The Economic Ripple Effects of a Temporary Shutdown*

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Abstract

We analyze the economic ripple effects of a temporary shutdown, such as those experienced during the Covid-19 pandemic. Using a model incorporating financial and labor market frictions, we explore how varying magnitudes and durations of shutdowns impact output, employment, and firm dynamics. We find that the effects are not persistent if workers on temporary layoffs can be recalled without frictions and if government policies effectively protect the balance sheets of financially constrained firms. With imperfect insurance, young firms are disproportionately affected. Additionally, we find that recovery is more prolonged if shutdowns are accompanied by other shocks that cause additional reallocation within or across industries. Although motivated by the Covid-19 pandemic, the model can be applied to other large, temporary shocks such as wars, cyber-attacks/outages, and natural disasters.

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1 Introduction

This paper examines the effects of temporarily shutting down parts of the economy. The primary motivation is the temporary lockdowns implemented by many countries in response to the Covid-19 pandemic, which led to record-breaking GDP contractions in most countries (Neumeyer et al., 2020). However, the mechanisms proposed in our model extend beyond pandemic-induced shutdowns. They are also relevant to other large, temporary shocks such as wars, natural or nuclear disasters, cyber-attacks/outages, or any events that severely disrupt parts of the economy for a limited time. Examples include the temporary shutdown of the region around the Fukushima Daiichi plant following the 2011 nuclear accident, the disruptions to the Israeli economy caused by war after October 7, 2023, or the July 2024 Crowdstrike outage.[1]

Our goal is to address the following questions: How long does it take for the economy to return to normal following such a shock? Do credit and labor market frictions significantly slow the recovery? Which firms are most affected, and which ones recover more quickly? How do macroeconomic and firm dynamics change if the temporary shutdown shock causes lasting changes in certain industries? What role do policies play in the speed of recovery?

Our central hypothesis is that the ripple effects of a shutdown depend on its duration, breadth, and policies supporting labor markets and firms' balance sheets. We examine this hypothesis using a model economy with entrepreneurial production, subject to credit constraints and labor market frictions, building on the model developed by Buera et al. (2015). We make two new assumptions motivated by the temporary shutdowns. First, we assume that immediately after the economy reopens, firms can directly rehire their furloughed workers without undergoing the frictional labor matching process. If the match is not restored upon reopening, the furloughed workers will seek other jobs, and firms will fill vacancies through the standard frictional hiring process. Second, we assume that firms adapt to the shutdown and the accompanying broader changes with varying degrees of effectiveness. We model this as a reallocation shock, which represents a redistribution of entrepreneurial productivity across individuals.

A key element in our analysis of recovery from a shutdown shock is the impact of the losses sustained by firms during the shutdown period. Prolonged losses diminish firms' net worth and collateral. Credit-constrained firms are subsequently unable to return to their pre-shutdown activity levels and may even be forced to close permanently. As a result, their workers enter the open labor market, where it takes time to be matched with new jobs, thereby slowing the recovery process. By contrast, in an economy with

[1] According to Wikipedia, Crowdstrike's software glitch on July 19, 2024 caused the shutdown of 8.5 million computers for a day. It caused an estimated damage of USD 10 billion, approximately 10 percent of the US daily GDP.

frictionless credit and labor markets, the return to the previous equilibrium occurs immediately after the shutdown ends.

In our benchmark calibration, recovery is rapid for three key reasons. First, in a highly developed economy with imperfect but well-functioning financial markets like the US, the vast majority of employment (83 percent) is in financially unconstrained firms, which can rebound quickly from a shutdown. Second, firms can recall their furloughed workers without undergoing the frictional labor matching process, facilitating a swift return to normal operations. Third, the balance sheet support policy covers firms' wage bills (though not their fixed capital costs) during the shutdown, helping to mitigate the negative impact on firms' net worth. In contrast, a policy requiring firms to cover the wage bill at the pre-shutdown employment level[2] inflicts greater losses on firms, tightens credit constraints, and leads to a more persistent recession.

However, for young firms, the ripple effects of the shutdown are larger and more persistent. In the stationary equilibrium, 90 percent of young firms (those five years old or younger) are financially constrained, and these firms account for 55 percent of employment among all young firms. The shutdown losses either force these firms to exit the market, or it takes several years for those that survive to recover to their pre-shutdown trajectory.

