The Economic Ripple Effects of COVID-19*

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Abstract

What are the ripple effects of a temporary lockdown of the economy? Do firms' deteriorating balance sheets and labor market frictions propagate and prolong the effects? We answer these questions in a model with financial and labor market frictions. The model makes quantitative predictions about the effect of lockdowns of varying magnitude and duration on output, employment and firm dynamics. We find that the effects are not persistent if (i) workers on temporary layoff can be recalled by their previous employers without having to go through the frictional labor market and (ii) the government provides employment subsidies to firms during the lockdown. However, the effects are heterogeneous and young non-essential firms are disproportionately affected. Furthermore, if lockdowns lead to more permanent reallocation across industries, the recovery gets more protracted. The framework, motivated by COVID-19, can be readily applied to large, temporary shocks of a different nature.

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1 Introduction

The goal of this paper is to quantitatively evaluate the ripple effects of a large transitory shock to the economy. A case in point is the temporary shutdown of parts of the economy, as implemented by many countries in response to the Covid-19 pandemic. Indeed, the Covid-19 shutdown was one of the largest shocks to GDP on record for most countries (Neumeyer et al., 2020). How long does it take for the economy to go back to normal following such a shock? What explains the cross-country differences in the depth of the recession and the speed of the recovery? Do negative balance sheet effects and labor market frictions significantly slow down the recovery? Which firms are more affected and which ones recover faster? How do the macroeconomic and firm dynamics change if the temporary shutdown shock generates lasting changes in some industries, to which firms adapt?

Our quantitative analysis is motivated by the Covid-19 recession that started with the shutdown of nonessential, contact-intensive businesses in early 2020.[1] However, the ideas in the model we propose go beyond the case of a pandemic-induced shutdown. They apply to other large temporary shocks, such as natural or nuclear disasters, wars or other events that severely disrupt parts of the economy for a short duration.

We answer the above questions using a model economy with financial and labor market frictions. In our benchmark quantitative exercise, the shutdown shock causes a short-lived V-shaped recession with small persistent effects if (i) workers on temporary layoff can be recalled by their previous employers without having to go through the frictional labor market and (ii) laid-off workers receive unemployment insurance. An equivalent institutional setup that yields a quick recovery is one where non-essential workers remain employed and the government pays the wage bill of shut down firms. A longer lockdown or one that shuts down a larger part of the economy has a predictably larger impact for longer periods, but the economy still rebounds quickly after the lockdown ends. Rigid labor markets policies without balance sheet support result in more protracted recoveries.[2]

However, one real possibility is that the temporary shutdown shock leads to lasting changes in people's and firms' preferences and behaviors. The idea is that the pandemic renders some goods and services less appealing (e.g., cruises) and others more appealing (e.g., telework and online shopping, including food and grocery delivery) to consumers in a permanent way, and some firms adapt better to new practices. We model this as a permanent reallocation shock that reshuffles productivity across firms without affect-

[1] Nonessential, contact-intensive industries represent 25% of final demand and 35% of employment in the US (Leibovici et al., 2020). GDP in these industries fell by 40 to 54% between the end of 2019 and the second quarter of 2020. Consumption of transportation services, recreation services, and food services and accommodations fell by 41, 54, and 40%, respectively, between 2019Q4 and 2020Q2.

[2] These results extends to small open economies with tighter financial frictions.

ing their average productivity.[3] We find that, if the reallocation shock accompanies the temporary shutdown shock, the recession becomes significantly protracted. The reallocation shock generates not only unemployment but also misallocation of capital and labor, because some of those firms that become suddenly more productive are too credit-constrained to produce at the larger scale corresponding to their new productivity and the labor market frictions slow down the reallocation of workers.[4] The misallocation gets undone slowly over time, as the credit-constrained productive entrepreneurs save up to overcome the constraint and the frictional labor market eventually reallocates workers to growing firms. The one-time reallocation shock leaves a persistent negative effect on aggregate TFP and GDP, delaying the return to normal.

Both the shutdown shock and the reallocation shock have heterogeneous effects across firms. For young non-essential firms, which are more likely to be financially constrained, the shutdown shock has an important negative balance sheet effect. Some of them exit and, even for those that remain, it takes several years for their employment to fully recover. The reallocation shock causes a burst of firm creation and destruction.

Our model builds on the model with financial and labor market frictions in Buera et al. (2015). The most important difference is that we allow for recall (or rest) unemployment. Workers who are temporarily laid off due to the shutdown can return to their previous employer without having to go through the hiring market subject to matching frictions. This assumption is supported by the analysis of Hall and Kudlyak (2020), who show that unemployed workers with jobs (on furlough or temporary layoff) accounted for 93% of the increase in unemployment between the first and the second quarter of 2020. Unemployed workers with jobs returned to employment much faster than "jobless" unemployed workers who had no job to return to.[5]

The second important assumption is the institutional setup in which firms can costlessly lay off workers during the shutdown, unemployed workers collect unemployment insurance benefits with a 100% replacement rate (Ganong et al., 2020), and the unemployment insurance is financed with long-term debt. This institutional setup captures the policy adopted by the US government through the Coronavirus Aid, Relief, and Economic Security (CARES) Act. Other countries, for example the UK, supported firms and workers in non-essential sectors during the pandemic through transfers to firms to cover wage bills during the shutdown.[6] In our model, supporting firms' balance sheet by covering their labor costs and providing income insurance to workers are

[3] Barrero et al. (2021) report evidence of expected reallocation shocks using data of expected sales and employment extracted from an online firm survey.

[4] Without these frictions, a pure reallocation shock would have no aggregate effect.

[5] Bick and Blandin (2020), Cajner et al. (2020) and Lee et al. (2021) provide further evidence on the importance of recall unemployment in 2020.

[6] The Paycheck Protection Program (PPP) in the US CARES Act did the same, but only for small businesses.

equivalent. They only differ in the label of the workers who are not working and whose wage is paid for by taxes.

These assumptions play an important role in the speed of the economic recovery. Without recall unemployment, all laid off workers must go through the frictional labor market to find new jobs when the shutdown ends, substantially slowing down the recovery. Without the balance sheet support, firms suffer stronger deterioration of their balance sheets during the lockdown and cannot rehire all the labor they laid off during the shutdown. The workers who are not re-hired by their previous employers have to go through the labor market matching process as the demand for labor recovers. As a result, the recovery will be more drawn out.

This paper is part of a growing literature on the macroeconomic effects of Covid-19. A strand of the literature traces how household behavior responds and feeds back to disease dynamics and government policies, using integrated macroeconomic and epidemiological models (e.g., Eichenbaum et al., 2020; Kaplan et al., 2020; Aum et al., 2021; Hevia et al., 2021). Guerrieri et al. (2020) shows how complementarities across sectors and household credit constraints propagate and lead to aggregate demand shortages. While our paper abstracts from the epidemiological side, it complements this literature by focusing on the lasting effects of shutdowns after they are gone and by analyzing how shutdowns and economic policy affect firms in an environment with credit constraints and labor market frictions. Our analysis is in the tradition of Bernanke and Gertler (1989) who study the dynamic repercussions of balance sheet effects. Our focus on the firm side separates us from the large literature on the economic impact of the pandemic, and our use of recall unemployment in a quantitative framework is another unique contribution.

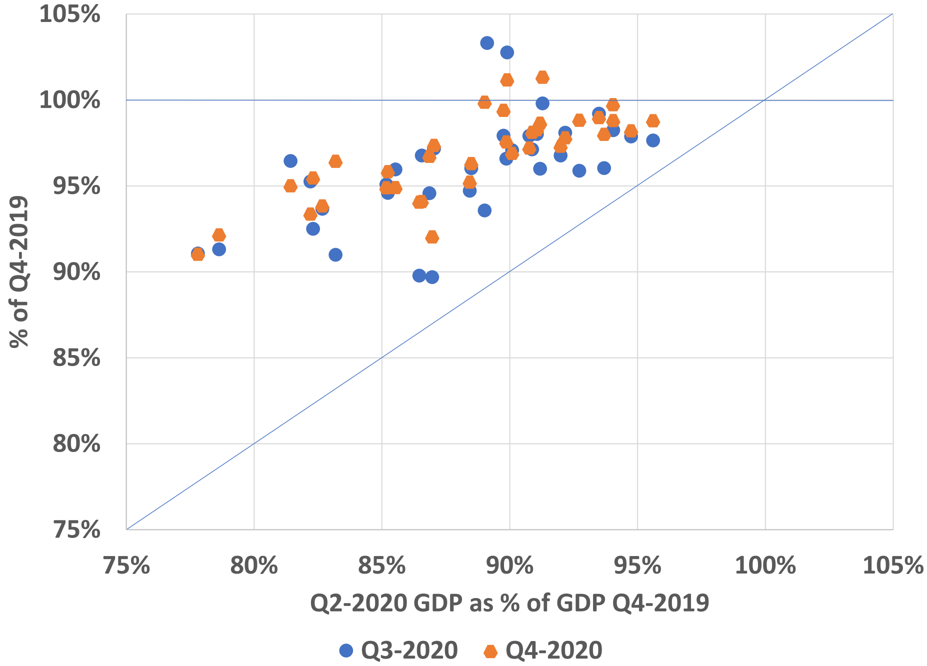
The rest of the paper is organized as follows. Section 2 shows the data on the recession and recovery across countries and also some relevant micro-level data. Section 3 develops the model. Section 4 works out the quantitative exercises using the model to better understand the role of various model elements, including the nature of shocks and the policy responses. Section 5 studies the role of the reallocation shock and Section 6 concludes.

2 Motivating Evidence

The Covid-19 shutdown was one of the largest shocks to GDP on record for most countries around the globe (Neumeyer et al., 2020). In this section we focus on the recession and early recovery of OECD countries and then delve deeper into the cases of the United States and New Zealand.

Figure 1 shows the data on GDP for the second, third, and fourth quarters of 2020

Fig. 1: GDP in OECD countries



Source: OECDstats.

for OECD countries relative to their respective GDP before the pandemic in the last quarter of 2019. The dispersion of observations along the horizontal axis shows the heterogeneity in the impact of the shutdown in the second quarter, which ranges from 5% to more tan 20%. Along the vertical axis, the speed of the recovery in the third and the fourth quarter is measured by the distance between each point and the 45° degree line (no recovery) and the 100% (full recovery) line. For example, the United States and New Zealand had a similar reduction of GDP in the second quarter of 2020, 10% relative to the pre-pandemic quarterly GDP, but the recovery was different. New Zealand's output was 103% and 101% of the fourth quarter of 2019 GDP in the third and fourth quarters of 2020, respectively; while the corresponding numbers for the United States were 97% and 98%. Table 2 in Appendix A has the data underlying Figure 1.

In our model, we take the size of the shutdown as an unanticipated shock, which determines the fall in GDP during the lockdown. We are interested in characterizing the speed of the recovery.

We find the cases of the United States and New Zealand of particular interest. The US is our calibration benchmark and we assess the quantitative implications of our laboratory economy using the US data. Our interest in New Zealand, in turn, lies in the starkness of its containment policies. It implemented a very intense, but brief shutdown in the second quarter of 2020 and, except for some time intervals and locations, lifted mobility restrictions thereafter. In this sense, New Zealand fits very well our benchmark experiment of a one quarter shutdown.[7]

Figure 2 shows the dynamics of macroeconomic aggregates in New Zealand and the US. The left panels depict GDP, consumption, and investment. In both countries, GDP fell about 10% in the second quarter of 2020 and rebounded quickly, the US concluding the year about 2% below the pre-pandemic level, and New Zealand about 1% above it. Consumption and investment also fell sharply during the second quarter, the contraction in investment being more pronounced in New Zealand than in the US.

