopolistic trade unions set sticky wage rates. Governments purchase the local final good; make transfers to households; levy labour, profit, and consumption taxes; and issue debt. We integrate automatic fiscal stabilisation via tax revenues, constant spending in real terms and unemployment insurance. Trade and financial markets link the EU (based on EU-27 shares) and the rest-of-world. A limited interest rate response captures restricted monetary policy. We next present the core of the EU model block. The RoW block has the same structure except for the zero lower bound (ZLB) constraint on monetary policy (but features a block-specific calibration). *-superscript denotes RoW variables.² To ease notation, the presentation abstracts from linear taxation of consumption, labour, and profits.

2.1. HOUSEHOLDS

The household sector consists of two representative households $h \in \{R, C\}$, of total mass one. The Ricardian household, indexed R , enjoys full access to financial markets. The other household is liquidity-constrained and indexed by C . This household does not trade on asset markets. Instead, she

² Parameters such as the degree of openness differ across the EU and RoW. See the discussion below.

consumes her entire disposable wage and transfer income in each period. Both households have this utility function over consumption $C_t^{h,U}$ and leisure $(1 - N_t^i)^3$:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{1}{1 + \psi_t} \right) \log(C_t^{h,U}) - \chi \frac{(N_t^i)^{\kappa+1}}{\kappa + 1} \right] \quad (1)$$

where β is the subjective discount factor and $\kappa > 0$. $\left(\frac{1}{1 + \psi_t} \right) < 1$ captures a self-imposed demand constraint in t as in Eichenbaum et al. (2020). Moreover, $C_t^{h,U} \leq \bar{C}^{h,U}$ represents a regulatory constraint on consumption (binding in t , see below). We denote the multiplier attached to the regulatory constraint by ϕ_t .

The aggregate value of any household-specific variable X_t , in per-capita terms, is given by $X_t = (1 - s^{lc})X_t^r + s^{lc}X_t^l$, where s^{lc} denotes the relative size of the liquidity constrained household.

2.1.1. The Ricardian household

The Ricardian household maximises utility subject to a sequence of budget constraints

$$\Delta L_t + \Delta B_t + \Delta V_t = r_{t-1}B_{t-1} + r_{t-1}^L L_{t-1} + D_t - C_t^{R,U} + W_t^r N_t^R + TR_t^R + ben_t^R - T_t, \quad (2)$$

where W_t^r , N_t , T_t , and TR_t^R denote the real wage rate (same for both households), labour supply, direct taxes paid by households, household-specific transfers, respectively. Assets of the household are made up of loans to firms L_t (the return r_{t-1}^L includes a loan default risk premium), bonds B_t (an internationally traded bonds⁴ and government bonds) with net return r_{t-1} , and firm shares V_t , yielding dividends D_t . ben_t^R summarises STW allowances, stw_t , and unemployment benefits, $uben_t$:⁵

$$ben_t^R = (uben_t)(1 - npart - N_t^R) + stw_t(N_t^R - N_0^R), \quad (3)$$

where $(1 - npart)$ and N_0 denote the labour force participation rate and baseline labour demand, respectively.

In equilibrium, intertemporal consumption-saving choice satisfies:

$$\frac{C_{t+1}^R}{C_t^R} = \beta(1 + r_t^f)(1 + \psi_t^R)(1 + \phi_t^R), \quad (4)$$

where r_t^f denotes the risk-free rate. Both constraints imply a negative shock to consumption in t . The consumption constraint $C_t^{R,U} \leq \bar{C}^{R,U}$ becomes binding in period t and $\phi_t^R > 0$ if $C_t^R = \bar{C}^R$. Note that both consumption constraints, self-imposed (ψ_t^R) and regulatory (ϕ_t^R), have the same effect on the

³ Households supply differentiated types of labour services i , which we assume to be distributed equally over both household types. Unions bundle the differentiated labour services provided by the two types of households and maximise a joint utility function for each type of labour i . See below.

⁴ The international bond features a country risk premium which depends on the net foreign asset position to ensure long-run stability of the model (Schmitt-Grohé and Uribe, 2003).

⁵ The unemployed $(1 - npart - N_t)$ receive benefits $uben_t = benrr W_t^r$, where $benrr$ is the exogenous benefit replacement rate.

Euler equation.⁶ In the following, we assume $\phi_t > 0$ and $\psi_t = 0$, corresponding to a shock to current consumption in the Euler equation.

2.1.2. The liquidity-constrained household

Voluntary social distancing and regulatory constraints on consumption also apply to the constrained household; namely a self-imposed consumption constraint

$$W_t^r N_t^L - T_t + TR_t^C + ben_t^C > C_t^C \quad (5)$$

and a regulatory constraint

$$W_t^r N_t^L + TR_t^C + ben_t^C > \bar{C}^C. \quad (6)$$

As a result, the constrained household features forced savings:

$$\Delta B_t^C = W_t^r N_t^C + TR_t^C + ben_t^C - T_t - C_t^C \quad (7)$$

and dissaving in periods following the lockdown $C_{t+\tau}^C = W_{t+\tau}^r N_{t+\tau}^C + TR_{t+\tau}^C + ben_{t+\tau}^C - T_{t+\tau} + sB_{t+\tau-1}^C$, where τ denotes the post-lockdown period.

2.2. INTERMEDIATE GOODS FIRMS

There is a continuum of intermediate goods indexed by $j \in [0,1]$. A single firm produces each good. Firms face symmetric decision problems and make identical choices. Firm j has technology $Y_t^j = A(N_t^j)^\alpha (u_t^j K_t^j)^{1-\alpha}$ where Y_t^j, N_t^j, u_t^j and K_t^j are the firm's output, labour input, capacity utilisation and capital stock, respectively. A is a constant common productivity level. The law of motion of firm j 's capital stock is $K_t^j = (1 - \delta)K_{t-1}^j + I_t^j$, with depreciation rate δ and gross investment I_t^j . The period t dividend of intermediate good firm j is:

$$D_t^j = p_t^j Y_t^j - W_t N_t^j - p_t^K I_t^j - r_{t-1} L_{t-1}^j + L_t^j + \Gamma_t^j, \quad (8)$$

where p_t^j and p_t^K denote the price charged by the firm and the price of production capital, respectively. L_t^j are one-period loans. Γ_t^j summarises quadratic price and factor adjustment costs.⁷ Firm j maximises the present value of dividends $V_t^j = D_t^j + \Lambda_{t,t+1} V_{t+1}^j$, where $\Lambda_{t,t+1}$ denotes the discount factor of Ricardian households. For later purpose, it useful to define the (real) gross operating surplus: $GOS_t^j = Y_t^j - W_t^r N_t^j$. We model labour and capital/investment adjustment costs as⁸:

⁶ However, consumption responds different to policies for the two shocks. With a self-imposed reduction of consumption, household consumption will respond to fiscal measures (e.g. a reduction of VAT), while the government imposed constraint on consumption is a quantity constraint which cannot be affected by fiscal measures.

⁷ Quadratic price adjustment costs imply that the inflation rate of local intermediates obeys an expectational Phillips curve. See Annex B.

⁸ Given substitutability between capital and labour allowed by the production technology, firms could increase the utilisation of capital to partly offset the labour input constraint. We find this an unrealistic option in the short run given the scale of the supply constraint. Therefore, we impose a partial short-run complementarity between labour and utilised capital

$$\frac{\Delta N_t}{N_t} \approx \frac{\Delta UC_t}{UC_t}.$$

$$\Gamma_t^{N,j}(N_t^j) \equiv \frac{\gamma^N}{2} \left(\frac{N_t^j}{N_{t-1}^j} - 1 \right)^2 \quad (9)$$

$$\Gamma_t^{K,j} \equiv \frac{\gamma^K}{2} \left(\frac{I_t^j}{K_{t-1}^j} - \delta \right)^2 p_t^I \bar{K}_{t-1}^j + \frac{\gamma^I}{2} p_t^I (\Delta I_t^j)^2 \quad (10)$$

Next, we discuss the two transmission channels of the pandemic on the production side: Labour input restrictions and liquidity constraints. Lockdown measures imply a downward shift in labour demand. In addition, the reduction in output induced by the pandemic and its associated demand and supply lockdown measures leads to falling investment via liquidity problems for firms.

2.2.1. Labour input constraints: Lockdown shocks

To prevent infections at the workplace, governments impose restrictions on labour input. Firms can only use \bar{N}_t employees during the lockdown. Precautionary distancing measures at the workplace imply then $N_t \leq \bar{N}_t$. A binding constraint shifts down the labour demand schedule:

$$\frac{\partial Y_t^j}{\partial N_t^j} = W_t^r + \theta_t^N, \quad (11)$$

where $\theta_t^N \geq 0$ is the Lagrange multiplier of the labour input constraint.