The shock underlying the temporary shutdown may lead to lasting changes in preferences or accelerate technological change, to which firms and entrepreneurs adapt with varying degrees of effectiveness. For example, the pandemic shutdown shifted preferences towards remote work and online shopping, and some firms adapted better to these changes. Bagga et al. (2024) and Lee et al. (2024) attribute unique features of the labor market during the Covid-19 recession to a permanent shift in worker preferences towards remote work and work-life balance. Similarly, the 2011 Fukushima nuclear accident shifted social preferences away from atomic energy (Kim et al., 2013), prompting firms to alter their energy mix. The 2023-4 Gaza war may also influence Israelis' preferences regarding living in border areas and affect practices in the construction and agriculture industries, which heavily rely on foreign guest workers (Bank of Israel, 2024).

We model these changes as a one-time reset of entrepreneurial productivity for a segment of the population, resulting in a reallocation of entrepreneurial productivity across individuals. This reallocation leads to some workers becoming entrepreneurs, some entrepreneurs exiting the market, and others adjusting their scale of operation. This process generates additional economic disruption and create its own recessionary impact, which delays the recovery from the temporary shutdown. Capital becomes misallocated when new and existing firms are unable to produce at their efficient scale due

[2] A policy implemented by Argentina's government in 2020-21.

to credit constraints. Similarly, labor becomes misallocated because the frictional labor matching process slows down the necessary reallocation of workers and adjustments in optimal firm size following the reshuffling of entrepreneurial productivity. Over time, these misallocations are gradually corrected as credit-constrained entrepreneurs save to overcome their credit constraints, and the frictional labor market eventually reallocates workers to growing firms. In summary, the one-time reallocation of entrepreneurial productivity results in a persistent negative effect on aggregate productivity and output, which gradually diminishes as the economy returns to its stationary equilibrium.

Our benchmark institutional setup assumes that firms can lay off workers without incurring costs during the shutdown. Unemployed workers receive unemployment insurance benefits with a 100 percent replacement rate (Ganong et al., 2020), and this unemployment insurance is financed with long-term debt. This setup reflects the policy implemented by the US government through the Coronavirus Aid, Relief, and Economic Security (CARES) Act. Other countries, such as Australia, New Zealand, the UK, and the EU, supported affected firms and workers during the pandemic through transfers to firms to cover wage bills during the shutdown, encouraging firms to retain their workers.[3] In our model with recall unemployment, supporting firms' balance sheets by covering their labor costs or providing income insurance to furloughed workers is equivalent. The only difference lies in the labeling of the workers who are not working and whose wages (or benefits) are paid by the government. This type of policy has also been implemented in other instances where the government imposed a temporary shutdown. For example, this was the case in Fukushima following the Great Eastern Japanese Earthquake, and in Israel after the onset of the October 2023 Gaza war.