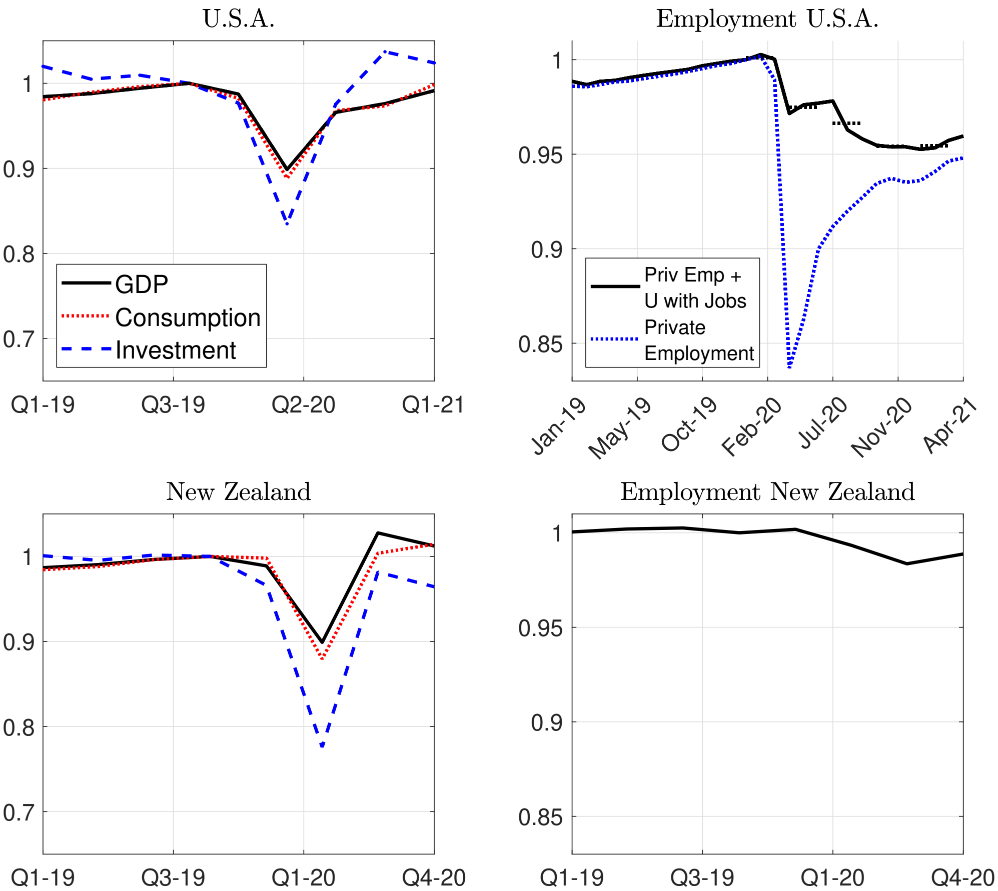
The dynamics of consumption are worth emphasizing, for they are informative about the nature of shocks that we introduce into our model. Interpreting the Covid-19 shock as a large temporary decline in TFP in a neoclassical growth model, investment would experience a sharp contraction mirroring households' desire to smooth consumption. In contrast, the data shows a drop in consumption that roughly mimics the decline in GDP. Empirically, the fall in consumption is rationalized by the peculiarities of the Covid-induced recession, which disproportionately affects contact-intensive consumption activities. For the model, then, it means we must introduce a complementary force that counteracts the consumption smoothing. We do this by means of a demand shock that raises the marginal utility of consumption in the period following the lockdown. Our calibration section discusses how we discipline this demand shock.

The right panel of Figure 2 shows the evolution of private employment normalized by its value in December 2019 in the United States (monthly data) and in the fourth quarter of 2019 in New Zealand (quarterly data). The different institutional setup in the two countries explains the difference in employment dynamics. While in the US firms can easily furlough employees, who collect unemployment insurance while they are temporarily laid off, in New Zealand firms received a subsidy to keep employees who are not working due to the shutdown on their payroll. As a result, the fall in (measured) employment in the second quarter of 2020 is small in New Zealand. The US institutional setup motivates our modeling choice of having rest unemployment with full-replacement unemployment insurance benefits. If we add to the number of employed workers in the United States the unemployed with jobs, the employment dynamics of the two countries become more similar.[8] Between the second quarter of 2020 and the first quarter of 2021, this measure of employment took the values of 97.4%, 96.5%, 95.2%, and 95.4% relative to the US employment in the last quarter of 2019, while New Zealand's employment in the last three quarters of 2020 was 99.3%, 98.4%, and 98.9% of its value at the end of 2019.

[7] Figure 16 in Appendix B shows, using data from Google mobility reports on visits to shopping venues and workplaces, that New Zealand had a brief intense shutdown and that the US experienced a longer-lasting one.

[8] Hall and Kudlyak (2020) refer to those on temporary layoff as unemployed with jobs.

Fig. 2: New Zealand and United States



Source: Aggregate macroeconomic data for the United States is from FRED[a]. Following Hall and Kudlyak (2020) we classify Job Losers on Layoff as unemployed with jobs[b]. The dotted black lines in the top right panel are the monthly averages for each quarter of the sum of US private employment and unemployed persons with jobs. New Zealand data from https://www.stats.govt.nz/.

[a]Real Gross Domestic Product, Real Personal Consumption Expenditure, Real Gross Private Domestic Investment, Total Private Employment, Job Losers on Layoff

[b]Current Population Survey (Household Data) Table A-11. Unemployed persons by reason for unemployment

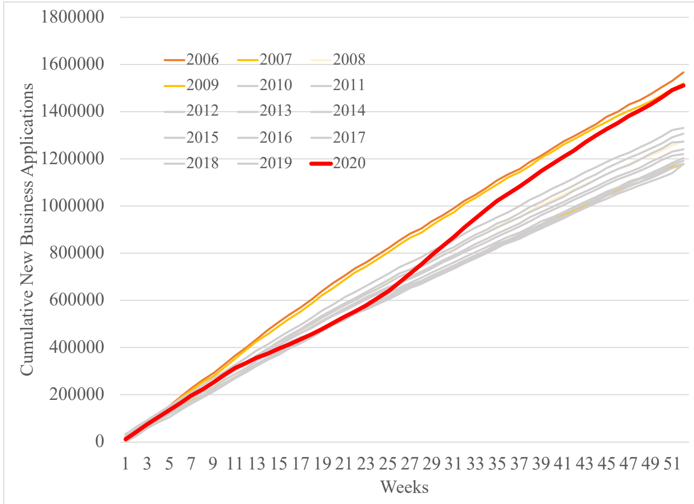
In our benchmark economy, with balance sheet support policies that shield shut down firms from paying wages during the shutdown, the ripple effects of a shutdown are small. These policies could be implemented by furloughing workers, who then receive unemployment insurance benefits, or transferring resources to firms so that they pay the wages of employees who are "unemployed" within the firm. This sort of policies were adopted by New Zealand and the United States, among other countries. For example, the Small Business Pulse Survey conducted by the US Census Bureau reports that over 70% of small businesses received assistance from the PPP and other programs. During the shutdown, their cash-on-hand increased and the arrears in servicing loans and other costs decreased.

The large shock naturally impact the soundness of more vulnerable firms. Indeed, preliminary evidence (Crane et al., 2020) suggests that firm exit has been elevated among small firms and establishments in sectors most exposed to social distancing. Overall, the establishment exit rate was one fourth to one third above normal. Consistent with this, any rise in business exits has not reached larger business units or enough smaller units to account for a material share of employment. This evidence is consistent with quantitative implications of the model, where the excess exit of firms is not only concentrated among the small (and young), but of comparable order of magnitude.

The cross-country differences in the speed of recovery could be the result of weaker balance sheet support policies, longer lockdowns, or reallocation shocks. In our interpretation, the slow recovery of employment and output in the United States relative to New Zealand is the consequence of a more prolonged lockdown, which could also have induced a reallocation shock that would not have materialized under a shorter lockdown. Concerning the latter, there is mounting evidence in the US that this is indeed the case. Barrero et al. (2021) report evidence on reallocation from an online survey of businesses, showing that excess job and sales reallocation across firms rose sharply since the pandemic struck. The Business Formation Statistics (BFS) reported in Figure 3 and Dinlersoz et al. (2021) also suggest a reallocation shock, manifested by a surge in new business applications, following a temporary contraction in the first weeks of the pandemic.[9] Bloom et al. (2021) report a shift in patent applications during 2020 toward working from home technologies, which are likely to result in more permanent reallocation modes of work and sectors. We assess the implications of a reallocation shock in our model in Section 5.

[9] See also Guilford and Scott (2020), who report a version of this figure and also provide real world examples.

Fig. 3: Business Formation Statistics



Source: This figure shows the cumulative new business applications that have a high propensity of turning into businesses with payroll, as reported in the Business Formation Statistics (BFS), United States Census Bureau. See https://www.census.gov/econ/bfs/pdf/bfs_current.pdf for further details.

3 Modeling the Great Shutdown

Building on Buera et al. (2015), we model an economy with entrepreneurial production subject to financial and labor market frictions. There is a continuum of individuals, who are heterogeneous in their entrepreneurial productivity, employment opportunity, and wealth. Furthermore, an unanticipated shock can shut down a fraction of them temporarily, but since it is completely unanticipated, it has no impact on peoples' behavior ex ante.

Access to capital is determined by entrepreneurs' wealth through a simple collateral constraint, motivated by the imperfect enforceability of capital rental contracts. One entrepreneur can operate only one production unit in a given period. Entrepreneurial ideas are inalienable, and there is no market for managers or entrepreneurial talent.

We assume that there is a centralized labor market where hiring entrepreneurs compete for available workers. The arrival of unemployed workers into this centralized hiring market is subject to frictions modeled as a simple matching function.

We model the "Great Shutdown" as the combination of two unanticipated shocks that hit the economy in the first period, with a period corresponding to a quarter: (i) a productivity shock (or shutdown shock) affecting a subset of the entrepreneurs, which we label non-essential, regardless of their productivity or wealth, and (ii) a demand shock affecting the utility from consumption in the first period. The firms cannot produce when hit by the shutdown shock, but we assume that the shock disappears in the following period and that this is common knowledge. Given the transitory nature of the aggregate shock, we allow for a simple form of rest unemployment in the spirit of Alvarez and Shimer (2011). Laid-off workers who do not enter the centralized labor market can be re-hired by their previous employers in the following period without going through the frictional labor market. Similarly, we assume that the demand shock disappears in the following period. We extend the model to consider reallocation shocks (Section 5) and in the robustness section we consider longer and larger shutdowns.

3.1 Model Elements

Demographics and Heterogeneity The population size of the economy is normalized to one with no population growth. People live indefinitely and are heterogeneous in their financial wealth a, entrepreneurial productivity $z \in \mathcal{Z}$, and employment opportunity. Their wealth is chosen endogenously by forward-looking saving decisions, but their entrepreneurial productivity follows an exogenous stochastic process. To be specific, an individual retains her entrepreneurial productivity from one period to the next with probability ψ. With probability $1-\psi$, she has to draw a new entrepreneurial productivity from a time-invariant distribution with a cumulative density $\mu(z)$. The new draw is independent of her previous productivity level but $\psi > 0$ makes the process persistent. In each period, an individual with an employment opportunity chooses whether to work for a wage or to operate an individual-specific technology (entrepreneurship). Those without an employment opportunity choose between searching for a job and entrepreneurship.

The unanticipated lockdown in period $t = 1$ temporarily shuts down a fraction ϕ of the entrepreneurs, labeled as non-essential, and is orthogonal to their wealth or entrepreneurial productivity.

Employed workers earn a wage that clears the hiring market in each period. Unemployed workers receive unemployment benefits and search for a job. Following the unanticipated shutdown shock, unemployed workers may rest and wait to be recalled by their previous employers in the following period.

Preferences Individual preferences are described by the following expected utility over sequences of consumption, c_t:

$$U(c) = \mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1} \xi_t u(c_t)\right] , \quad u(c_t) = \frac{c_t^{1-\sigma}}{1-\sigma} ,$$

where β is the discount factor, σ is the coefficient of relative risk aversion, and ξ_t is the sequence describing the unanticipated preference shock, with $\xi_1 < 1$ and $\xi_t = 1$, for all $t > 1$. There is no disutility from working or searching for a job. The expectation is taken over the realizations of the entrepreneurial productivity z but not over the unanticipated shutdown or preference shocks. These shocks are completely unanticipated but, upon their arrival, their future paths are completely deterministic.

Technology An entrepreneur with productivity z produces using capital k and labor l according to a decreasing-return-to-scale production function f:

$$zf(k,l) = zk^{\alpha}l^{\theta}, \tag{1}$$

where α and θ are the elasticities of output with respect to capital and labor, with $\alpha + \theta < 1$.