2.2.2. Investment liquidity constraints

Below we consider an extended model in which a subset $0 \leq s_t^{li} < 1$ of intermediate goods firms faces temporary binding liquidity constraints of the form:⁹

$$L_t \leq \mu K_{t-1}, \quad (12)$$

where μ is the loan-to-value ratio. For these firms, adverse demand and supply shocks increase liquidity needs and trigger a credit tightening. A binding collateral constraint binding imposes a reduction in investment. Therefore, the investment rate for constrained firms follows:

$$\left(\frac{I_t^j}{K_{t-1}^j} - \delta \right) = \mathcal{H} \left(\frac{GOS_t^j}{K_{t-1}^j} \right) \equiv \zeta_1 \left(\frac{GOS_t^j}{K_{t-1}^j} - \delta \right) - \zeta_2, \quad (13)$$

where parameters ζ_1 and ζ_2 govern the strength of the liquidity constraint. The share of constrained firms is endogenous and follows:

$$s_t^{li} = a_0 - a_1 GOS_t. \quad (14)$$

As shown in Annex A, this reduced-form equation with parameters a_0 and a_1 is consistent with a micro-founded liquidity constraint.

⁹ By contrast, in the baseline model $s_t^{li} = 0 \forall t$.

The remaining unconstrained firms decide investment according to a standard Q -equation $Q_t^j = 1 + \Gamma_t^{j,j'} \left(\frac{I_t^j}{K_t^j} \right)$, where Q_t^j represents the discounted value of physical capital. The net investment rate is a function of Q_t^j , i.e. $\left(\frac{I_t^j}{K_{t-1}^j} - \delta \right) = \mathcal{F}(Q_t^j)$ for $j \in [s_t^{li}, 1]$. Thus, the aggregate net investment follows:

$$\left(\frac{I_t}{K_{t-1}} - \delta \right) = \int_0^{s_t^{li}} \mathcal{H} \left(\frac{GOS_t^j}{K_{t-1}^j} \right) dj + \int_{s_t^{li}}^1 \mathcal{F}(Q_t^j) dj. \quad (15)$$

2.3. FINAL GOOD FIRMS

Final good producers have access to a CES production technology $Y_t = \left[(s^d)^{1/\nu} O_t^{v-1} + (1 - s^d)^{1/\nu} M_t^{v-1} \right]^{\frac{v-1}{v}}$, with home bias $0.5 < s^d < 1$. $O_t = \left[\int_0^1 (Y_t^j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}}$ is an aggregate of the local intermediates, where ε is the exogenous substitution elasticity between varieties. M_t denotes intermediate imports from the RoW. The final good is used for domestic private and government consumption, and investment.

2.4. WAGE SETTING

A trade union ‘differentiates’ homogenous labour hours provided by the two domestic households into imperfectly substitutable labour services. Both households work the same hours and receive the same wage. The labour input N_t in the production process of intermediate goods is a CES aggregate of these differentiated labour services. The union sets wage rates at a mark-up μ_t^W over the marginal rate of substitution between leisure and consumption. μ_t^W is inversely related to the degree of substitution between labour varieties. The mark-up is countercyclical because of nominal wage adjustment costs. Following Blanchard and Gali (2007), we allow for real wage inertia; the current period real wage rate is a weighted average of the desired net real wage and the past (net) real wage:

$$(1 - \tau_t^N) W_t^r = [(1 + \mu_t^W) mrs_t]^{1-\xi} [W_t^r (1 - \tau_{t-1}^N)]^\xi, \quad (16)$$

where mrs_t is a weighted average of the two households’ marginal rates of substitution between consumption and leisure. The parameter ξ is an index of real wage rigidity.

2.5. PUBLIC POLICY

2.5.1. Monetary policy

EU monetary policy is subject to a ZLB constraint.¹⁰ The notional interest rate follows a smooth Taylor rule with respect to inflation and the output gap:

¹⁰ Monetary policy in the RoW does not hit the ZLB.

$$i_t = \max \left\{ 0, \rho_i i_{t-1} + (1 - \rho_i) \left(\bar{r} + \pi^{tar} + \tau_\pi \left(\frac{\pi_{t,yoy}^C}{4} - \pi^{tar} \right) + \tau_y y_t^{gap} \right) \right\}. \quad (17)$$

The central bank has an inflation target π^{tar} , adjusts its policy rate relative to the steady-state value \bar{r} when actual CPI inflation deviates from the target, where $\pi_{t,yoy}^C \equiv P_t^C / P_{t-4}^C - 1$ is year-on-year CPI inflation, or in case of a non-zero output gap (y_t^{gap}).¹¹

2.5.2. Fiscal policy

We assume that the government keeps its expenditure (G_t) constant in real terms. Real government debt evolves as:

$$B_t^G = (1 + r_t^G) B_{t-1}^G + G_t + (uben_t)(1 - npart - N_t) + stw_t(N_t - N_0) + TR_t^L + TR_t^R - R_t^G, \quad (18)$$

where r_t^G denotes the government interest rate. R_t^G , government revenues, are the sum of consumption, labour, and profit taxes. Time-varying labour taxation stabilises the debt-to-GDP ratio:

$$\tau_t^N = \tau_{t-1}^N + d_t^G \left(\tau^B \left(\frac{B_t^G}{4Y_t} - \overline{btar} \right) + \tau^{def} \Delta B_t^G \right), \quad (19)$$

with \overline{btar} being the target level of government debt-to-GDP. Parameters τ^{def} and τ^B control the feedback rule. d_t^G is a dummy that allows to turn off the debt rule temporarily.

2.6. MODEL CALIBRATION AND SOLUTION

In our model calibration, one period corresponds to one quarter. Tables 1 summarises the main parameter values. Table 2 features block-specific parameter values. Macroeconomic aggregates that characterise the steady state, like private and public consumption and investment, trade openness, and trade linkages match block-specific data from national accounts and the GTAP database (Narayanan and Walmsley, 2008).

Behavioural parameters that govern the dynamic adjustment to shocks are based on earlier estimates of QUEST model versions. In particular, the model estimations have identified high labour adjustment costs for the EU ($\gamma^N = 25$).¹² Annex B shows additional details on the convex adjustment costs related to price setting and capacity utilisation. Concerning financial market frictions, we set the share of the Ricardian household to 60% - close to the estimates in Ratto et al. (2009), Dolls et al. (2012) and Kaplan et al. (2014). We microfound the firm liquidity needs based on collateral constraints in Annex A. In our simulation, the endogenous share of constrained firms reaches around 30 per cent in 2020Q2 (including policy). This value is in line with recent estimates (OECD, 2020) and based on a collateral constraint parameter μ of 0.3.¹³ The labour supply elasticity is set at 0.2 slightly below the estimate in Kollmann et al. (2016). Concerning adjustment costs on labour, goods, and capital, we broadly follow earlier QUEST-based estimates. The tax rule parameters assure a smooth transition to the long-run debt-to-GDP ratio. The latter reflects average pre-pandemic EU data. Taylor rule parameters are standard values in the literature.

¹¹ The output gap concepts comes from a production function framework. See Ratto et al. (2009).

¹² See, for example, in 't Veld et al. (2015) and Kollmann et al. (2016).

¹³ EU corporate debt is around 30% of the private capital stock.

We solve the model nonlinearly under perfect foresight using a Newton-Raphson algorithm.

Table 1. **Selected parameter values**

Parameter	Value	Description
β	0.997	Discount factor
$1/\kappa$	0.2	Labour supply elasticity
γ^N	25	Head-count adjustment costs parameter
γ^P	20	Price adjustment costs parameter
$\gamma^{ucap,1}$	0.04	Linear capacity-utilisation adjustment cost
$\gamma^{ucap,2}$	0.1	Quadratic capacity-utilisation adjustment cost
γ^K	20	Capital adjustment cost
γ^I	75	Investment adjustment cost
ξ	0.8	Real wage inertia
ν	1.2	Elasticity of substitution in total trade
$1 - 1/\varepsilon$	0.12	Price mark-up
α	0.65	Cobb-Douglas labour share parameter
\bar{G}	0.17	Government expenditure (share in GDP)
μ^W	0.2	Steady-state wage mark-up
δ	0.015	Depreciation rate (quarterly)
ζ_1	1.1	Intensity of liquidity-constraints (firms) parameter 1
ζ_2	0.1	Intensity of liquidity-constraints (firms) parameter 2
a_1	42	Share of liquidity-constrained firms parameter
μ	0.3	LTV in affected sectors
\bar{s}^{li}	0	Steady-state share of liquidity-constrained firms
τ^b	0.05	Tax rule parameter on debt
τ^{def}	0.1	Tax rule parameter on deficit
ρ_i	0.8	Taylor rule persistence
τ_π	2	Reaction to inflation in Taylor rule
τ^y	0.1	Reaction to output gap in Taylor rule

Source: Commission services.

Table 2. **Region-specific parameter values**

Parameter	EA	RoW	Description
s^{lc}	0.4	0.5	Share of liquidity-constrained households
$1 - npart$	0.71	0.76	Labour force to population
N	0.64	0.66	Steady-state employment to population
$benrr$	0.40	0.30	Benefit replacement rate
\overline{TR}	0.16	0.12	Transfer share (share in GDP)
s^d	0.22	0.06	Steady-state share of imports
$btar$	0.8	0.4	Baseline government debt-to-GDP ratio

Source: Commission services.