1.1 Motivating Evidence and Interpretation

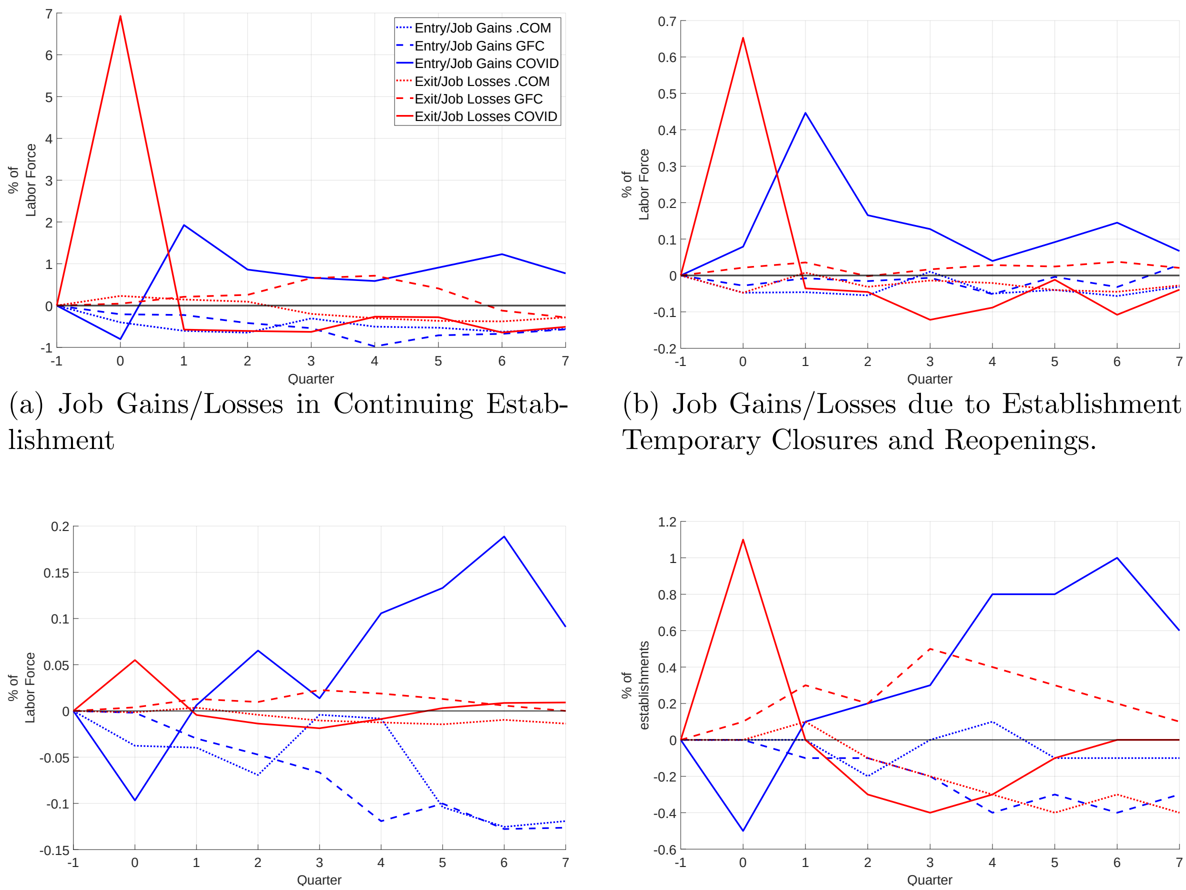
This paper presents several mechanisms for the ripple effects of a temporary shutdown. The temporary nature of the shock, along with the option to recall or re-establish the labor matches that existed prior to the shutdown, suggests that the recovery should be swift. However, three factors may delay this recovery. First, the reopening of the economy after the shutdown may be gradual, mechanically extending the duration of the recession. Second, firms may not be able to rehire all their previous employees due to tightened financial constraints resulting from losses and deteriorated balance sheets during the shutdown. Finally, a reallocation of entrepreneurial productivity further disrupts the economy, necessitating additional reallocation of capital and labor. This process is hindered by financial and labor market frictions. As a result, while contractions are immediate, recovery requires time. This section presents supporting

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

evidence that these mechanisms are at play.

1.1.1 Employment Dynamics

Fig. 1: Establishment Employment Dynamics



(a) Job Gains/Losses in Continuing Establishment

(b) Job Gains/Losses due to Establishment Temporary Closures and Reopenings.

(c) Job Gains/Losses due to Entry/Exit

(d) Establishment Entry and Exit Rates

Note: $t = 0$ corresponds to NBER Business cycle dates Q2-2001 for .COM, Q1-2008 for GFC, and Q2-2020 for Covid. (The NBER date is March, which we interpret as Q2.) We report differences from the quarter before the recession date. Panel (1a) reports job gains and losses for continuing establishments. Panel (1b) for establishments with temporary closures/openings, which are computed as the difference between total job gains/losses of opening/closing establishments net of births and deaths (entry-exit). Panel (1c) reports the employment gains and losses from the entry and exit of establishments as a share of the labor force. Panel (1d) reports establishment births and deaths as a share of total establishments.

Source: Business Employment Dynamics supplementary tables 1, 9, and 10, Bureau of Labor Statistics; downloaded on September 9, 2024. Civilian Labor Force Level from the BLS, retrieved from FRED (CLF16OV).

Figure 1 presents evidence on employment dynamics across establishments for the three recessions within the Business Employment Dynamics dataset: the Covid-19 recession (Q2-2020), the Global Financial Crisis (GFC) recession (Q1-2008), and the .COM recession (Q2-2001). The first three panels illustrate job gains and losses for different categories of establishments: continuing establishments (panel a), establishments that temporarily closed and then reopened (panel b), and job gains/losses from establishment births and deaths (panel c). All figures report differences from the quarter preceding the recession date.