Financial Markets Productive capital and government bonds are the only assets in the economy. There is a perfectly-competitive financial intermediary that receives deposits, rents out capital to entrepreneurs, and invests in government bonds. Both assets are safe and the return on deposits and government debt—i.e. the interest rate in the economy—is denoted by r_t. The zero-profit condition of the intermediary implies that the rental price of capital is $r_t + \delta$, where δ is the depreciation rate of capital.

We assume that entrepreneurs' capital rental k is limited by a collateral constraint $k \leq \lambda a$, where $a \geq 0$ is individual wealth and λ measures the degree of credit frictions, with $\lambda = +\infty$ corresponding to perfect credit markets and $\lambda = 1$ to financial autarky where all capital has to be self-financed by entrepreneurs. The same λ applies to everyone.[10]

Labor Markets We first describe the workings of the labor market without rest unemployment, which becomes relevant only after the unanticipated arrival of the temporary shutdown shock. Entrepreneurs hire new workers in a competitive centralized hiring market. We assume that (i) all employed workers must be paid the wage that

[10] A microfoundation for this parsimonious constraint is provided in Buera and Shin (2013). Alternatively, we can assume that entrepreneurs directly own capital, invest in government bonds, and issue bonds subject to the limit $b \geq (1-\lambda)/\lambda k$. This decentralization is equivalent provided that the entrepreneurial productivity for the following period is realized at the end of the current period, before the portfolio choice is made (Moll, 2014).

clears the hiring market in each period and (ii) employers may terminate the employment relationship at any time.

Unemployed workers, whether because they are laid off or they quit entrepreneurship, must re-enter the hiring market before getting employed, and this is where the labor market frictions matter. To be specific, a matching function determines the fraction of the currently unemployed that enters the centralized hiring market, in which everyone gets hired at the market-clearing wage. It is assumed that all unemployed workers face the same probability of entering the hiring market.[11]

Formally, denoting with M_t the number of unemployed workers that enter the hiring market in period t, the matching function is:

$$M_t = \gamma \left(U_t + JD_t\right) \tag{2}$$

where U_t is the number of unemployed workers at the end of the previous period and JD_t is the job destruction at the beginning of the current period.[12]

The job destruction can be written as:

$$JD_t = \int \left[\underbrace{\max\left\{l_{t-1} - l_t\left(a, z\right), 0\right\}}_{\text{layoffs}} + \underbrace{\mathbb{I}\{l_{t-1} > 0 \wedge l_t\left(a, z\right) = 0\}}_{\text{exiting entrepreneur}} \right] dG_t\left(a, l_{t-1}, z\right)$$

where l_t is labor demand of an individual (positive for entrepreneurs and zero for workers) and G_t is the joint cumulative distribution function of wealth (a), previous period employment (l_{t-1}), and current entrepreneurial productivity (z). The second term in the integral captures exiting entrepreneurs with indicator functions $\mathbb{I}$, who enter the pool of unemployed workers. The employees of exiting entrepreneurs enter the first term of the integral.

The law of motion of the unemployment rate is then:

$$U_{t+1} = U_t + JD_t - M_t - UB_t, \tag{3}$$

where the last term UB_t is the measure of new entrepreneurs in period t who were unemployed workers at the end of period $t-1$. Equations (2) and (3) imply that unemployment evolves according to $U_{t+1} = (1-\gamma)\left(U_t + JD_t\right) - UB_t$.

[11] Our modeling of the labor market closely follows Alvarez and Veracierto (2001). Our model can also be interpreted as a simplified version of Veracierto (2016).

[12] It is critical for the dynamic stability of U_t that a fraction of the laid-off workers and exiting entrepreneurs enters the hiring market and be employed within the period, as implied by the JD_t term appearing in the right-hand side of equation equation (2).

Rest Unemployment We enrich the model of the labor market by giving the non-essential employers (those hit by the short-lived shutdown shock) the option to rehire their laid-off workers as soon as the shock is gone, bypassing the frictional labor market represented by the matching function. Following Alvarez and Shimer (2011), we refer to this state of the labor market as rest unemployment (unemployed with jobs in Hall and Kudlyak (2020)). Importantly for the purpose of this paper, the extent to which employers will be able to recall the resting workers is endogenously shaped by the interaction between the financial frictions and the lockdown duration. While inactive, firms must still pay for their capital rental payments, drawing down their financial assets. As a result, depending on the external financing needs of the firms, their ability to rehire and resume operations after the lockdown will be shaped by the extent of asset depletion vis-a-vis the collateral requirements. The fraction of the resting workers that could not be recalled when the lockdown ends will join the regular unemployment pool.[13]

The measure of workers laid off in period 1 (when the unanticipated shock hits) and recalled by their previous employers in period 2 (when the shutdown ends) is R_2, given by

$$R_2 = \psi \int \max\left\{\min\left\{l_2(a,z), l_{1-}\right\}, 0\right\} dG_2^{NE}\left(a, l_{1-}, z\right), \tag{4}$$

where l_{1-} is the number of employees in period 1 immediately before the unanticipated shock hits, and G_2^{NE} is the joint cumulative distribution function in period 2 of those hit directly by the shutdown shock, with $G_2^{NE}(\infty,\infty,\infty) = \phi$, the fraction shut down, and NE standing for non-essential. Only continuing firms have the option to recall their former employees who are unemployed, so the probability of keeping the entrepreneurial productivity for a period, ψ, appears. (Again, an entrepreneur who continue to operate after hit by the idiosyncratic productivity shock is interpreted as starting a new firm.)

An inspection of equation (4) shows that the key equilibrium object determining the ripple effects from a shutdown shock is given by the joint distribution $dG_2^{NE}\left(a, l_{1-}, z\right)$. While wages and interest rates also shape the labor demand of an entrepreneur with a given productivity and wealth post-lockdown, $l_2(a,z)$, it is the joint distribution of producers across these dimensions that ultimately determines the extent of worker recall. The asset depletion that non-essential entrepreneurs suffer during the lockdown period shows up in the wealth distribution of continuing entrepreneurs. Because of the collateral constraint, an increase in the number of entrepreneurs with a worsened financial position undermines the capital and labor demand possibilities of firms post-

[13] Although this option is not available in the initial stationary equilibrium, it would not be relevant even if it were, because our entrepreneurial productivity shock process implies that a firm that is laying off workers will not increase employment in the following period. If an entrepreneur lays off workers but then is hit by a higher productivity shock the next period, which implies more hiring, we interpret it as the entrepreneur starting a new, more productive firm.

lockdown, thereby weakening the recovery. Lastly, the balance sheet deterioration may lead to non-essential entrepreneurs endogenously exiting the market when the lockdown ends, as captured by entrepreneurs transitioning to a wealth level for which $l_2(a,z) = 0$—zero labor demand meaning out of entrepreneurship.

Given the measure of resting unemployed workers, the measure of workers matched to the hiring market in period 1 and the unemployment rate in period 2 are:

$$M_1 = \gamma\left(U_1 + JD_1 - R_2\right)$$

and

$$U_2 = U_1 + JD_1 - M_1 - UB_1 - R_2\ . \tag{5}$$

Unemployment Benefits We assume that unemployed workers receive a transfer b_t equal to the period wage, which is partially financed with debt to be paid off by period T.

In particular, we assume that for $t = 1, \cdots, T-1$, the lump-sum tax is constant over time $\tau_t = \tau^B$ and the debt policy satisfy the budget constraint of the government:

$$\tau^B + B_{t+1} - B_t = w_t U_{t+1} + r_t B_t,\ 1 \leq t < T, \tag{6}$$

with $B_1 = 0$ and $B_t = 0$ for $t \geq T$. That is, the government had no debt prior to the unanticipated shutdown shock and chooses the lump sum transfer τ^B so that it repays its debt by period T.[14] For $t \geq T$, the government reverts to the balanced budget with no debt, i.e., the lump-sum taxes are given by equation

$$\tau_t = w_t U_{t+1},\ t \geq T, \tag{7}$$

where the right-hand side is the product of the wage w_t that clears the hiring market in each period (because we assume full replacement unemployment benefits– i.e. $b_t = w_t$) and the measure of unemployed workers at the end of period t, U_{t+1}.

3.2 Individuals' Problem

In the initial stationary equilibrium, an individual's state is summarized by his financial wealth a and entrepreneurial productivity z. To be precise, the state of an individ-

[14] Appendix C considers two alternative debt financing schemes: (i) a full adjustment of the lump sum transfer to balance the budget every period and, (ii) a laxer repayment option where taxes are held unchanged for 12 quarters, and increased by a fixed amount thereafter to cancel the debt in 12 years. As shown in the appendix, our main finding of the swift recovery of output and the unemployment rate remains insensitive to fiscal policy, while consumption and investment will be more sensitive to these alternative assumptions. We resume this discussion when presenting baseline results in section 4.

ual also includes his employment/unemployment status. However, as we assume that unemployed benefits are exactly equal to the market wage every period, from an individual's point of view, there is no difference between being a wage earner and being unemployed.

With the unanticipated shutdown shock that affects only a fraction of the firms, it becomes necessary to distinguish those shut down from those who were not. In a completely unanticipated manner, a fraction ϕ of firms are classified as non-essential (NE) to be shut down temporarily, and the remaining $1-\phi$ of firms are classified as essential (E) and continue operation. The classification into the essential and the non-essential sector is independent of a firm's productivity or assets, (z, a).

Assuming that the shock hits the economy in period 1 and disappears the very next period, the following is the recursive formulation of an individuals' problem in all periods, except for the non-essential entrepreneurs' problem in period 1.

$$v_t(z,a) = \max_{c,a' \geq 0} \ \xi_t \frac{c^{1-\sigma}}{1-\sigma} + \beta \mathbb{E}_t v_{t+1}(z', a') \tag{8}$$
$$\text{s.t.} \quad c + a' = \max\left\{w_t, \pi_t(z, a; r_t, w_t)\right\} + (1+r_t)\, a - \tau_t$$

where

$$\pi_t(z, a; r, w) = \max_{k,l} \ z k^{\alpha} l^{\theta} - (r_t + \delta)\, k - w_t l$$
$$\text{s.t.} \quad k \leq \lambda a,$$

and the occupation choice of an individual is denoted by $o_t(a, z) \in \{0, 1\}$, meaning people choose entrepreneurship ($o = 1$) if and only if the period profit exceeds the hiring market wage (which is the same as the unemployment benefit): $w_t < \pi_t(z, a; r_t, w_t)$. The capital input of entrepreneurs is subject to the collateral constraint. We denote the labor and capital input choices of an entrepreneur by $l_t(a, z)$ and $k_t(a, z)$, both of which are zero for employed and unemployed workers.

The problem of the entrepreneurs unexpectedly classified as non-essential and shut down in period 1 is as follows.

$$v_1^{NE}(z_1, a_1, k_{1-}) = \max_{c_1, a_2 \geq 0} \ \xi_1 \frac{c_1^{1-\sigma}}{1-\sigma} + \beta \mathbb{E}_1 v_2(z_2, a_2) \tag{9}$$
$$\text{s.t.} \quad c_1 + a_2 = -(r_1 + \delta)\, k_{1-} + (1 + r_1)\, a_1 - \tau_1.$$

The timeline is such that the unanticipated shutdown shocks hits *after* the occupational choice and capital rental have been set, given the expectation of factor prices before the shock. Non-essential entrepreneur still pay for the capital rental, denoted by

$k_{1-} = k(z_1, a_1)$, while no output gets produced. In our baseline quantitative exercise, we assume that non-essential entrepreneurs temporarily lay off all their employees, who enter rest unemployment. In Section 4.4, we also consider the case where the non-essential entrepreneurs must also pay the wage bill even though no output gets produced. Once the shutdown shock disappears in period 2, there is no distinction between essential and non-essential entrepreneurs, so the continuation value does not have the superscript NE anymore.