3. LOCKDOWN AND PANDEMIC IN A MACRO MODEL

We now discuss our assumption on exogenous shocks. For clarity, we assume that containment measures are active in March until June with a peak early in Q2. The pandemic shocks thus last two quarters, with a stronger effect in the second quarter. The shocks end in the third quarter. As discussed above, the pandemic shocks are the two shocks associated with supply and demand disruptions, i.e. restrictions on labour input and consumption (see Jonung and Roeger, 2006). In reality, the separation of demand and supply is difficult. For example, supply constraints are only one factor behind the closure of shops and factories. Moreover, we do not necessarily see a trade-off between economic costs and lockdown. Timely containment measures may also prevent disruptions by avoiding larger-scale outbreak at a later stage. Moreover, in multi-sector models with incomplete markets, supply shocks can have “Keynesian” features (Guerrieri et al., 2020).

All shocks are global, i.e. they are symmetric in both regions of the model. We calibrate the shock size as roughly consistent with the Spring Forecast of the European Commission (2020). The forecast employed detailed sectoral assumptions, e.g. particularly strong declines in air transport, accommodations, restaurants, tourism etc.

Two remarks are in order. First, we do not believe that the pandemic will end in 2020Q3. Yet, this assumption allows us to distinguish the direct pandemic shocks from their endogenous transmission in a transparent way. Second, we do not consider the exogenous shocks included in the simulations to be the only economic disruptions caused by the pandemic. Other channels, such as heightened uncertainty (e.g. Baker et al., 2020), financial risks such as cascading bankruptcies, or permanent changes in consumption patterns, complement the analysis presented in this paper.¹⁴

Regarding public policy, the simulations assume an inactive debt rule for 40 periods, i.e. $d_t^G = 0$ for $t = 2020Q1:2030Q1$ and 1 otherwise. This setting allows a clearer assessment of the budgetary effects of the pandemic and the economic policy response. In our simulations, the ZLB binds for two years. The simulations without discretionary policy intervention assume that governments only rely on automatic stabilisers (in particular unemployment benefits). All scenarios assume that government consumption and other transfers are constant in real terms (unless explicitly specified).

4. MACROECONOMIC TRANSMISSION OF THE PANDEMIC

This section looks at the transmission channels of the pandemic shock and quantifies its impact. The next section then adds the economic policy response to the analysis.

4.1. THE COVID-19 SHOCK ABSENT LIQUIDITY CONSTRAINTS

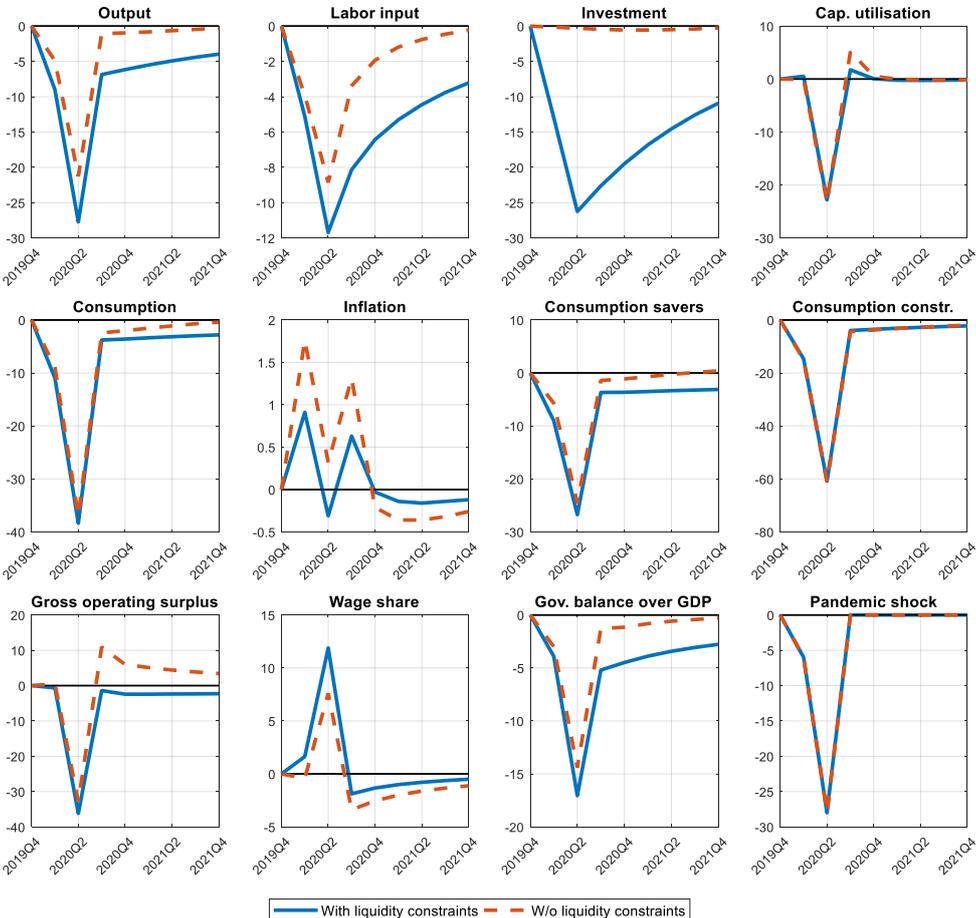
The COVID-19 crisis has a very large detrimental economic impact on the EU and the world economy as shown in Figure 1. In the basic model version without firm liquidity constraints, the economic impact closely follows the pandemic and required containment measures (shown with red dashed

¹⁴ As mentioned above, our related work in the European Commission’s (2020) spring forecast addresses these two points. It considers additional channels, relaxes the assumption on duration, and considers other pandemic patterns such as second waves.

lines).¹⁵ The result for this model is essentially a V-shaped recession in Q1 and Q2. There is a massive decline in consumption, where reduced labour income adds to the adverse impact of the demand shock. Some persistence in adjustment frictions in employment prevent an immediate adjustment. Higher capacity utilisation partly offsets a delayed response of the labour inputs, which, however, remains limited as we assume a partial short-run complementarity between capital and labour. The crisis also has a distributional dimension. Consumption of the constrained households depends more on labour income and falls more strongly than the consumption of the Ricardian household.

The baseline model version only generates a small decrease in investment. Investors foresee the temporary nature of the shock (as we abstract from uncertainty effects). Supply and demand shocks alone cannot generate a fall of investment. Yet, we find a strong decline in the gross operating surplus since labour costs remain high. This result indicates the relevance of liquidity constraints, as we discuss next.

Figure 1: Simulations absent policy response



Note: This figure expresses the wage share, quarterly inflation, and the government balance in percentage point deviation from steady state. All other variables are expressed in percent deviation from steady state. The pandemic shock is an illustrative index of the exogenous shock process.

Source: Commission services.

¹⁵ We always maintain the assumptions that a share of households is liquidity constrained.

4.2. THE IMPACT OF LIQUIDITY CONSTRAINTS

We now show that the firm liquidity constraints lead to a deeper and more U-shaped recession. In contrast to the baseline setup, the firm liquidity channel in this model version amplifies supply and demand shocks and generates a sizable decline in investment as shown in Figure 1 (blue solid lines). The endogenous fall in the GOS increases the share of liquidity-constrained firms and generates a sizable contraction in private investment. Investment adjustment costs, a plausible empirical feature, generate additional persistence. The magnitude of the investment decline is roughly in line with the Commission's investment forecast (European Commission, 2020). In the baseline model supply constraints dominate and generate (quarterly) inflationary pressure. By contrast, the impact from liquidity constraints amplifies the deflationary demand effects leading to a more balanced picture. Once the lockdown can be lifted, higher capacity utilisation and recovering consumption lead to an increase prices.

The amplification from the occasionally binding liquidity constraints also renders the reduction in labour input more persistent even though the constraint binds only in the first and second quarter. This effect strongly reduces output growth in 2020 and 2021 as shown in Table 4. GDP growth falls by 13 per cent below the no-shock path, compared to -8 per cent in the absence of the liquidity constraints. In sum, the amplification leads to a more U-shaped pattern of output and motivates the focus on liquidity constraints when analysing the EU policy response in the next section.

5. ECONOMIC POLICY RESPONSE

This section analyses the economic policy response in the EU with a focus on (i) short-time work allowances and (ii) loan guarantees. Both measures target the distortion arising from firms' liquidity constraints. As shown above, given the sharp fall in the gross operating surplus, liquidity constraints substantially prolong the recession, if not addressed appropriately by economic policy. These measures, however, cannot prevent a temporary decline in production because of sickness, restrictions on the mobility of workers or supply chain interruptions.

5.1. OVERVIEW STABILISATION MEASURES

The fiscal measures announced in the Member States consist of stimulus measures with a direct impact on the budget, as well as liquidity measures without direct budgetary impact. Table 3 provides information about fiscal measures and their composition for the EU-27. Total liquidity support by EU Member States amounts to approximately 22% of GDP, mostly in form guarantees and tax delays. In addition, the stimulus measures amount to around 2.8% of GDP, mainly as STW allowances and transfers. We leave the analysis of the sizable supranational EU support for future work.