The data show that the Covid-19 recession was distinctive in that job losses were exceptionally large across all establishments but lasted for only one quarter. This suggests that both direct and indirect job losses induced by the shutdown were immediate. Subsequent job gains following the shutdown support the concept of "rest" unemployment or recall and highlight the frictions that prevent an immediate full recovery. We observe sharp employment gains in continuing establishments (panel 1a) and temporarily closed establishments (panel 1b) in Q3-2020, a pattern not seen in the other recessions. At the same time, the employment gains in Q3-2020 did not fully offset the job losses experienced in Q2-2020. In our model, this can be attributed to either the gradual lifting of the shutdown or firms being unable to rehire all their previous workers due to financial constraints.[4]

The two bottom panels of figure 1 support the hypothesis of a reallocation shock.[5] Panel 1d shows that the Covid-19 recession was an outlier in terms of establishment entry and exit behaviors. Exit rates of establishments spiked during the shutdown and subsequently fell below pre-shutdown levels. Similarly, there was a notable dip in entry rates during the shutdown, followed by a persistent excess in the entry of new establishments after the shutdown. Early business application data from the Business Formation Statistics (BFS), reported in figure 19 in Appendix A.1, indicates a spike in business applications during the shutdown months. Panel 1c shows that the quarterly job destruction due to establishment exits was negligible (0.05 percent of the labor force). The employment gains attributable to new entrants, however, are larger because, after the initial quarter, new entrants are classified as continuing establishments. As shown in panel 1a, these continuing establishments exhibit unusually high and sustained employment growth for at least two years after the shutdown. The other two recessions do not exhibit this persistent excess job creation.

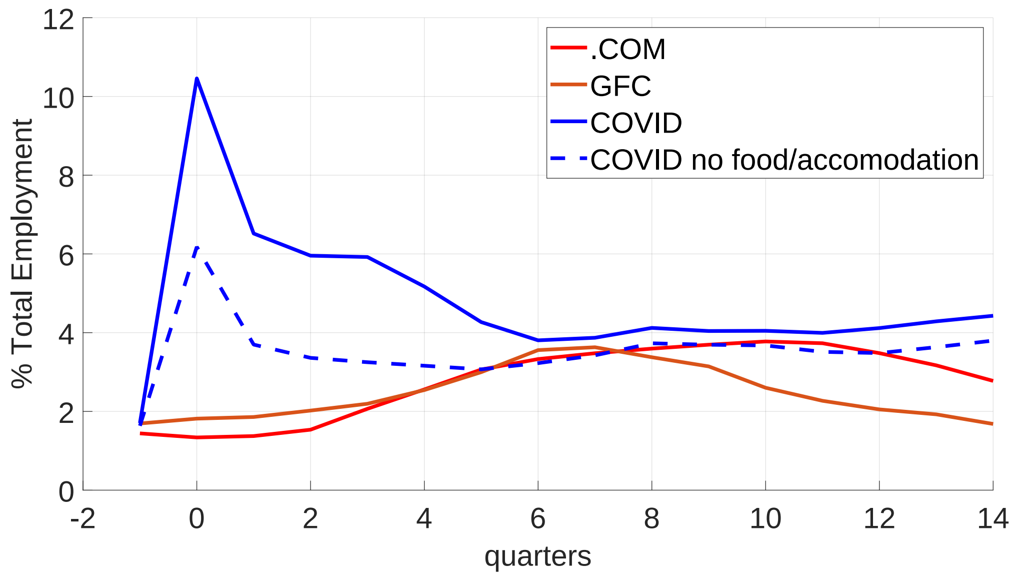
Figure 2 provides additional evidence that the Covid-19 recession differed from the other two recessions in terms of greater reallocation across industries. We compute a reallocation index,

$$\mathcal{R}_t = \sum_{i \in \mathcal{S}_t} \left| \ell_{it} - \bar{\ell}_{it} \right|,$$

[4]We did not model the possibility of workers choosing not to return to their jobs.

[5]Anecdotal evidence on reallocation is available in a Wall Street Journal article (Guilford and Scott, 2020).