3.3 Competitive Equilibrium

Given an initial distribution of wealth, the previous period's labor input, and entrepreneurial productivity $G_1(a, l_{-1}, z)$, initial and terminal values of government debt $B_1 = B_T = 0$, and tax policy τ_t, a competitive equilibrium comprises prices $\{w_t, r_t\}_{t=1}^{\infty}$, allocations $\{c_t(a,z), a_{t+1}(a,z), k_t(a,z), l_t(a,z), o_t(a,z)\}_{t=1}^{\infty}$, the measure of unemployed workers $\{U_t\}_{t=1}^{\infty}$, the rest unemployed in period 1, R_2, and lump-sum taxes $\left\{\tau_t = \tau^B\right\}_{t=1}^{T-1}$ and $\{\tau_t = w_t U_{t+1}\}_{t=T}^{\infty}$ such that:[15]

1. Given prices $\{w_t, r_t\}_{t=1}^{\infty}$ and the lump-sum taxes $\{\tau_t\}_{t=1}^{\infty}$, the allocations are solutions to the individual problems (8) and (9) for all $t \geq 1$;
2. The measure of unemployed workers follows the equilibrium law of motion (3) and (5);
3. The government budget constraints given by (6) and (7) are satisfied for all $t \geq 1$;
4. Asset markets clear for all $t \geq 1$:

$$K_t \equiv \underbrace{\int k_t(a,z)\, G_t(da, dl_{-1}, dz)}_{\text{capital demand}} = \underbrace{\int a G_t(da, dl_{-1}, dz) - B_t}_{\text{capital supply}}; \tag{10}$$

5. Labor markets clear for all $t \geq 1$:

$$\underbrace{\int l_t(a,z)\, G_t(da, dl_{-1}, dz)}_{\text{labor demand}} = \underbrace{1 - \int \mathbb{I}\{o_t = 1\} G_t(da, dl_{-1}, dz) - U_{t+1}}_{\text{workers in hiring market}}, \tag{11}$$

   where the left-hand side is the demand for labor and the right-hand side is the measure of workers in the hiring market, which is the total population net of entrepreneurs and unemployed workers;

[15] To be precise, we need to define a binary variable j which takes the value of zero if the individual is unemployed and one otherwise. The proper cumulative distribution function is then $G_t(a, l_{-1}, z, j)$, $j = 0, 1$. However, because the market wage and the unemployment benefits are always the same, trivially, $G_t(a, l_{-1}, z, j = 0) = U_t G_t(a, l_{-1}, z)$ and $G_t(a, l_{-1}, z, j = 1) = (1 - U_t) G_t(a, l_{-1}, z)$.

6. The joint distribution of wealth, previous period's labor input, and entrepreneurial productivity $\{G_t(a, l_{-1}, z)\}_{t=1}^{\infty}$ evolves according to the following equilibrium mapping:

$$G_{t+1}(a, l_{-1}, z) = \psi \int_{a_{t+1}(\tilde{a},z)\leq a, l_t(\tilde{a},z)\leq l_{-1}} G_t(d\tilde{a}, d\tilde{l}_{-1}, z) + (1-\psi)\,\mu(z) \int_{a_{t+1}(\tilde{a},\tilde{z})\leq a, l_t(\tilde{a},\tilde{z})\leq l_{-1}} G_t\left(d\tilde{a}, d\tilde{l}_{-1}, d\tilde{z}\right).$$

In the capital and labor market clearing conditions, one could have integrated out the previous period's employment from aggregate capital and labor demand. This is because, in general, the previous period's employment is not in the state space underlying the firms' capital and labor demand, $k_t(a, z)$ and $l_t(a, z)$. In the period right after the lockdown, however, past employment does constrain firms' labor and capital choices, as recalled workers cannot exceed the employment level of a given non-essential firm prior to the lockdown. For this reason, and to economize on the number of equations, we carry l_{-1} as a state variable in every period.

3.4 Calibration

Our model is parameterized so that the stationary equilibrium matches relevant aggregate and establishment-level moments in the US economy. We set the length of a time period to be a quarter.

Following the standard practices, we set the coefficient of relative risk aversion σ to 1.5, the annual depreciation rate to 0.06, that is, $(1-\delta)^4 = 0.94$, and the ratio $\alpha/(\alpha+\theta)$ to 0.33, to match the aggregate capital income share. As for the parameter for the hiring market matching function, we set $\gamma = 0.37$ so as to obtain an unemployment rate of 4 percent in the stationary equilibrium.

Entrepreneurial productivity is assumed to follow a Pareto distribution, with cumulative density given by $\mu(z) = 1 - z^{-\eta}$ for $z \geq 1$. Each period, an individual retains his z with probability ψ, while a new entrepreneurial productivity is drawn with the complementary probability $1-\psi$.

The remaining parameters to be calibrated are $\alpha+\theta$, η, ψ, β and the collateral constraint λ of the initial stationary equilibrium. To do so, we target the following moments in the US data: employment share of the top decile of establishments by size (number of employees), the top 5 percent earnings share, the annual exit rate of establishments, the real interest rate, and the ratio of external finance to total non-financial assets of the non-financial business sector.

Table 1 shows the moments in the US data and their counterparts in the calibrated model. The decile of the largest establishments (in terms of employment) accounts for

	US Data	Model	Parameter
Top 10% Employment Share	0.69	0.69	$\eta = 5.25$
Top 5% Earnings Share	0.30	0.30	$\alpha + \theta = 0.79$
Establishment Exit Rate (Annual)	0.10	0.10	$\psi = 0.97$
Real Interest Rate (Annual)	0.04	0.04	$\beta = 0.98$
Credit Market Instruments to Non-Financial Assets	0.70	0.70	$\lambda = 7.5$

Table 1: Calibration

69 percent of total employment in 2000. The earnings share of the top 5 percentiles is 30 percent in 1998. The annual establishment exit rate is 10 percent in the Business Dynamics Statistics from the US Census. We assume that the annual interest rate is 4 percent. Lastly, we target the ratio of credit market instruments to total non-financial fixed assets in the non-financial business sector of 0.7, a level attained one year before the 2008 financial crisis.

Although all parameters are jointly pinned down in the model equilibrium, we can determine which empirical moments are mostly dependent on each parameter. For instance, the tail parameter of the Pareto distribution of entrepreneurial productivity, holding other parameter values constant, controls the fraction of employment accounted for by the decile of largest establishments. Similarly, $\alpha + \theta$ can be mapped into the earnings share of the top 5 percent of the population, who are mostly entrepreneurs in the model as well as in the data. There is also a direct link from the parameter governing the persistence of the entrepreneurial productivity process ψ to the probability that an entrepreneur exits from production and hence the annual establishment exit rate in the data. The discount factor, unsurprisingly, is closely tied to the target interest rate. The collateral constraint parameter λ is primarily responsible for the ratio of external finance to capital in the aggregate,

$$\frac{\int \max\left\{k_t\left(a,z\right) - a, 0\right\} G_t\left(da, dl_{-1}, dz\right)}{K_t}, \tag{12}$$

which corresponds to the ratio of credit market instruments to total non-financial assets in the non-financial business sector in the Flow of Funds data.

In our benchmark exercise, we assume $\phi = 10\%$ of firms are non-essential and shut them down for one quarter. This matches the fall in the US GDP in the second quarter of 2020. As for the unanticipated demand or preference shock accompanying the shutdown shock, we calibrate the preference shock ξ_1 so that the ratio of the fall in consumption to the fall in investment in period $t = 1$ is similar to the one observed in the US data in the second quarter of 2020 (see Figure 2)— i.e., $I_1/I_0 = 0.92 C_1/C_0$. Finally, we assume that the debt issued during the lockdown gets fully repaid over $T = 48$ quarters.

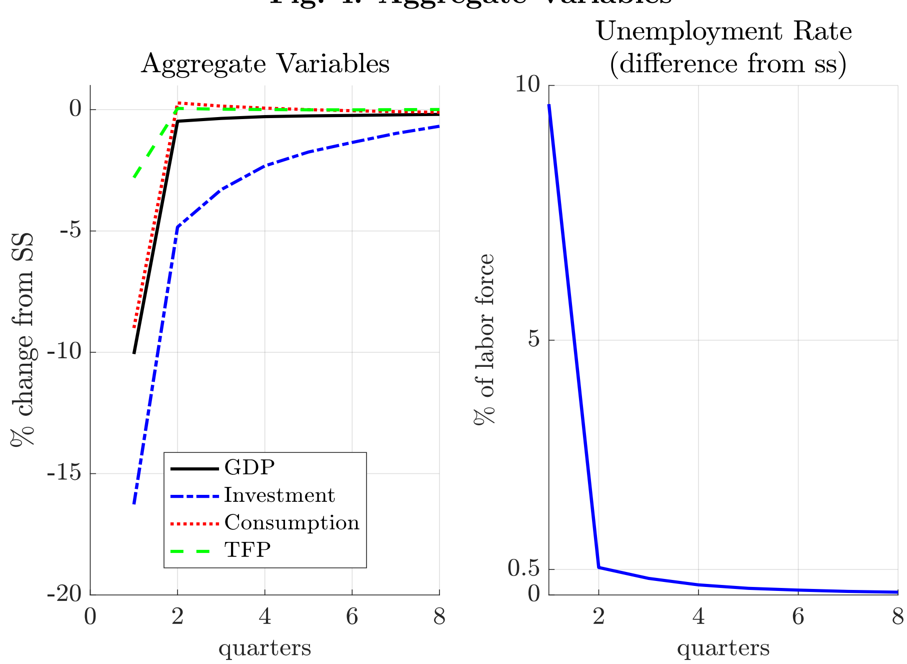
4 The Ripple Effect of a Lockdown

In this section, we show the transition dynamics following an unexpected shock that shuts down $\phi = 10\%$ of firms for one quarter and a concurrent unexpected demand shock that lowers the marginal utility of consumption during the lockdown. Unemployed workers that were employed in these firms receive full unemployment insurance benefits financed by government debt and can be reemployed directly by their previous employers without going through the matching process in period 2.[16] During the shutdown, non-essential entrepreneurs have to pay the rental cost of capital, which can be viewed as a fixed cost, and decide how much to draw their assets down and how much to consume.

We first present the aggregate implication of the lockdown, and then dive into the micro-level implications for employment and consumption dynamics across different firms and individuals.

4.1 Aggregate Variables

Fig. 4: Aggregate Variables



[Figure 4](#) shows the trajectory of aggregate variables. The left panel shows GDP, investment, consumption, and total factor productivity, while the right panel illustrates

[16]An equivalent interpretation is that the government provides locked-down firms with a 100% wage subsidy to finance the wage bill during the temporary shutdown, conditional on "employing" their existing workers.

the dynamics of unemployment. The most salient feature of the figure is the swift recovery of the aggregate output. After falling by 10% on impact, GDP bounces back to just 0.4% below the initial steady state level in the quarter following the lockdown. The behavior of the unemployment rate shows that, to a large extent, the swift recovery in GDP is a reflection of the swift recovery in employment. The decline in investment explains the slight delay in the recovery of output. The fall in TFP on impact is simply a reflection of the unused physical capital by non-essential entrepreneurs.

Figure 4 also shows that, with the aid of a demand shock, the model generates a large drop in consumption as in the data, which is calibrated to the relative decline of consumption and investment in the US data. The dynamics thereafter, however, are driven by the endogenous model mechanism. In particular, the quick recovery in consumption and the sluggish recovery in investment are the result of the interaction between the non-Ricardian structure of the model and the repayment scheme for the government debt. In the model, because of the borrowing constraint ($a \geq 0$) the consumption of workers is more sensitive to temporary changes in income and the profile of taxes.[17] Fiscal policy, which fully replaces the wage income to the unemployed through debt financing, allows constrained workers to sustain a high consumption. At the same time, the government debt crowds out private investment from aggregate savings. Given the protracted repayment path of the government debt, investment remains depressed for longer than aggregate output. As further discussed in Appendix C, increasing lump-sum taxes to balance the government budget reverses this pattern.