Table 3. Overview of announced measures by EU-27 Member States

	<i>bln EUR</i>	<i>% of GDP</i>
1. Measures with a direct budgetary impact	368	2.8
2. Liquidity measures without budgetary impact		
a. Tax delays	248	1.9
b. Public guarantees	2301	17.6
c. Others	334	2.6
Total liquidity support	2882	22.1

Source: Commission services.

5.2. SHORT-TERM WORK ALLOWANCES

Our modelling focuses on two differences of STW allowances compared to unemployment benefits: First, STW reduces employment adjustment costs. Unemployment benefits are paid to unemployed workers who have lost their job. By contrast, STW allowances are paid for workers staying in the firm. Since workers stay in the firm, firms avoid matching frictions and hiring or firing costs. We capture this improved allocative efficiency under STW by setting $\gamma^N = 0$ – a parsimonious way to capture the absence of matching frictions. Second, STW allowances are more generous than unemployment benefits. We capture this effect by including additional transfers to liquidity-constrained households, $TR_{2020Q3:2020Q4}^C$, which can be spent only after the pandemic.¹⁶ For analytical purposes, we separate the two channels via two simulations.

5.2.1. Stabilisation gains under identical ex-ante costs

We first compare stabilisation gains of STW under identical ex-ante fiscal cost, i.e. the STW rate equals the benefit replacement rate. Assuming the same generosity of STW allowance and unemployment benefits, allows us to highlight the difference in allocative efficiency. Temporary unemployment entails layoff and search costs, which STW schemes avoid. To keep capture the absence of matching friction and employment adjustment costs, we eliminate labour adjustment costs from the model. Figure 2 then compares the dynamics under STW (red dotted lines) to those of the baseline model discussed in Section 4.2, where only unemployment benefits active (solid blue line).

The absence of employment adjustment frictions under STW allows firms to adjust their labour input more strongly during the peak of the shock (2020Q2). However, by the same logic, STW schemes support the exit from the pandemic shock by avoiding a costly and time-consuming hiring process and allowing firms to increase labour input more rapidly.

The interaction of STW with liquidity constraints. STW addresses two interacting frictions in the model: Employment and liquidity frictions. The cost-saving effect of STW improves the corporate liquidity position. By allowing for a stronger reduction of labour input, STW schemes help lower the wage bill without incurring firing costs. Importantly, the stabilisation of the gross operating surplus reduces the impact of firm liquidity constraints, as fewer firms become constrained. The smaller distortion from liquidity constraints implies that investment declines less, and labour input recovers faster and more strongly – especially after the pandemic. This, in turn, makes the recession less persistent. This result highlights the gains from allocative efficiency even under identical ex-ante fiscal costs.

STW implies a larger government deficit in 2020. The expenditure on STW allowances is higher than under unemployment benefits scheme since firms reduce labour input more strongly (even under same generosity). However, once the government can lift the lockdown restrictions, STW policy achieves higher revenues from labour, consumption, and profit taxation. In annual terms, the (total) government balance to GDP ratio falls by around 9 percentage points in 2020 and remains at -3 pps in 2021.

The fact that STW is a desirable policy depends on the significant labour adjustment costs in European countries. The relative gains compared to unemployment benefits could be smaller for economies (or sectors) with a higher degree of labour market churning.¹⁷

5.2.2. The generosity of STW allowances

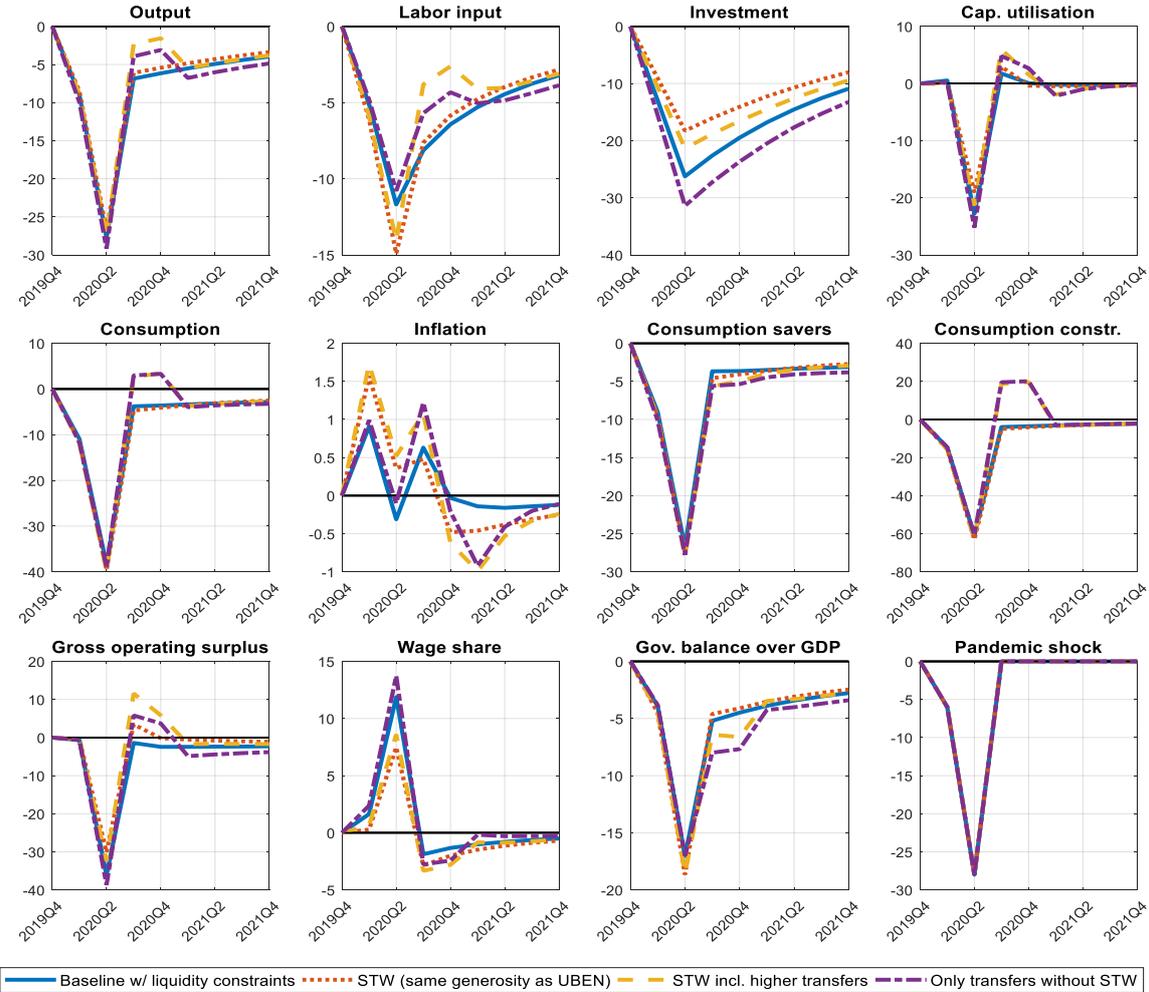
We now turn to the more realistic case, where the generosity under STW is higher than under unemployment benefits. Unlike in the previous simulation, STW allowances entail higher ex-ante

¹⁶ The Annex shows results for transfers to both households (non-targeted).

¹⁷ See, e.g., Davis et al. (2012) for a discussion on labour market flows in the US.

budgetary costs than unemployment benefits. A second simulation captures this aspect by adding transfers to constrained households of 2.8% of EU-27 GDP. This value corresponds to the policy measures credibly announced as of now (see Table 3). Since the containment measures partially curtail spending opportunities, households can spend transfers only in Q3 and Q4. Moreover, we assume that transfers target liquidity-constrained households. The Annex relaxes this assumption.

Figure 2: Short-term work allowances



Note: This figure expresses the wage share, quarterly inflation, and the government balance in percentage point deviation from steady state. All other variables are expressed in percent deviation from steady state. The pandemic shock is an illustrative index of the exogenous shock process.

The higher generosity implies sizable output gains. Constrained households have a high marginal propensity to consume, implying a higher multiplier than non-targeted transfers. Since the containment measures partially curtail spending opportunities, we assume that transfers are paid and spent in Q3 and Q4. A sizable rebound of consumption materialises in these periods. The simulation shows that the support for household consumption facilitates exit. In 2020, the level of consumption is 2.7% higher than without discretionary policy intervention. Higher transfers provide a strong boost to employment, which under STW can expand more rapidly. STW thereby also improves risk-sharing among households, with a more balanced distribution of consumption across households. In sum, STW and associated higher transfer allowances cushion the fall in real GDP by around 2.2 pps. in 2020.

The higher generosity of STW also implies ex-ante a stronger deterioration of the government balance.¹⁸ However, the faster recovery implies increased tax revenues (from relative increases in consumption, labour, and profits) as well as lower unemployment benefits. In sum, STW allowances increase the deterioration in the deficit-to-GDP ratio by less than 1 pps. (on average in 2020 and 2021) compared to the baseline simulations with only unemployment benefits active.

Interestingly, the two aspects of STW analysed here, namely avoiding job match destruction and higher generosity, interact. The improved allocative efficiency under STW leads to stronger effects of transfers. Figure 2 shows the results by adding a simulation with “only transfers” where employment adjustment costs remain at the baseline values. In this case, additional transfers provide smaller stabilisation gains, because employment adjustment costs slow down the response of hours worked and wages, translating into a smaller increase in household income.