Fig. 2: Sectoral Reallocation



Note: Business cycle dates are in figure 1. Reallocation index$_t$ = $\sum_{i \in \mathcal{S}_t} \left| \ell_{it} - \bar{\ell}_{it} \right|$, where ℓ_{it} is the employment share of 3-digit sector i at time t, and $\bar{\ell}_{it}$ is the extrapolation of the linear trend over the five years preceding quarter 0. The dashed blue line excludes food and accommodation services and rescales the sectors so that the sum of employment shares is 1.

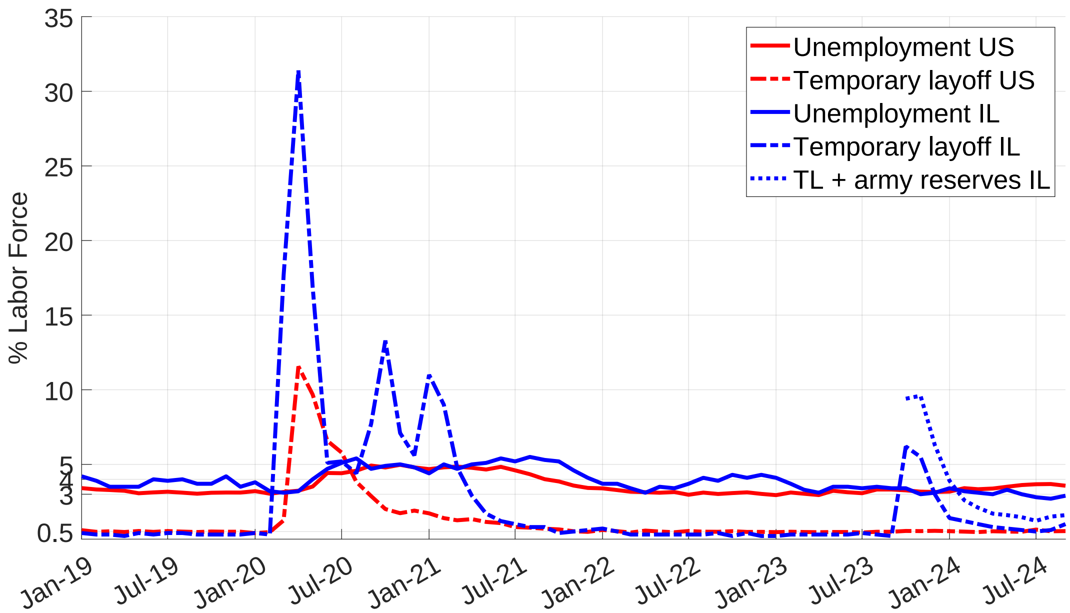
Source: Table B-1a. Employees on nonfarm payrolls by industry sector and selected industry detail, seasonally adjusted. Current Employment Statistics - CES (National), Bureau of Labor Statistics.

where ℓ_{it} is the employment share of 3-digit sector i at time t, and $\bar{\ell}_{it}$ is the extrapolation of the linear trend over the five years preceding quarter 0. Figure 2 shows a spike in reallocation in Q2-2020, which is both macroeconomically significant and persistent. More than three years after the shutdown, we still observe significant reallocation of labor relative to the pre-pandemic trend. Initially, the spike in reallocation was primarily driven by deviations in employment shares in industries that were most acutely affected by the shutdown, such as food and accommodations. The initial reallocation out of these industries accounted for as much as 4 percent of total employment in Q2-2020.[6] Although most of this effect dissipated six quarters after the shutdown, the reallocation index remains elevated, especially when compared with the other two recessions.

Figure 3 supports the notion that temporary layoffs are the primary driver of unemployment during recessions caused by temporary shutdowns, not only during the pandemic (in the US and Israel) but also during a local war (in Israel). Following Hall

[6]See the difference between the blue solid and dashed lines. The sectors that expanded include professional and business services, financial activities, trade, transportation and utilities (trucks), building, gas stations, health services, information, manufacturing, and chemicals.