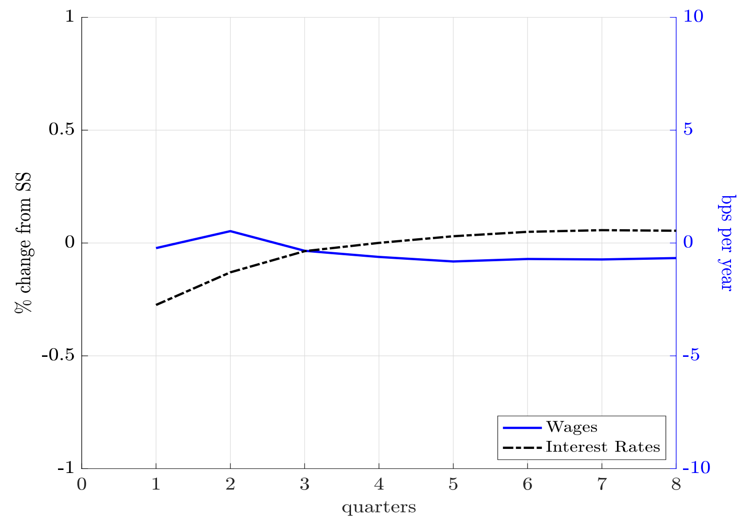
Figure 5 shows the behavior of factor prices. Wages and the interest rate barely move in the benchmark. Rest unemployment plays a crucial role here. Despite the massive rise and fall in unemployment, wages barely move as most changes in employment are not intermediated through the hiring market. This is because newly unemployed workers wait to be recalled. The interest rate falls following the shutdown shock, because non-essential entrepreneurs demand less capital due to their deteriorated balance sheet and more binding credit constraint. The interest rate is above the steady state level later in the transition, as the marginal product of capital is high due to the temporarily low capital stock.[18]

The quick recovery in the unemployment rate is explained by the rest unemployment and the fact that the negative balance sheet effect is not large enough, especially for

[17]More specifically, as is typically the case in models with heterogeneous agents and incomplete markets, the interest rate is lower than the rate of time preference. Workers are in the lowest income state, so their wealth converge to zero in finite time. As a results, workers with low wealth consume a large fraction of a transfer that is financed with taxes that are levied far enough into the future.

[18]The decline of the interest rate in the second period, and the subsequent reallocation of capital to the essential sector, explains the temporary rise in the wage. Essential firms with access to cheaper funding have an incentive to hire more workers, but the reallocation of non-essential workers who are not rehired is slowed by the labor market friction. Therefore, the wage rate in the hiring market is temporarily high.

Fig. 5: Factor Prices



the old and relatively unconstrained non-essential firms, which account for a large fraction of employment among non-essential firms. After the sudden layoff of their workers, which increases the unemployment rate by 9 percentage points, non-essential entrepreneurs recall 89% of the resting workers as soon as the shutdown is lifted, leaving the unemployment rate only slightly above the initial level.[19] Despite a depletion of the non-essential firms' financial assets, credit conditions are such that, in the aggregate, these firms can re-hire a large fraction of their initial level of employment.

4.2 Micro-Level Implications

The quick recovery of the aggregate variables masks substantial heterogeneity in the pace of recovery across firms. The shutdown shock by construction affects non-essential firms but not the essential firms. Within the set of non-essential firms, the shock has a longer-lasting effect on the young firms, because they are more likely to be credit-constrained even before the shock and suffer more from the large hit to the balance sheet when shut down.

The dynamics of employment across different types of firms are shown in Figure 6. The left (right) panel shows the employment dynamics of a cohort of young (old) entrepreneurs, defined as less (more) than 5 years old. That is, we identify the firms 5 years and younger (older) prior to the lockdown, and track the aggregate employment dynamics of the cohort over time. In each panel we separately present the dynamics

[19] Ganong et al. (2021) estimate, using the data on the customers of JPMorgan Chase Bank N.A., that 75% of unemployment-to-employment transitions in May/June 2020 was such recalls, and this number fell to 50% by October 2020.

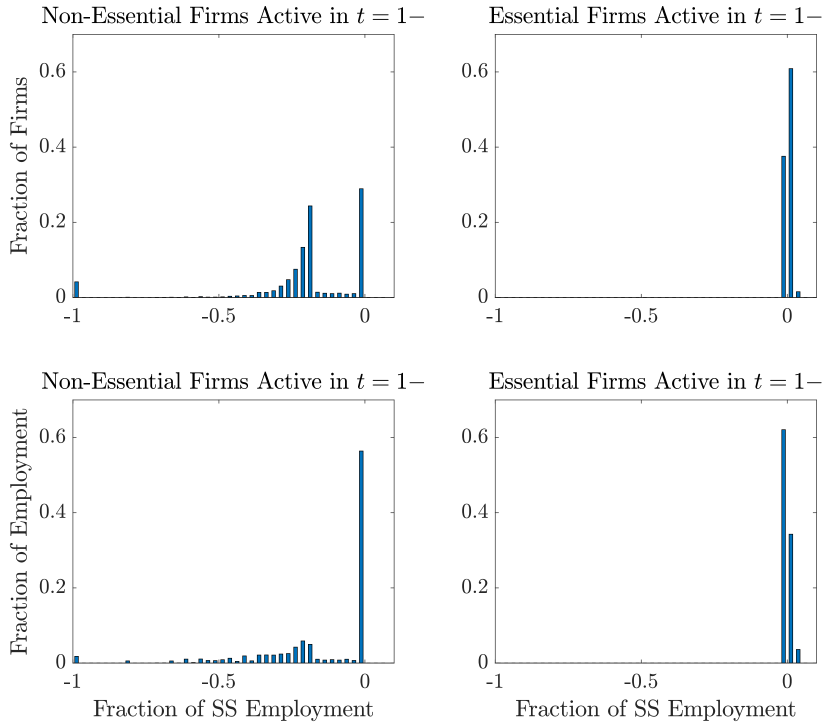
Fig. 6: Micro-Level Implications: Employment Dynamics

for essential (dashed line) and non-essential (solid line) entrepreneurs, together with their common life-cycle in the stationary equilibrium (dash-dot line). In all cases, we normalize employment to its value in the initial period, before the unanticipated shock is realized.

Beginning with each cohort's life cycle in the stationary equilibrium, Figure 6 shows the importance of financial frictions in shaping the patterns of life-cycle dynamics of young and old cohorts. Young firms are dominated by productive but relatively poor entrepreneurs whose efficient scale is limited by collateral constraints. As time elapses and net worth is accumulated, these young businesses grow out of their constraints, hence exhibiting a period of employment growth. Old firms, on the contrary, have mostly grown out of the financial constraint so employment dynamics follow the fate of the average entrepreneurial productivity of the cohort, which drifts down due to the exit of firms when entrepreneurs redraw their productivity and due to the mean reversion of the remaining entrepreneurial productivity shocks.

Consider next the dynamics of essential and non-essential firms in the aftermath of the lockdown. Following the drastic initial drop, the employment of young non-essential firms is 20% below trend on impact, and does not catch up with their essential counterpart for over 20 quarters. This is explained by the fact that the net worth of young firms is low to begin with and then negatively affected by the need to pay for the capital rental without generating any revenue during the shutdown. On the contrary, the employment of old non-essential firms recovers almost completely the period after the shock. This is because old entrepreneurs tend to be richer and can overcome the credit constraint rather easily.

Fig. 7: Micro-Level Implications: Distribution of Employment Growth

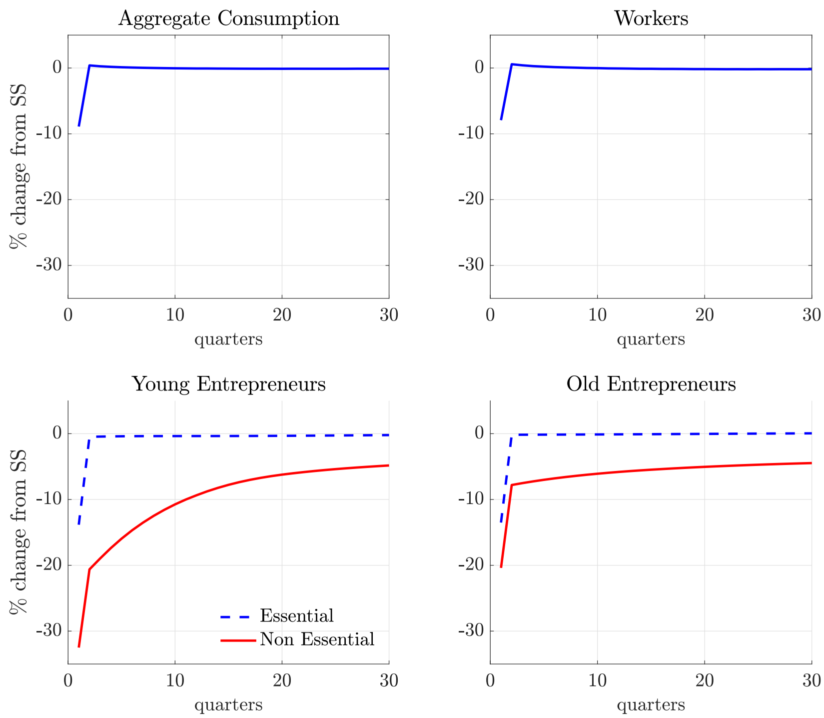


Note: The fraction of steady state employment corresponds to $(l_2 - l_2^{ss})/l_2^{ss}$, where l_2 is the employment one period after the lockdown ($t = 2$) of the firms active in the steady state.

To further illustrate the large persistent effects for a subset of firms in the context of the negligible persistent effects in the aggregate, Figure 7 shows the weighted (top panels) and unweighted (bottom panels) distributions of employment growth, for both essential (left panels) and non-essential firms (right panels). In the horizontal axis we report the deviation in employment relative to the counterfactual employment that firms would have had in the second period absent the shutdown shock. In the top panels, the vertical axis shows the fraction of firms falling in different employment growth bins, while in the bottom panels it shows the fraction of employment accounted for by the firms in each bin. To focus on the impact of the unanticipated aggregate shock, we only look at the set of firms that maintained their idiosyncratic productivity (fraction ψ).

The top-left panel shows that the majority of non-essential firms experienced large declines in employment, more than 20% on average, and 5% of the firms exited because of the shutdown shock, which is consistent with preliminary evidence on firms exit during 2020 (Crane et al., 2020).[20] These large effects are diluted in the aggregate because, first, only 10% of the firms are affected directly by the shutdown and, second, even among the non-essential firms, the negatively affected firms, which tend to be young and financially constrained, account for a small fraction of the total employment, as can be clearly seen by comparing the top and bottom left panels. In contrast, the distribution of employment growth of essential firms is concentrated around zero, with some gaining employment thanks to the lower capital rental rate in $t = 2$.

Fig. 8: Micro-Level Implications: Consumption Dynamics



The heterogeneous responses of employment across firms have a close parallel in the differential responses of consumption across workers and entrepreneurs, as shown by Figure 8. For workers and essential entrepreneurs, consumption drops in the first period as a consequence of the aggregate preference shock. For non-essential entrepreneurs, the decline is two to three times larger, and very persistent. Entrepreneurs operating young firms (bottom left panel), who likely have a low net worth and are financially constrained, experience a larger and more protracted decline in consumption, since they have have to rebuild their wealth to overcome the credit constraint. Wealthier non-essential entrepreneurs (bottom right panel) can smooth out their consumption

[20]The 5% increase in the exit rate among the 10% share of non-essential firms corresponds roughly to $1/5$ $(= 0.05 \times 0.1/(0.1/4))$ of the quarterly exit in the stationary equilibrium. This falls in the ballpark of the $1/4 - 1/3$ excess exit measured by Crane et al. (2020).

better once the shutdown shock and the preference shock disappear.

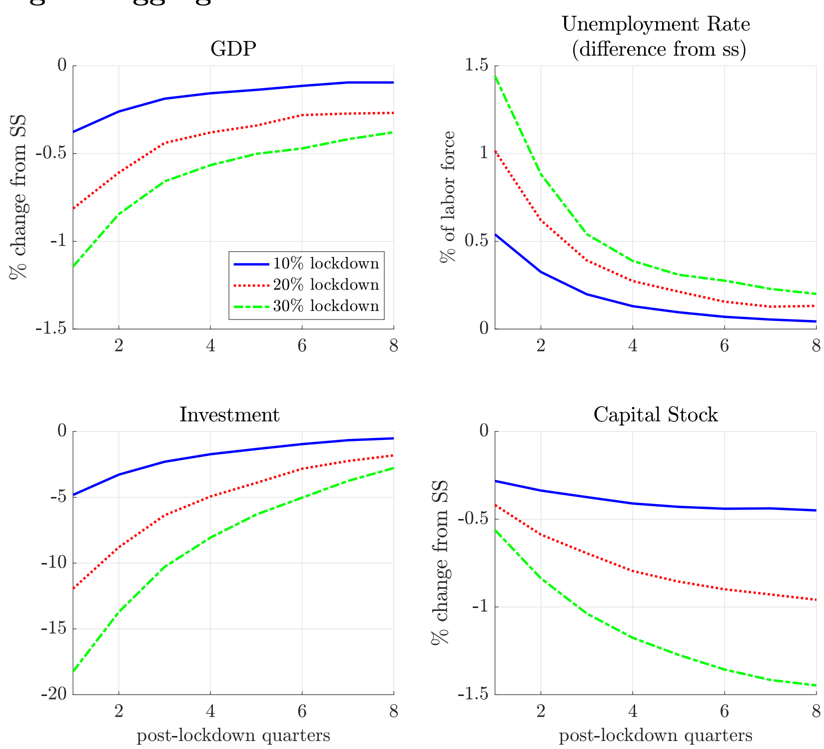
4.3 Effect of the Size and Duration of the Lockdown

In the benchmark exercise, the lockdown closed 10% of the firms for a single quarter. The temporary nature of the shock gives us a stark illustration of its persistent consequences, but the cross-country experiences documented in Section 2 show large heterogeneity with respect to the magnitude and duration of the shock. We explore these dimensions next.