Finally, note that the effectiveness of transfers depends on the marginal propensity to consume of the receiving households. The Annex shows that targeted transfers are significantly more efficient by supporting households with a higher marginal propensity to consume in line with the findings provided by Bayer et al. (2020).

5.3. LIQUIDITY SUPPORT

Liquidity support in the form of lending guarantees amounts to a maximum of 22% of GDP. One important goal of these programs is to stabilise investment of liquidity-constrained firms.

It is challenging to operationalise the liquidity guarantees in a macro model. Since there is some heterogeneity of initial conditions and on how severely individual firms are affected by the shock, a fraction of firms will defer investment even with guarantees. There are also specific eligibility criteria, which exclude certain types of firms from the schemes or restrict the schemes to certain sectors. Also generally, an upper bound on the guarantee per firm is imposed. Modelling the take up rate would require more information about the distribution of the shock across firms and the constraints imposed by governments.

In the absence of detailed up-to-date information, we will assume that 50% of the liquidity-constrained firms are not revising their investment plans or are excluded from funding. This allows us to say something about the ‘guarantee multiplier’. Under the assumption that firms keep dividend payouts stable and that investment does not affect gross operating surplus of the firm in the current period, the investment multiplier to a loan increase for liquidity-constrained firms is one.

To see this, consider a liquidity-constrained firm (superscript C). The budget constraint restricts investment of this firm to the loan supply of the bank and current gross operating surplus minus debt service and dividend payments

$$I_t^C = \Delta L_t^C + GOS_t^C - rL_{t-1} - D_t^C \quad (20)$$

Keeping current period dividends and GOS constant, the increase in investment due to a (guarantee-secured) extension of the loan is given by

$$I_t^G - I_t^C = \Delta L_t^G - \Delta L_t^C, \quad (21)$$

where $\Delta L_t^G - \Delta L_t^C$ is the loan expansion fully guaranteed by the government and superscript G denotes variables following the provision of guarantees. This is likely to be an upper bound since some of the additional funds may be diverted to increase dividends. However, apart from firm specific preferences, diversion of funds is limited because guarantee schemes by EU governments generally impose temporary restrictions on dividend payments for firms, which receive funding under public loan

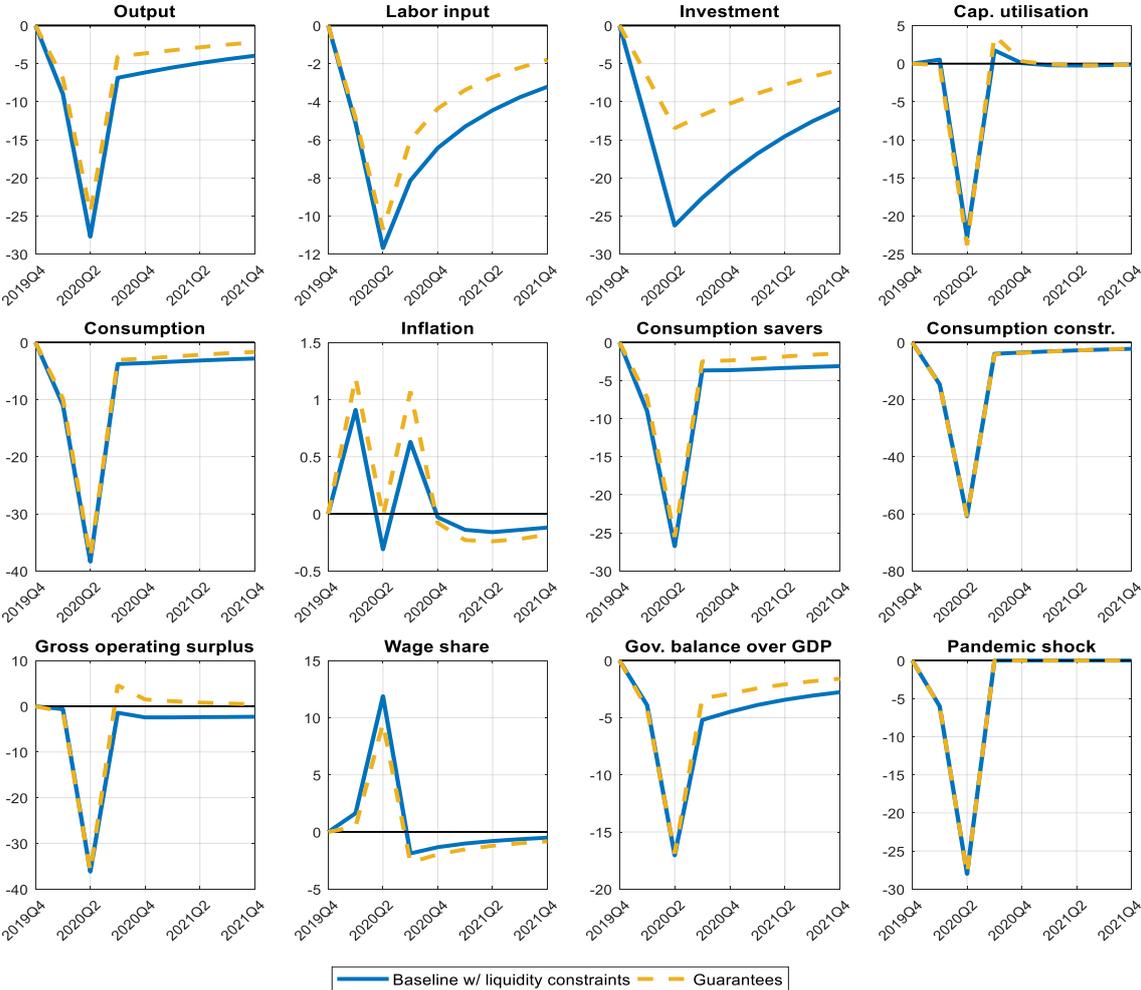
¹⁸ We assume that the government covers the additional generosity. There are no additional costs for the firms.

guarantee schemes. Based on information about non-performing loans¹⁹, we can assume that about ten per cent of these loans will default. This value gives a guarantee-multiplier of

$$m^G = \frac{Y_t^G - Y_t^C}{(\Delta L_t^G - \Delta L_t^C)} = m^I * loss \tag{22}$$

Thus, essential for the fiscal multiplier is the investment multiplier (m^I) and the loss rate of the guaranteed loan.²⁰ This multiplier is an upper bound since it ignores possible windfall gains to the banking sector. The banking sector might use the loan guarantees also for loans to unconstrained firms, thereby covering losses, which would otherwise be borne by the banking sector.

Figure 3 : Lending guarantees



Note: This figure expresses the wage share, quarterly inflation, and the government balance in percentage point deviation from steady state. All other variables are expressed in percent deviation from steady state. The pandemic shock is an illustrative index of the exogenous shock process

¹⁹ Consolidated banking data from the ECB shows a ratio of lower non-performing loans to total loans. However, during peak crisis times around 2013, the share reach around eight percent. See also: https://www.ecb.europa.eu/press/pr/date/2019/html/ecb.pr191106_1~a993d312e7.en.html

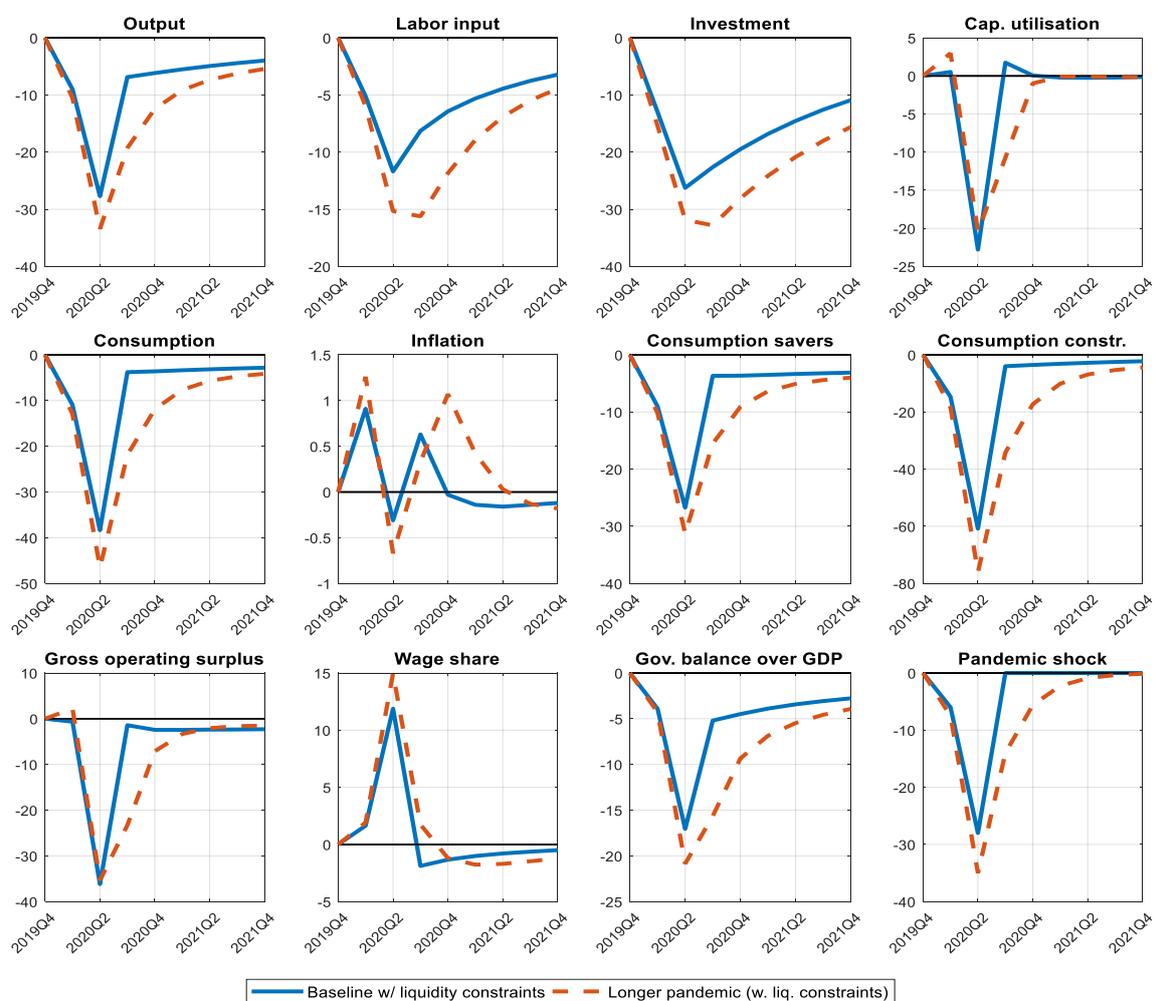
²⁰ The loss rate is defined by how much of the value of the investment project associated with defaulting loans must be written off.