Fig. 3: Unemployment



Note: US unemployment corresponds to Hall and Kudlyak (2022a)'s "unemployed without jobs" computed as the difference between the unemployment rate (UNRATE in FRED) and temporary layoffs (Job Losers on Layoff (LNS13023653) as a share of the Civilian Labor Force Level (CLF16OV)). Israeli temporary layoffs correspond to employed persons absent from work all week for economic reasons and army reserves to persons absent from work due to reserve army service. Israel's official unemployment corresponds to Hall and Kudlyak (2022a)'s unemployed without jobs.

Source: US unemployment data is from the U.S. Bureau of Labor Statistics, retrieved from FRED; September 9, 2024. Israeli data is from Central Bureau of Statistics (2024). We combine data in the Labor Force Monthly Report (table 3) with press releases on army reserves (not seasonally adjusted).

and Kudlyak (2022a), we distinguish temporary layoffs from unemployment. Temporary layoffs correspond to the concept of "rest" unemployment in Alvarez and Shimer (2011) and "unemployed with jobs" in Hall and Kudlyak (2022a). Unemployment, on the other hand, corresponds to Hall and Kudlyak (2022a)'s "unemployed without jobs" and follows the Israeli definition of unemployment, which excludes temporary layoffs. The Israeli data is particularly interesting because it includes three rounds of shutdowns during the pandemic, as well as disruptions in economic activity due to the conflict ignited by Hamas's attack on October 7, 2023. The war generated a wave of temporary layoffs due to economic reasons similar in nature to the pandemic waves, as well as another wave of worker absences due to army reserve duty.[7]

[7]Israel's temporary unemployment figures exclude individuals who were temporarily absent from work to care for children, as well as those in areas adjacent to Gaza and the northern border who were forced to leave their workplaces. In October, out of a labor force of approximately 4.5 million, around 144,000 workers in these areas were evacuated from their jobs; about 310,000 parents of young children were absent due to the

Steady-state total unemployment and temporary layoffs in both the US and Israel are approximately 3-4 percent and 0.5 percent of the labor force, respectively. The Covid-19 pandemic shutdown led to a spike in temporary layoffs, reaching 12 percent of the labor force in April 2020 in the US. In Israel, temporary layoffs surged to 31 percent of the labor force during the first wave in April 2020, and to 13 percent and 11 percent during the second and third waves in October 2020 and January 2021, respectively. Temporary layoffs returned to their steady-state level of 0.5 percent of the labor force in the second half of 2021 in both countries. Following the initial shutdown, unemployment rose to 5 percent in both economies, indicating that not all furloughed workers were reemployed. It took a year and a half after the first shutdown for unemployment to return to its pre-pandemic level. In Israel, unemployment remained elevated for a longer period, possibly due to the ripple effects of the additional shutdowns. After Hamas's attack in October 2023, temporary layoffs (including army reservists) reached almost 10 percent of the labor force in November and gradually declined without impacting permanent unemployment. The rise and fall in temporary unemployment associated with Israel's 2023-4 war suggest that the same mechanism that shaped the pandemic employment recovery applies to the temporary disruption of economic activity due to the war.[8]

1.1.2 Output Responses

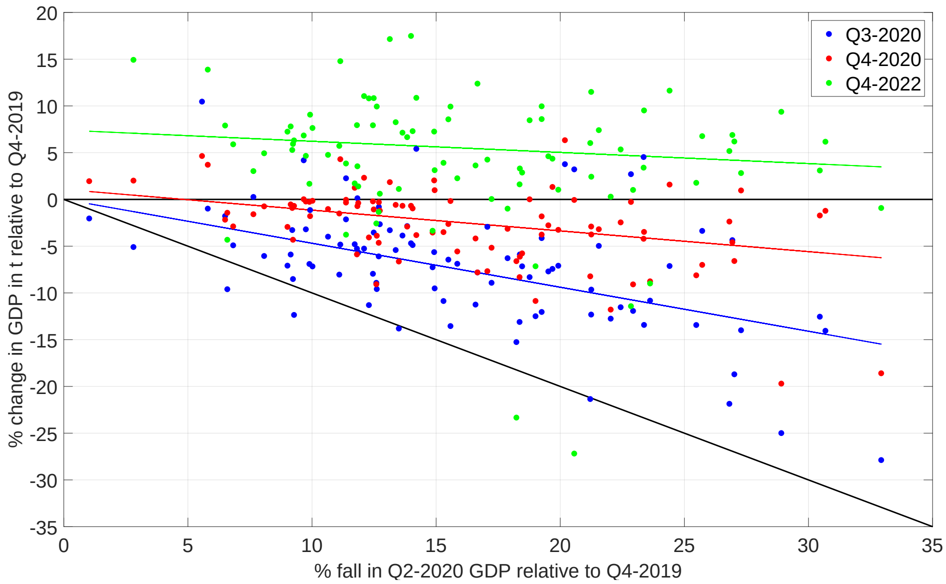
We now document the relationship between the magnitude of the Covid-19 shutdown in terms of lost output during Q2-2020 and the speed of recovery across countries.