4.3.1 Lockdown Size

In addition to the 10% in the benchmark, we explore the implications of shutdowns of 20% and 30% of the economy. In each case, the demand shock is re-calibrated to achieve the same relative decline between investment and consumption as in the benchmark. Figure 9 illustrates the dynamics of GDP, the unemployment rate, investment, and the capital stock. We do not show the effects during the lockdown period, which are in any case merely mechanical, and focus on the ripple effects of the shocks in the post-lockdown quarters.

Fig. 9: Aggregate Variables: Alternative Size of Lockdown



The main takeaway from Figure 9 is the magnification of the ripple effects from stronger lockdowns. The unemployment rate is 1 and 1.5 percentage points above the initial level relative to the 10% lockdown baseline, reflecting a more widespread balance sheet deterioration across firms. The capital stock declines by more and remains below the initial level for much longer, explained by the larger decline of output on impact and the more persistent fall in employment. The stronger ripple effects stem not from making a given non-essential firm's balance sheet worse, but from expanding the number of firms being shut down. The effects of the lockdown size on wages and the interest rate are rather small.

Fig. 10: Aggregate Variables

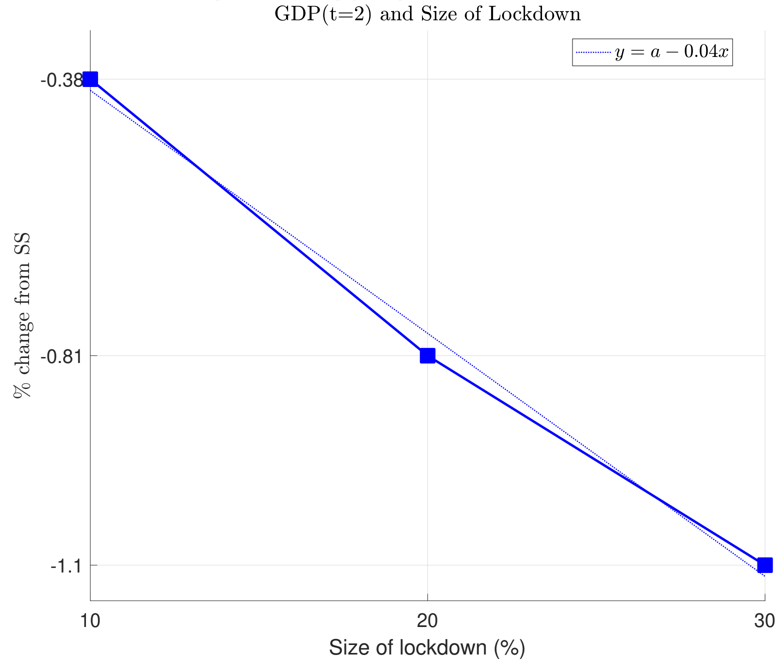
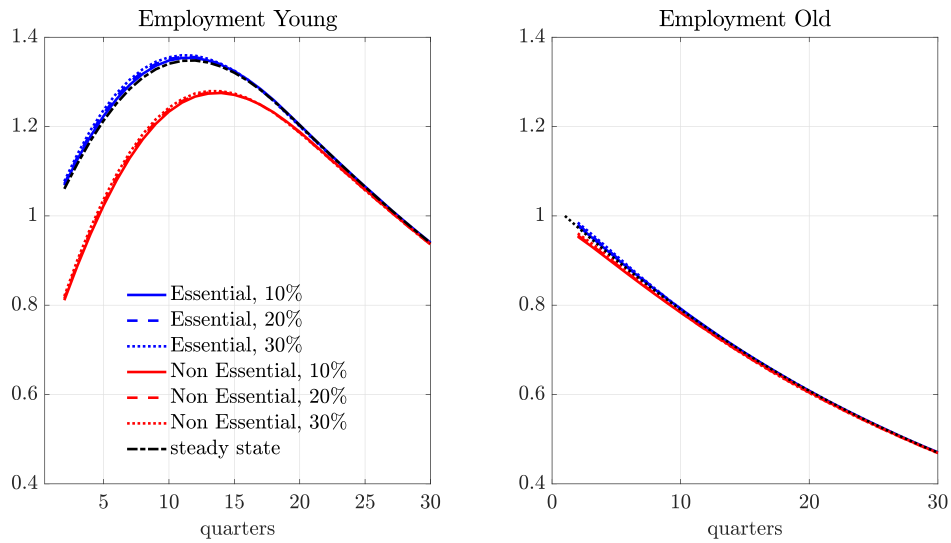


Figure 10 shows the loss in output in the period after the lockdown ($t = 2$) from the initial level on the vertical axis against the size of the lockdown in the horizontal axis. It reveals that the output response is close to linear with respect to the magnitude of the lockdown. Figure 9 suggests that we should obtain similar results if we plotted this relationship for other periods.

Turning to the heterogeneity of the effects, Figure 11 shows that the life-cycle dynamics by firm type are nearly indistinguishable across lockdowns of varying sizes. For instance, the left panel illustrates the employment dynamics of the cohorts of young essential and non-essential firms, and the life-cycles are almost on top of each other across all lockdown sizes. This again shows that the magnification of the aggregate ripple effects from large lockdowns stems not from a strengthening of the effect on a given set of affected firms but, rather, from the expansion of the number of affected firms. There is, however, a slight improvement in the dynamics of young essential

Fig. 11: Micro-Level Implications: Alternative Lockdown Size



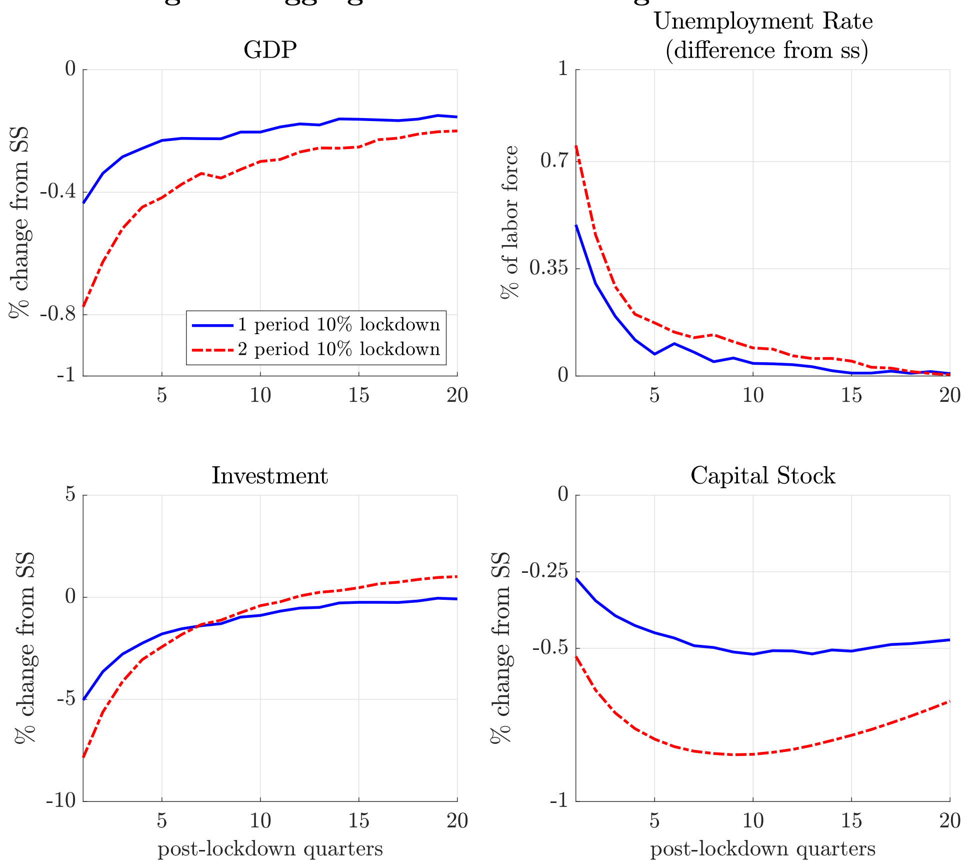
businesses under bigger lockdowns which is worth emphasizing, as it reflects an insight from our general equilibrium framework. The larger falls in wages and interest rates following bigger lockdowns mean that essential firms benefit from lower labor and capital costs.

4.3.2 Lockdown Duration

We now turn to the macroeconomic and micro-level implications of longer lockdowns. We maintain the size of the lockdown at 10% of all firms as in our benchmark but extend the lockdown to multiple periods. We keep the assumption that non-essential firms furlough their workers, who remain in rest unemployment and receive the unemployment benefit for the duration of the lockdown. Once the lockdown ends, non-essential firms can recall their former employees bypassing the labor market friction, as many as their financial capabilities permit. Regarding the rental cost of capital of continuing non-essential firms, we assume that they have to pay the rental cost of the undepreciated portion of their rented capital. This way, we parsimoniously introduce irreversibility in capital decisions while allowing for some capital reallocation during lockdown periods. Additional capital reallocation occurs from non-essential firms that, while in lockdown, draw new idiosyncratic productivity shocks and exit as a result. These exiting entrepreneurs and the workers they laid off join the regular unemployment pool and, hence, are subject to the labor market frictions in entering the hiring market.

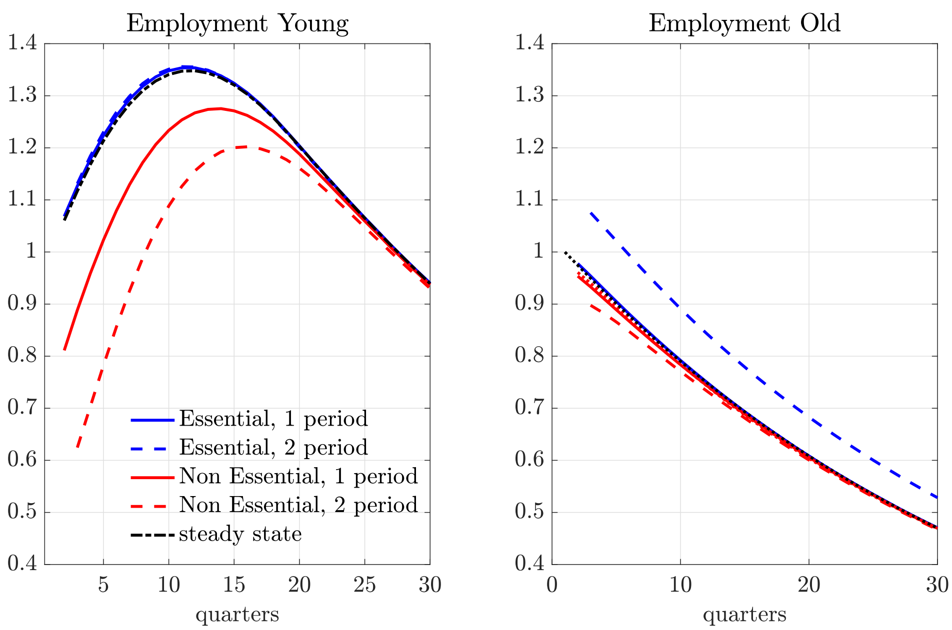
We first show the behavior of the aggregate variables in Figure 12. The horizontal axis is quarters after the lockdown, so in the case of a 2-period lockdown, the first

Fig. 12: Aggregate Variables: Longer Lockdown



observation corresponds to period $t = 3$, while it corresponds to period $t = 2$ in the benchmark. The figure shows that GDP after a 2-period lockdown falls roughly twice as much as in the benchmark. The deeper contraction reflects a higher rate of unemployment and a more pronounced fall in investment. Unlike with lockdown size, a longer lockdown drags on the economy by further weakening the financial position of the same set of non-essential firms, which are now undergoing longer periods of capital expenses without revenue. When the lockdown is over, this further erosion of their net worth implies they can recall fewer workers, and as a result the unemployment rate is higher and recovers more slowly after the lockdown.