6. ROBUSTNESS

For analytical clarity, we have considered a very short pandemic. Yet, it is increasingly clear that the pandemic and the associated lockdown will continue for a longer time. Therefore, Figure 4 considers also a longer pandemic, extending partially also into 2021 (see bottom right figure). Dashed red lines show the simulations of the longer pandemic, while blue solid lines correspond to the main simulations (with firm liquidity constraints) as shown in Figure 1.

Figure 4 shows that the duration of the pandemic is crucial for the length of the economic downturn: the adverse impact on investment and output increases and becomes more persistent into the second year (see final columns in Table 4 below). Note that the longer pandemic scenario includes automatic stabilisers, but no STW and guarantees. The Commission’s forecast (European Commission, 2020) has also considered other pandemic scenarios such as a second wave.

Figure 4: Longer pandemic



Note: This figure expresses the wage share, quarterly inflation, and the government balance in percentage point deviation from steady state. All other variables are expressed in percent deviation from steady state. The pandemic shock is an illustrative index of the exogenous shock process.

7. DISCUSSION

COVID-19 is a rare disaster with enormous economic costs. This paper has analysed the transmission channels of the pandemic using a TANK model. In the baseline model, demand and supply shocks lead to a V-shaped recession. However, an augmented model with firm liquidity constraints provides a different picture. In this framework, the strong decline in the gross operating surplus following the pandemic and its associated lockdown induces a strong reduction in investment due to a tightening of liquidity constraints. This effect amplifies the economic fallout and generates persistence. It also provides an important entry point for economic policy.

Table 4. **Overview of results**

Variable/Scenario	No liq. constr.		Liq. constraints		STW (without add. transfers)		STW		Guarantees		STW + Guarantees		Longer pandemic (absent policy)	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
	GDP	-7.9	-0.9	-13.0	-4.8	-12.1	-3.7	-10.8	-4.2	-10.7	-3.1	-8.7	-2.5	-19.8
Consumption	-12.9	-1.2	-14.1	-3.0	-15.0	-2.9	-11.4	-3.2	-13.4	-2.1	-10.8	-2.3	-23.3	-5.6
Investment	-0.5	-0.6	-20.2	-13.6	-14.3	-10.0	-16.9	-11.8	-10.7	-7.4	-8.6	-6.3	-27.0	-19.6
Labor input	-4.8	-0.9	-7.8	-4.1	-8.6	-3.7	-6.6	-3.7	-6.6	-2.6	-5.3	-2.3	-12.2	-6.4
GOS	-4.4	3.8	-10.1	-2.2	-6.8	-0.7	-3.9	-1.6	-8.1	0.6	-1.9	0.7	-15.9	-2.1
Wage share	0.4	0.4	2.6	2.6	0.7	-1.1	0.8	-0.8	1.4	-1.1	0.0	-1.0	4.4	-1.5
Gov. balance/GDP	-5.3	-0.8	-7.7	-3.2	-8.0	-2.9	-9.2	-3.2	-7.0	-2.1	-8.4	-2.1	-12.5	-5.2

Source: Commission services.

Our analysis then quantifies two central policy responses in the EU-27: Short-term work (STW) allowances and liquidity support. Both policies support the recovery after the pandemic shocks. Given that the demand effects of lockdowns cannot be stabilised at the time of implementation, policies should target a rapid exit, once the pandemic ceases and governments can lift the associated lockdown. Our paper shows that STW is a desirable policy, given the significant labour adjustment costs in European countries. Apart from reducing stress for employees associated job loss, STW allows more labour input flexibility and softens liquidity constraints of firms. In addition, liquidity guarantees target investment and employment and address the externalities arising from constrained firms. Together both policies reduce the output loss of COVID19 and its associated lockdown by about one fourth (see Table 4): Instead of dropping by 13.0 per cent in 2020, the simulated fall in real GDP reaches 8.7%. However, the policy measures cannot prevent a sharp temporary decline in production during the lockdown phase.

The focus of the paper has been on time-limited short-term support schemes. In particular, we have abstracted from the negative impact that these support policies may have on medium-run allocative efficiency through reducing exit-entry rates and labour market churning. We leave this important topic for future research.

REFERENCES

- Acemoglu D., Chernozhukov V., Werning I., and Whinston M.D. (2020). A Multi-Risk SIR Model with Optimally Targeted Lockdown. NBER Working Paper No. 27102, May 2020
- Ampudia, M., Georgarakos, D., Slacalek, J., Tristani, O., Vermeulen, P., and Violante, G. (2018). Monetary Policy and Household Inequality. ECB Working Paper, No. 2170.
- Baldwin, R. and Weder di Mauro B. (2020), Mitigating the COVID Economic Crisis: Act Fast and Do Whatever It Takes, a VoxEU.org eBook, CEPR Press.
- Baker, S., Bloom N., Davis S. J., Kost K., Sammon M. and Viratyosin T. (2020), The Unprecedented Stock Market Reaction to COVID-19, Covid Economics: Vetted and Real-Time Papers 1, 3 April.
- Baqae D. and Farhi E. (2020), Keynesian Production Networks with an Application to the Covid-19 Crisis, Technical Report 2020.
- Bayer, C., Born, B., Luetticke, R., and Müller, G. (2020), The coronavirus stimulus package: how large is the transfer multiplier?, CEPR Discussion Paper DP14600.
- Bénassy-Quéré, A., Marimon, R., Pisani-Ferry, J., Reichlin, L., Schoenmaker, D., Weder di Mauro, B. (2020), COVID-19: Europe needs a catastrophe relief plan, VoxEU 11/03/202, <https://voxeu.org/article/covid-19-europe-needs-catastrophe-relief-plan>.
- Bigio, S., Zhang M., and Zilberman E. (2020), Transfers vs Credit Policy, Technical Report.
- Blanchard, O. and Galí J. (2007). Real Wage Rigidities and the New Keynesian Model. *Journal of Money, Credit and Banking* 39 (S1), 35-65.
- Brunnermeier, M., Landau J.-P., Pagano M., and Reis R. (2020), Throwing COVID Liquidity Life-Line.
- Claeys, G. and Wolff G. (2020), COVID-19 Fiscal response: What are the options for the EU Council? <https://www.bruegel.org/2020/03/esm-credit-lines-corona-bonds-euro-area-treasury-one-off-joint-expenditures-what-are-the-options-for-the-eu-council/>.
- Coenen, G., C. Erceg, C. Freedman, D. Furceri, M. Kumhof, R. Lalonde, D. Laxton, J. Linde, A. Mourougane, D. Muir, S. Mursula, C. de Resende, J. Roberts, W. Roeger, S. Snudden. M. Trabandt, J. in 't Veld (2012). Effects of Fiscal Stimulus in Structural Models. *American Economic Journal: Macroeconomics*, 4 (1): 22-68, available at: <http://pubs.aeaweb.org/doi/pdfplus/10.1257/mac.4.1.22>.
- Davis, S, Faberman J. and Haltiwanger J. (2012), “Labor Market Flows in the Cross Section and over Time”, *Journal of Monetary Economics*, 59 (1), 1–18.
- Dolls, M., Fuest, C., and Peichl, A. (2012). Automatic Stabilisers and Economic Crisis: US vs. Europe. *Journal of Public Economics* 96: 279-294.
- Eichenbaum, M., Rebelo S., and Trabandt, M. (2020). The Macroeconomics of Epidemics. NBER Working Papers 26882, National Bureau of Economic Research, Inc. <https://ideas.repec.org/p/nbr/nberwo/26882.html>.
- European Commission (2020), European Economic Forecast, Institutional Paper 125, May. https://ec.europa.eu/info/sites/info/files/economy-finance/ip125_en.pdf.