Fig. 13: Micro-Level Implications: Employment Dynamics, Longer Lockdown



The life-cycle implications of longer lockdowns, illustrated in Figure 13, reveal the channels through which the aggregate economy enters a deeper recession. In this case, a cohort of non-essential entrepreneurs undergoing a two-period lockdown (dashed red line in the left panel) resumes operations about 40% below the scale they would have achieved in the absence of the lockdown and 20% below the level they would have achieved under a 1-period lockdown. Unlike lockdown size, for which the cohort dynamics of the non-essential firms are unchanged and it is all about the number of firms hit by the shock, longer lockdowns deepen the recession by worsening the financial position of a given number of non-essential firms. The general equilibrium forces, i.e., lower factor prices, partially mitigate this effect, improving the prospects of essential firms, particularly the older and less credit-constrained ones. Despite this force, the aggregate impact is larger and lasts longer.

4.4 Unpacking the Ripples: Shocks, Policies, and Mechanisms

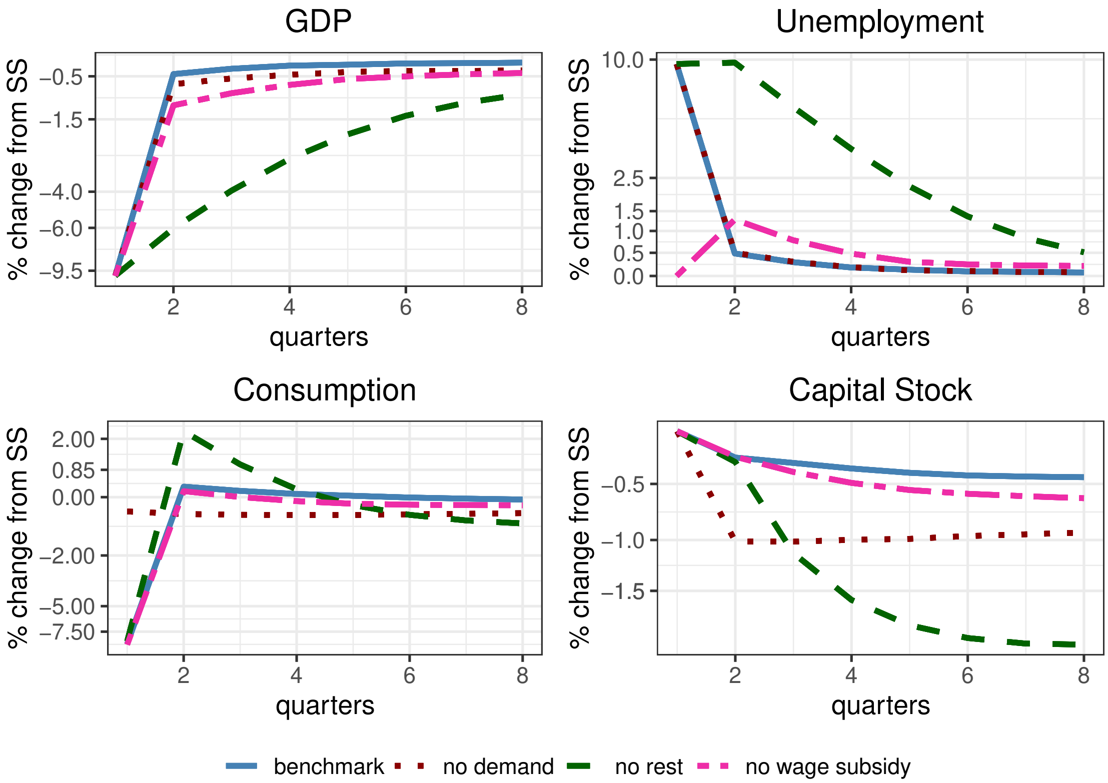
With the aim of capturing the policy and behavioral responses to the Covid-19 pandemic, our baseline characterization of the economy compounds several shocks, policies, and market frictions. What is the role played by these shocks and policies in the swift recovery predicted in the benchmark exercise? In this section we decompose the contribution of the following key ingredients: (i) the demand shock accompanying the lockdown, (ii) the rest unemployment, and (iii) the unemployment insurance transfers to the non-essential workers (or equivalently the wage subsidy to non-essential firms).

Figure 14 illustrates the dynamics of output, unemployment, consumption, and the capital stock in the following counterfactual scenarios following a one-period shutdown of 10% of all firms. Alongside the benchmark, we report the case without the demand (or preference) shock, which we label "No Demand Shock." Preserving the interaction between the lockdown and the demand shock, we also study the role of the rest unemployment by requiring that the unemployed and the returning non-essential businesses go through the regular labor market frictions ("No Rest"). Lastly, in terms of policies, we assess the importance of the unemployment insurance and costless firing of workers by working out an alternate case where non-essential entrepreneurs must pay for their wage bills during the lockdown ("No Wage Subsidy").

As for the no demand shock case, Figure 14 shows a slightly slower recovery in GDP with virtually indistinguishable effects on unemployment. Without a compensating preference shock favoring future consumption, standard consumption smoothing incentives imply a smaller fall in consumption and a stronger decline in investment, responses that can be seen in the bottom panels. As a result, the recovery in GDP weakens. The swift recovery in the labor market remains the same thanks to the rest unemployment and also a larger decline in wages (due to the lower capital stock).

The economy enters the most protracted recession when we do not allow rest unemployment. In this case, despite the temporary nature of the lockdown shock, returning non-essential businesses and unemployed workers must go through the labor market frictions to resume operations. While calibrated to an annual unemployment rate of 4% in the steady state, which implies only moderate frictions, the mass of temporarily laid off workers congests the labor market when the shutdown is lifted, leading to a higher wage in the hiring market and a lengthy rehiring process. The capital stock dynamics in the bottom right panel accompany the persistently high unemployment. Consumption, in turn, overshoots the quarter after the lockdown in reflection of the rise in wages in the hiring market and the fall in investment. In short, incorporating rest unemployment is important for the model to match the quick dissipation of recall unemployment in the US data in Hall and Kudlyak (2020).

Fig. 14: Shocks, Policies, and Mechanisms



Lastly, we discuss the role of debt-financed unemployment insurance and costless firing of workers. As a reminder, non-essential entrepreneurs in our baseline can lay off their workers during the lockdown without any severance payment or firing cost. The government issues new debt to provide full wage replacement to the unemployed. The "no wage subsidy" case in Figure 14 is the case in which non-essential businesses have to pay their wage bills while in lockdown. This keeps the unemployment rate low during the lockdown, since idled workers are still employed, but the unemployment rate goes up by 1 percentage point when the lockdown ends and remains persistently higher than in the benchmark. The GDP also recovers more slowly. The reason for the excess unemployment lies in the interaction between the balance sheet effect exacerbated by the wage bill payment during the lockdown and the capital rental constraint. Unlike in the benchmark, the additional financial wealth that must be devoted to wage payments during the lockdown (and no revenue) period deteriorates the non-essential firms' balance sheet more significantly, leading to a smaller labor demand after the lockdown and to a rise in unemployment.

5 Complementary Impulse: Reallocation Shock

Previous sections considered three plausible channels through which cross-country differences in the recovery from a lockdown may emerge: difference in lockdown size, duration, and policies supporting firms and workers. Here, we consider another channel, which we label as reallocation shock. The idea is that the pandemic renders some goods and services less appealing (e.g. cruises) and others more appealing (e.g. teleconferencing and online shopping) to consumers more *permanently*.

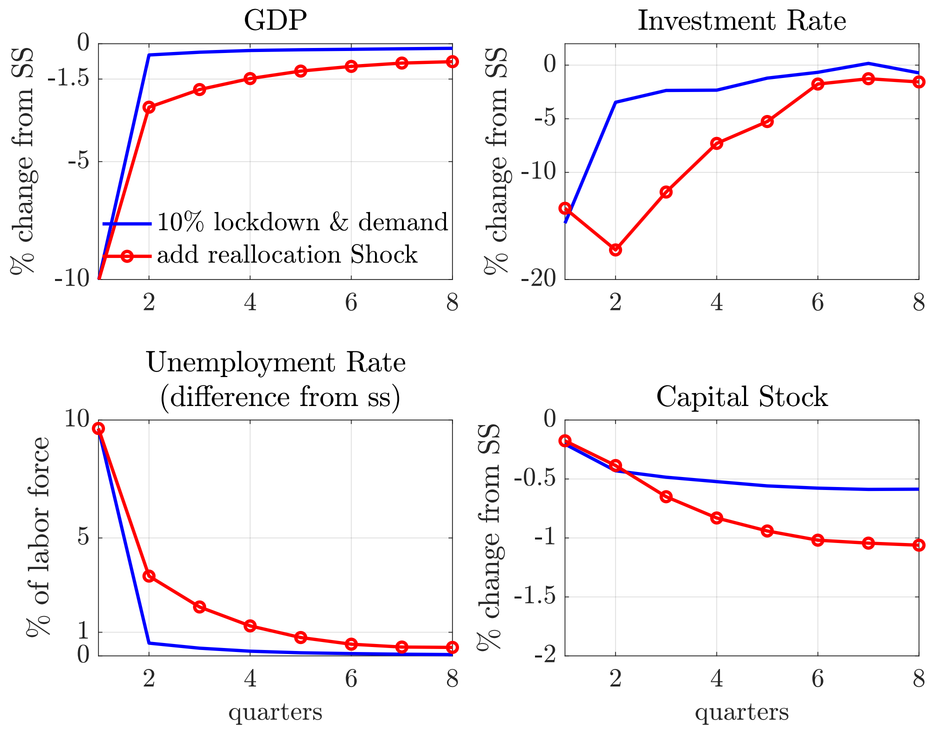
Since in our model all firms produce the same good, a tractable way to mimic this kind of reallocation shock is to temporarily change the persistence parameter ψ governing the evolution of entrepreneurial productivity. We force a larger-than-normal fraction of non-essential entrepreneurs to re-draw their entrepreneurial productivity in period 1 independently of their wealth or entrepreneurial productivity. In other words, we set $1-\psi_{t=1} > 1-\psi$ for period 1 and ψ returning to its normal value thereafter *only for non-essential firms*. In terms of disciplining the choice of $\psi_{t=1}$, we appeal to Bick and Blandin (2020), who provide survey evidence on the rest unemployed's expectations of being recalled by their former employer. Since the persistence parameter ψ has a direct mapping to the fraction of firms that recall resting unemployed workers—see Equation (4), this empirical moment is a useful calibration target. Following this strategy, we obtain $1-\psi_{t=1} = 0.36$ for non-essential firms, which is larger than $1-\psi = 0.03$.

Before going into the results, two comments are in order. First, the reallocation shock has aggregate effects in our model only if there are financial or labor market frictions. In a perfect-credit benchmark with frictionless labor markets, a reshuffling of entrepreneurs, who re-draw idiosyncratic productivity from the same distribution, has no bearing on aggregate quantities. Second, as a result of the same model assumptions, while the reallocation shock lives for only one period, it carries persistent effects. This is because it takes time for the frictional labor market to reallocate workers and for firms that become suddenly productive to build up their internal funds and overcome the financial constraint.

In Figure 15, the solid lines are the benchmark case with the lockdown and the demand shock, and the lines with circles are the result of adding the reallocation shock. By construction, there is no difference between the two cases on impact, because the reallocation shock affects the transition of non-essential entrepreneurs from the lockdown period to the next. Thereafter, however, we observe a notable weakening of the recovery. The unemployment rate is almost 3 percentage points higher than its $t = 2$ value in the benchmark and decreases slowly. Investment, capital stock and output remain below their initial levels for a longer period of time.

As mentioned above, financial and labor market frictions are at the core of the

Fig. 15: Lockdown, Demand, and Reallocation Shocks



weaker recovery. As older businesses exit and are replaced by newcomers, financial frictions impede the growth of those productive entrants who are not yet wealthy enough to overcome credit constraints. Furthermore, as workers leave their former employers and wait to be hired by newcomers, the labor market is congested by the matching friction, so the unemployment rate remains high for many quarters after the combination of shocks disappear. The evidence of a strong rise in business formation in the US in Section 2 provides a measure of empirical support for this reallocation channel.

6 Concluding Remarks

The Covid-19 pandemic triggered a burst of economic research seeking to understand its economic implications. Motivated by this episode, and also noting a scarcity of quantitative frameworks that can help us think about large temporary shocks more broadly, we propose one in this paper. Our model incorporates the main elements that can capture the first-order effects that operate upon impact and during the recovery: imperfect access to credit, costly reallocation of workers, recall unemployment (especially relevant given the transitory nature of the shock), and imperfect consumption insurance.

Disciplining the degree of the market frictions in the economy to the US data, we show that the deep but short-lived shutdown results in a deep but short-lived recession followed by a swift recovery. While the recovery is fast in the aggregate, it carries lasting scarring effects on young non-essential firms, who sustain a significant damage to their balance sheets and grow significantly slower over their entire life-cycle. Because these firms do not account for a large share of the aggregate employment or output, this channel has only a small macroeconomic effect.

More protracted ripple effects are possible, as shown by alternative specifications of the shocks and government policies. Longer and bigger lockdowns generate persistently higher unemployment rates. Without government policies supporting the firms and workers, the worsening balance sheets of non-essential firms can have significant negative effects in the aggregate, as is the case in the model under a requirement that these businesses pay their wage bills in lockdown. More important, the recovery is slower if a reallocation shock interacts with the lockdown, which is consistent with the latest evidence from the US. These alternative specifications show that our model can explain the wide heterogeneity in aggregate outcomes among the OECD countries in terms of the depth of the recessions and the speed of the recoveries.

In conclusion, our laboratory economy has sufficient richness and speaks to the main channels driving the downturn and the subsequent recovery from large transitory shocks. As time elapses and a better identification of shocks and policies is permitted by the data, our model can be a useful framework for interpreting the shock transmission channels and analyzing policy counterfactuals.

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A GDP in OECD countries

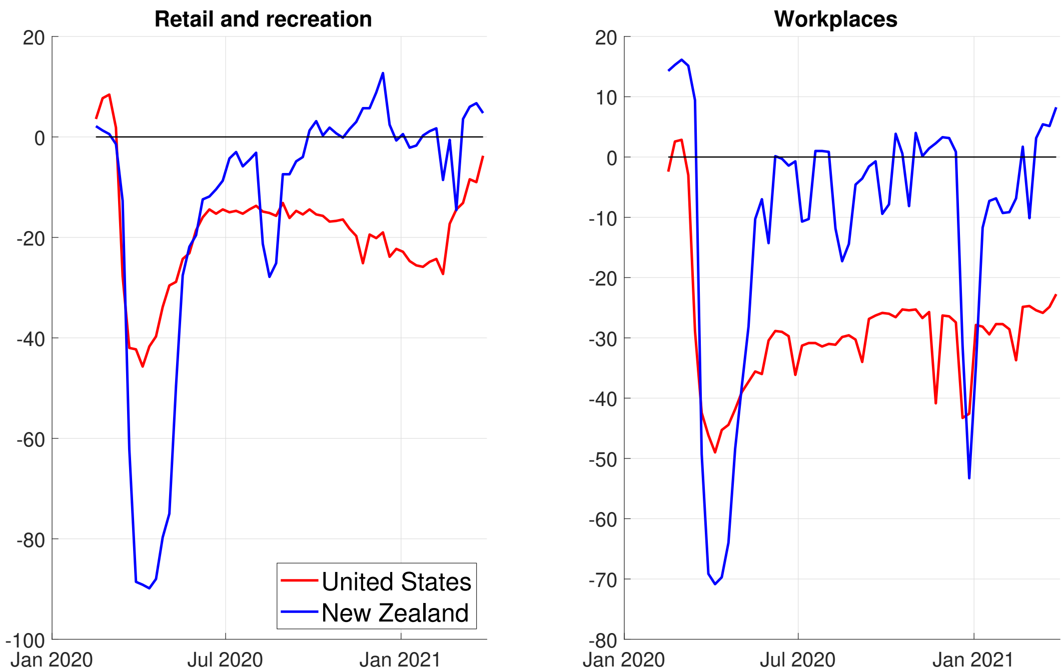
Table 2: GDP in OECD Countries

	Q2-2020	Q3-2020	Q4-2020
Spain	0.78	0.91	0.91
United Kingdom	0.79	0.91	0.92
France	0.81	0.96	0.95
Italy	0.82	0.95	0.93
Mexico	0.82	0.93	0.96
Portugal	0.83	0.94	0.94
Colombia	0.83	0.91	0.96
Belgium	0.85	0.95	0.95
Hungary	0.85	0.95	0.96
Slovenia	0.86	0.96	0.95
Iceland	0.86	0.90	0.94
Austria	0.87	0.97	0.94
Canada	0.87	0.95	0.97
Greece	0.87	0.90	0.92
Slovak Republic	0.87	0.97	0.97
Czech Republic	0.88	0.95	0.95
Germany	0.88	0.96	0.96
Chile	0.89	0.94	1.00
Turkey	0.89	1.03	1.05
Israel	0.90	0.98	0.99
United States	0.90	0.97	0.98
New Zealand	0.90	1.03	1.01
Netherlands	0.90	0.97	0.97
Poland	0.91	0.98	0.97
Latvia	0.91	0.97	0.98
Switzerland	0.91	0.98	0.98
Japan	0.91	0.96	0.99
Luxembourg	0.91	1.00	1.01
Denmark	0.92	0.97	0.97
Sweden	0.92	0.98	0.98
Australia	0.93	0.96	0.99
Lithuania	0.93	0.99	0.99
Estonia	0.94	0.96	0.98
Ireland	0.94	1.05	1.00
Norway	0.94	0.98	0.99
Finland	0.95	0.98	0.98
Korea	0.96	0.98	0.99

Source: OECD statistics (downloaded March 31st, 2021.).

B Mobility in New Zealand and the United States

Fig. 16: Mobility in the United States and New Zealand

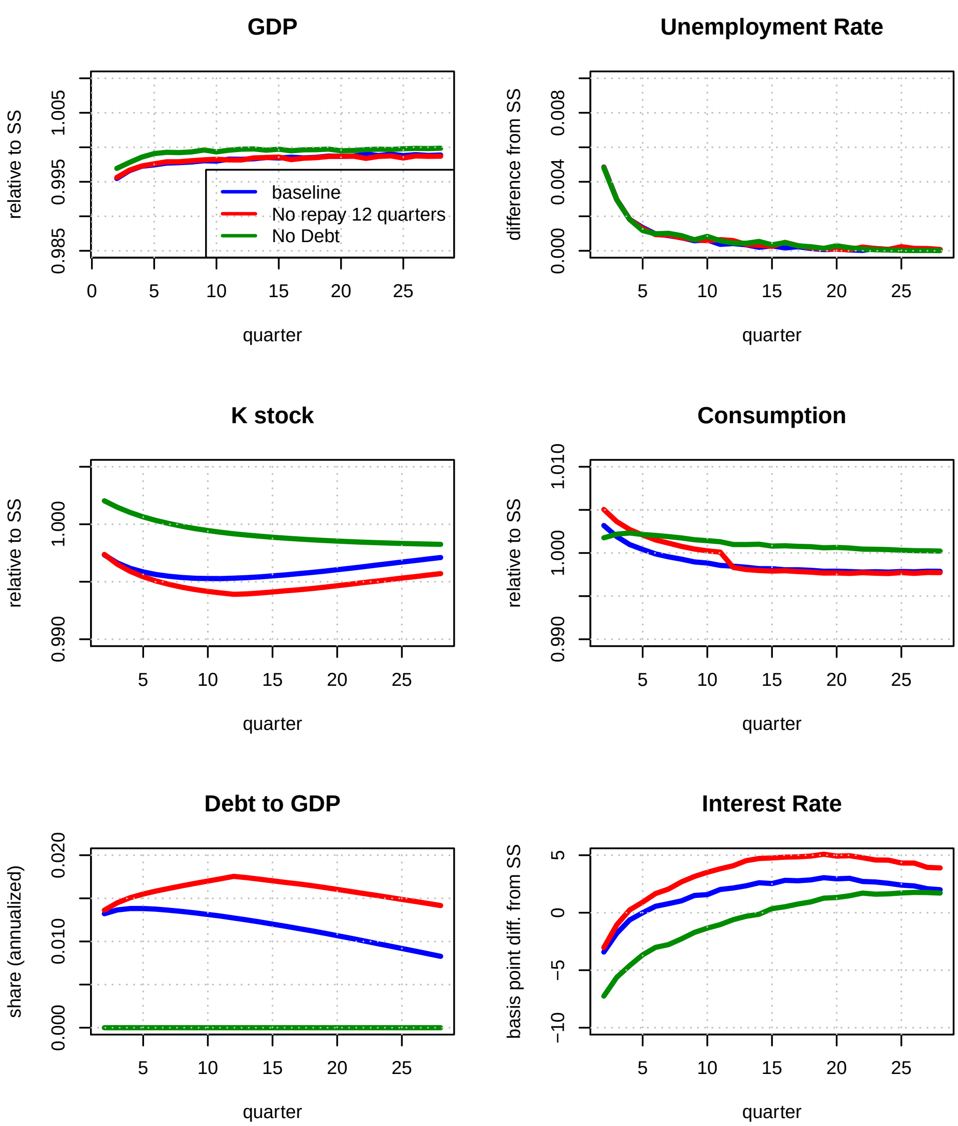


Source: Google Mobility Reports (downloaded April 5th, 2021.).

C Debt Repayment Strategies

The baseline exercise assumes the financing of the unemployment insurance benefits through debt issuance and a constant lump sum tax that is chosen so that the debt is fully repaid in T periods. To understand the sensitivity of the model dynamics to this assumption, we here consider the following two alternatives alongside the benchmark. First, we consider a case where lump-sum taxes are left unchanged for 12 quarters and then increased so that the debt is brought down to zero in 12 years. This differs from the benchmark in that the lump sum tax does not increase initially, instead of going up instantaneously. In both cases, the debt is repaid over 12 years. At the other extreme, we consider a case where the lump sum tax is adjusted every period to balance the budget. In both cases we adopt the baseline 10% lockdown shock and preserve the same calibrated value of the demand shock. Figure 17 illustrates the dynamics of the relevant aggregate variables in the three policy counterfactuals.

Fig. 17: Debt Repayment Strategies



The first key implication from Figure 17 is the insensitivity of the unemployment rate to the alternative financing schemes. As explained in the text, unemployment dynamics are mostly accounted for by young non-essential entrepreneurs. For them, the adjustments in the lump sum taxes do not carry enough weight on the balance sheet to alter the disruption caused by the lockdown. Therefore, their recall capabilities in the aftermath of the shock are roughly unchanged.

The second implication from Figure 17 is that consumption and investment are significantly affected by the time profile of taxes and debt. In the cases where net transfers to workers are maximized, as in the benchmark and even more so in the long repayment scenarios ("No repay 12 quarters"), investment falls by more and recovers more slowly. Conversely, when lump sum taxes are adjusted upfront, consumption falls the most and the capital stock booms after the shock (due to the boom in savings implied by the preference shock). Alongside such adjustments in quantities is a larger reduction in the interest rate under balance budget than under smooth repayment.

The cause for the heterogeneous response of consumption and investment lies in the non-Ricardian nature of many workers in the economy, whose consumption is more sensitive to temporary changes in income and the profile of taxes. More specifically, as is typically the case in models with heterogeneous agents and incomplete markets, the interest rate is lower than the rate of time preference. Workers are in the lowest income state, so their wealth converges to zero in finite time. As a results, workers with low wealth consume a large fraction of a transfer that is financed with taxes that are levied far enough into the future.

Under the benchmark and the long repayment cases, income is transferred towards workers with elastic consumption, while the financing of government debt crowds out constrained entrepreneurs from increasing capital demand. On the other hand, when the government balances the budget every period, workers' income declines and so does consumption. Despite the full wage repayment offered by the government to the unemployed, income flows back to the government in the form of higher taxes. Unconstrained entrepreneurs, in this case, increase capital demand stimulated by a lower cost of capital (see the bottom right panel).