Faria e Castro, M. (2020), Fiscal Policy during a Pandemic, Federal Reserve Bank of St. Louis Research Division Working Paper 2020-006D, <https://research.stlouisfed.org/wp/more/2020-006>.

Fornaro, L. and M. Wolf (2020), Covid-19 coronavirus and macroeconomic policy.

Glover, A., J. Heathcote, D. Krueger and J.-V. Rios-Rull (2020), “Health versus Wealth: On the Distributional Effects of Controlling a Pandemic”, CEPR Discussion Paper 14606.

Gopinath G. (2020), Limiting the economic fallout of the coronavirus with large targeted policies, in R. Baldwin and B. Weder di Mauro (eds.), *Mitigating the COVID economic crisis: Act fast and do whatever it takes*, VoxEU.org eBook, CEPR Press.

Guerrieri, V., Lorenzoni, G., Straub, L. and I. Werning (2020), *Macroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages?*

Hagedorn, M. and K. Mitman (2020), *Corona Policy According to HANK*, CEPR Discussion Paper DP14694.

Jones, C., T. Philippon and V. Venkateswaran (2020), *Optimal Mitigation Policies in a Pandemic: Social Distancing and Working from Home*, Manuscript, NYU: 6 April.

Jonung, L. and W. Roeger (2006), *The macroeconomic effects of a pandemic in Europe - A model-based assessment*. ECFIN Economic Papers No 251.

Kaplan, G., Violante, G., and Weidner, J. (2014). *The Wealthy Hand-to-Mouth*. *Brookings Papers on Economic Activity* 45: 77-153.

Kollmann, R., Pataracchia, B., Raciborski, R., Ratto, M., Roeger, W., and Vogel, L. (2016). *The Post-Crisis Slump in the Euro Area and the US: Evidence from an Estimated Three-Region DSGE Model*. *European Economic Review* 88(C): 21-41.

In 't Veld, J., Pagano, A., Raciborski, R., Ratto, M., and Roeger, W. (2015). *Imbalances and Rebalancing in an Estimated Structural Model for Spain*. *International Journal of Central Banking* 11: 1-41.

Jermann, U., and Quadrini V. (2012). *"Macroeconomic Effects of Financial Shocks."* *American Economic Review*, 102 (1): 238-71.

Lane, P. (2020), ‘The Monetary Policy Package: An Analytical Framework’ at <https://www.ecb.europa.eu/press/blog/date/2020/html/ecb.blog200313~9e783ea567.en.html>.

Narayanan, B., and Walmsley, T. (2008). *Global Trade, Assistance, and Production: The GTAP 7 Data Base*. Center for Global Trade Analysis, Purdue University.

OECD (2020), “Corporate sector vulnerabilities during the Covid-19 outbreak: assessment and policy responses”, *Tackling Coronavirus Series*.

Ratto, M., Roeger, W., and in 't Veld, J. (2009). *QUEST III: An Estimated Open-Economy DSGE Model of the Euro Area with Fiscal and Monetary Policy*. *Economic Modelling* 26: 222-233.

Schmitt-Grohé, S., and Uribe, M. (2003). *Closing Small Open Economy Models*. *Journal of International Economics* 61: 163-185.

The main text has used the following equations describing the investment behaviour of constrained firms:

$$\mathcal{H}\left(\frac{GOS_t^j}{K_{t-1}^j}\right) \equiv \zeta_1 \left(\frac{GOS_t^j}{K_{t-1}^j} - \delta\right) - \zeta_2,$$

$$s_t^{li} = a_0 - a_1 GOS_t$$

Liquidity-constrained investment

In this appendix, we show how a share of firms can become liquidity constrained if a shock hits in period t , which reduces the gross operating surplus of the firm. First, we look at an individual firm with budget constraint (dropping i indices to ease notation)

$$L_t = (1 + r_{t-1})L_{t-1} + D_t + I_t - GOS_t \quad (\text{A.1})$$

To facilitate our discussion, we make three assumptions: (i) the economy is initially on a balanced growth path, (ii) all firms are financially unconstrained before the shock occurs, and (iii) D_t does not change much across constrained and unconstrained regimes (see Jermann and Quadrini (2012) for a discussion). The firm faces an upper limit on loans which is determined by its capital stock

$$L_t \leq \mu K_t \quad (\text{A.2})$$

Prior to the unanticipated adverse shock, the firm is not constrained,

$$L_{t-1} < \mu K_{t-1} \quad (\text{A.3})$$

and becomes constrained after receiving a temporary negative GOS shock in period t , which increases borrowing to the collateral limit.

$$L_t^C = \mu K_t^C. \quad (\text{A.4})$$

Since the firm is unconstrained in $t - 1$

$$K_{t-1} = \left(\frac{1}{\mu} + x\right)L_{t-1} > \frac{1}{\mu_1}L_{t-1} \quad (\text{A.5})$$

Since collateral constraint is binding in period t ,

$$\Delta K_t^C = (K_t^C - K_{t-1}) = \frac{1}{\mu}\Delta L_t^C - xL_{t-1} < \frac{1}{\mu}\Delta L_t^C, \quad (\text{A.6})$$

where the inequality indicates that capital stock falls more than the loan since the firm is now facing a financial constraint. How much does investment decline relative to a situation where the firm is not hit by a negative GOS shock and a standard (unconstrained) Q -equation determines investment. Without adverse shock in t , balanced growth implies that the change in the capital stock (denoted by superscript B) would have exceeded ΔK_t^C :

$$\Delta K_t^B = \left(\frac{1}{\mu} + x\right)\Delta L_t^B > \Delta K_t^C. \quad (\text{A.7})$$

The difference between the change of capital with and without constraint $\Delta K_t^C - \Delta K_t^B = \frac{1}{\mu}\Delta L_t^C - xL_{t-1} - \left(\frac{1}{\mu} + x\right)\Delta L_t^B$. Thus,

$$\frac{1}{\mu+z}(\Delta L_t^C - \Delta L_t^B) = \Delta K_t^C - \Delta K_t^B < \frac{1}{\mu}(\Delta L_t^C - \Delta L_t^B) \quad (\text{A.8})$$

Since

$$\Delta K_t^C - \Delta K_t^B = I_t^C - I_t^B \quad (\text{A.9})$$

We get

$$(\mu + z)(I_t^C - I_t^B) = (\Delta L_t^C - \Delta L_t^B) \quad (\text{A.10})$$

From the budget constraint of the firm (and neglecting differences in dividend payouts in both regimes) we obtain the following relationship between investment and GOS in the constrained and unconstrained regime

$$(\Delta L_t^C - \Delta L_t^B) = (\mu + z)(I_t^C - I_t^B) = (I_t^C - I_t^B) - (GOS_t^C - GOS_t^B) \quad (\text{A.11})$$

$$(I_t^C - I_t^B) = \frac{1}{1 - (\mu + z)} (GOS_t^C - GOS_t^B) \quad (\text{A.12})$$

This result holds for the individual firm or for the case with all firms becoming liquidity constrained. The next section discusses the case when only a fraction of firms becomes constrained.

Aggregate relationship between GOS and Investment

In this section, we show how movement of (average) GOS affect the share of constrained firms by introducing a minimum amount of heterogeneity across firms. We first introduce some notation. There are i firms with $i \in [0,1]$. GOS has an aggregate and an idiosyncratic component governed by σ .

$$GOS_{it} = GOS_t + \sigma(i - 0.5) \quad (\text{A.13})$$

Firm i will respond to a temporary decline of gross operating surplus by increasing borrowing because of a smoothness restriction on dividend payouts, and convex investment adjustment costs, which makes investment a function of the present discount value of profits. Investment of the unconstrained firm deviates marginally from the investment the firm would have undertaken in t without the COVID shock (see scenario 1). We denote this difference e_t .

$$I_t^U = I_t^B - e_t \quad (\text{A.14})$$

$$L_{it}^C = (1 + r_{t-1})L_{t-1}^B + D_t^B + I_t^B - e_t - GOS_{it} = \mu K_t^B \quad (\text{A.15})$$

We denote the marginal firm, which stays unconstrained with \bar{i}

$$\frac{\sigma}{\mu K_t^B} (\bar{i} - 0.5) = \frac{(1+r_{t-1})(\mu+x)K_t^B + D_t^B + I_t^B - e_t - GOS_t}{\mu K_t^B} \quad (\text{A.16})$$

If GOS_t declines \bar{i} increases, i.e. the profitability threshold increases for firms to remain unconstrained. Since \bar{i} ranges between zero and one, it can also be interpreted as the share of constrained firms and the relationship between \bar{i} and GOS^C can be approximated linearly (where we ignore the term e_t)

$$s_t^{li} = \bar{i} = a_0 - a_1 \frac{GOS_t}{K_t^B} \quad (\text{A.17})$$

Equation (A.17) corresponds to the firm share equation presented in the main text. The parameter values can be determined using information about the share of liquidity constrained firms in the constrained and unconstrained regime. For the unconstrained regime, we assume a share equal to zero. By contrast, in the constrained regime, we use information about the share of output produced by firms directly affected from lockdown measures to set a lower bound of investment undertaken by constrained firms in the COVID regime. This share is set to 0.3. Therefore, we have two equations to determine the two parameter

$$0.3 = a_0 - a_1 \frac{GOS_t}{K_t^B} \quad (\text{A.18})$$

and

$$0.0 = a_0 - a_1 \frac{GOS_t^B}{K_t^B} \quad (\text{A.19})$$

Given the investment rule of constrained firm $i \in (0, \bar{i})$

$$(I_{it}^C - I_t^B) = \frac{1}{1 - (\mu + z)} (GOS_{it}^C - GOS_t^B) \quad (\text{A.20})$$

We obtain total investment of constrained firm by

$$I_t^C = \int_0^{\bar{i}} I_{it}^C di = \int_0^{\bar{i}} I_t^B di + \frac{1}{1-(\mu+z)} \int_0^{\bar{i}} (GOS_{it}^C - GOS_t^B) di \quad (A.21)$$

$$I_t^C = \bar{i} I_t^B + \bar{i} \frac{1}{1-(\mu+z)} \left((GOS_t - GOS_t^B) + \sigma 0.5(\bar{i}^2 - \bar{i}) \right)$$

$$I_t^C = \bar{i} \left(I_t^B + \frac{1}{1-(\mu+z)} \left((GOS_t - GOS_t^B) + \sigma 0.5(\bar{i} - 1) \right) \right) \quad (A.22)$$

With $\sigma 0.5(\bar{i} - 1) < 0$

Firm i which is not constrained invests according to the Q equation

$$I_{it}^U = \phi(Q_{it} - 1)K_{it-1} + \delta K_{it-1} = \phi(Q_t + \varphi(i - 0.5) - 1)K_{t-1} + \delta K_{t-1} \quad (A.23)$$

$K_{it-1} = K_{t-1}$ because firms are identical in t-1

$$I_t^U = \int_{\bar{i}}^1 I_{it}^U di = \int_{\bar{i}}^1 (\phi(Q_t + \varphi(i - 0.5) - 1)K_{t-1} + \delta K_{t-1}) di$$

$$I_t^U = (1 - \bar{i})(\phi(Q_t - 1)K_{t-1} + \delta K_{t-1}) + \varphi 0.5((1 - \bar{i}^2) - (1 - \bar{i}))K_{t-1}$$

$$I_t^U = (1 - \bar{i})(\phi(Q_t - 1)K_{t-1} + \delta K_{t-1}) + \varphi 0.5(\bar{i} - \bar{i}^2)K_{t-1} \quad (A.24)$$

Total investment

$$\begin{aligned} \frac{I_t}{K_{t-1}} &= \frac{I_t^U}{K_{t-1}} + \frac{I_t^C}{K_{t-1}} \\ &= (1 - \bar{i})(\phi(Q_t - 1) + \delta) + \varphi 0.5(\bar{i} - \bar{i}^2) \\ &\quad + \bar{i} \left(\frac{I_t^B}{K_{t-1}} + \frac{1}{1-(\mu+z)} \left(\left(\frac{GOS_t}{K_{t-1}} - \frac{GOS_t^B}{K_{t-1}} \right) + \frac{\sigma 0.5}{K_{t-1}} (\bar{i} - 1) \right) \right) \end{aligned}$$

$$\frac{I_t}{K_{t-1}} - \delta = \frac{I_t^U}{K_{t-1}} - (1 - \bar{i})\delta + \frac{I_t^C}{K_{t-1}} - \bar{i}\delta =$$

$$(1 - \bar{i})(\phi(Q_t - 1)) + \varphi 0.5(\bar{i} - \bar{i}^2) + \bar{i} \left(\frac{I_t^B}{K_{t-1}} - \delta + \frac{1}{1-(\mu+z)} \left(\left(\frac{GOS_t}{K_{t-1}} - \frac{GOS_t^B}{K_{t-1}} \right) + \frac{\sigma 0.5}{K_{t-1}} (\bar{i} - 1) \right) \right) \quad (A.25)$$

We assume that $\varphi 0.5(\bar{i} - \bar{i}^2)$ is small since Q_{it} does not respond a lot to temporary shocks.

Annex B FUNCTIONAL FORMS

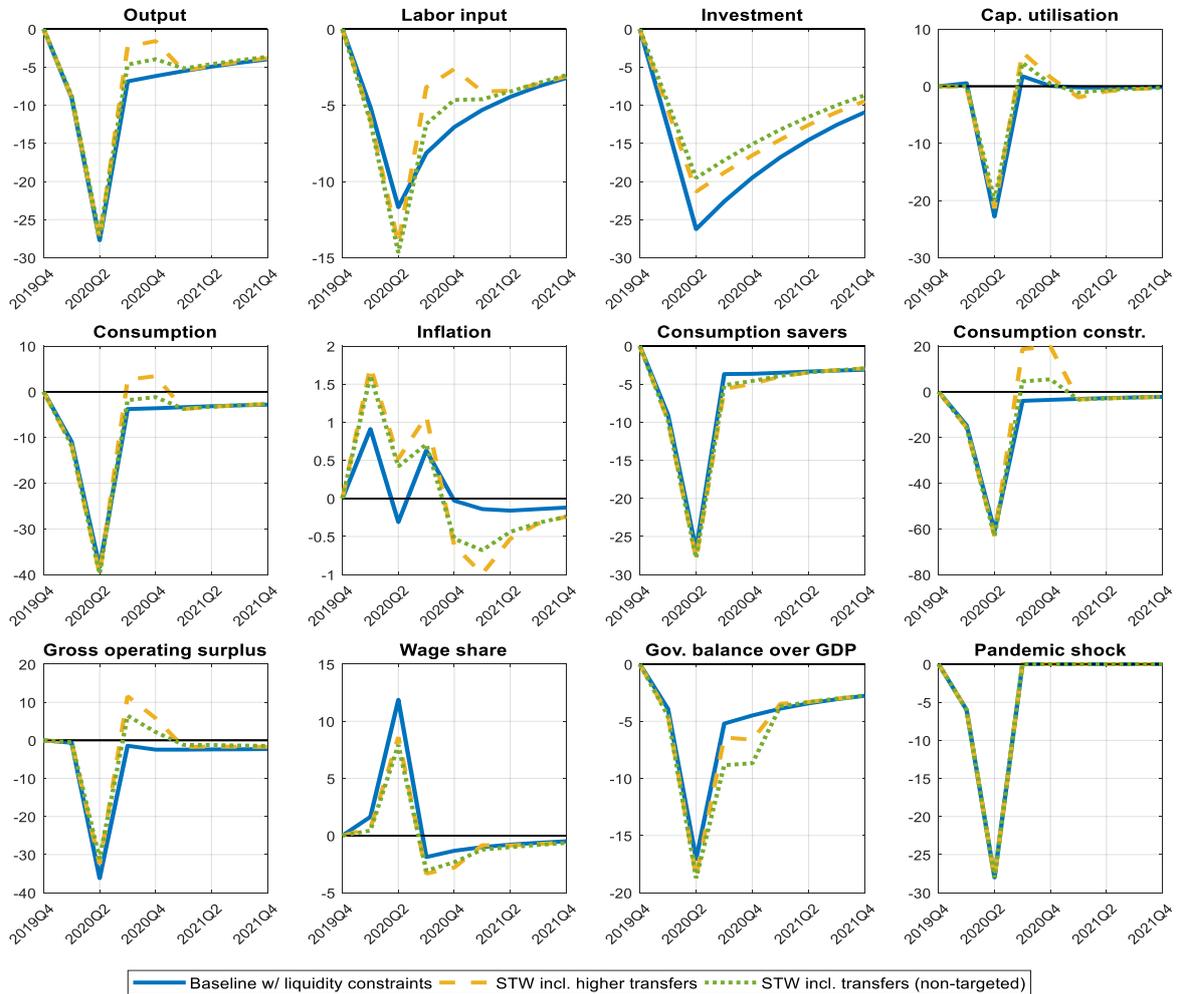
Price and capacity utilisation costs follow convex functions:

$$\Gamma_t^{P,j} \equiv 0.5\gamma_P (\pi_t^j)^2 P_{t-1}^j Y_t^j \text{ with } \pi_t^j \equiv P_t^j / P_{t-1}^j - 1 \#$$

$$\Gamma_t^{ucap,j} \equiv \left(\gamma_{ucap,1} (u_t^j - 1) + \frac{\gamma_{ucap,2}}{2} (u_t^j - 1)^2 \right) \frac{p_t^j}{p_t} K_t^j$$

Annex C ADDITIONAL RESULTS

Figure 5: **Non-targeted transfers**



Note: This figure expresses the wage share, quarterly inflation, and the government balance in percentage point deviation from steady state. All other variables are expressed in percent deviation from steady state. The pandemic shock is an illustrative index of the exogenous shock process.