Figure 4 illustrates the depth and persistence of the Covid-19 recession for 92 countries. The horizontal axis represents the depth of the recession, measured by the percentage drop in GDP from Q4-2019 to Q2-2020. The vertical axis shows the deviation of GDP in Q3-2020 (blue), Q4-2020 (red), and Q4-2022 (green) from Q4-2019 GDP, also in percentage terms. (Points with a positive value on the vertical axis indicate GDP above the Q4-2019 value.) This figure provides insights into the speed of recovery as a function of the magnitude of the initial impact of the shutdown. For example, the blue dots represent each country's output loss in Q2-2020 shown on the horizontal axis and the output gap in Q3-2020 on the vertical axis. Points closer to the 45-degree line indicate less economic recovery, while points nearer to the horizontal line at zero suggest a fuller recovery. The blue regression line reflects the average recovery in the quarter immediately following the deepest shutdown in Q2-2020. The blue line can be approximately expressed as $\hat{y}^i_{t_0+1} = -\frac{1}{2}\hat{y}^i_{t_0}$, where $\hat{y}^i_{t_0}$ is the output loss of country i in

disruption in the education system; and approximately 135,000 workers were absent due to damage to their workplaces. By November, the number of absent workers had decreased from about 900,000 to 500,000. For more information, see Bank of Israel (2024).

[8] See figure 23 in the appendix for Israel's National Accounts.

Fig. 4: GDP_t Relative to Q4-2019



Source: International Financial Statistics (IMF). The sample covers 92 economies (91 in Q4-2022), excluding Georgia, Mauritius, Macao and Cabo Verde due to errors or outliers.

quarter t_0 =Q2-2020, implying that the output loss in Q3-2020 was, on average, half of the Q2-2020 loss.

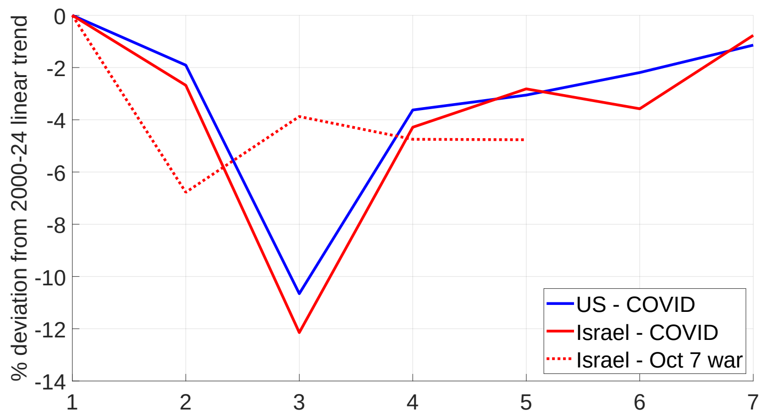
The red line shows that by the end of 2020, on average, only one-fifth of the Q2-2020 GDP loss remained. By the end of 2022, almost all countries in the sample had fully recovered from the shutdown recession. Their output gaps were no longer correlated with their Q2-2020 losses and, on average, were 6 percent above the Q4-2019 GDP level, consistent with an underlying 2 percent annual growth. Table 4 in Appendix A.2 reports the coefficients of the three regression lines in figure 4.

The patterns observed across countries may reflect differences in the breadth and duration of the shutdown, policies supporting labor markets and firms' balance sheet, and the extent of reallocation shocks.

We now zoom in on the Covid-19 recession in Israel and the United States and also consider the recession induced by the 2023-4 Gaza war in Israel. Figure 5 shows the percent deviation of GDP from the 2000-2024 linear trend, normalized to 0 in Q4-2019 (Covid-19) and Q3-2023 (Gaza War).[9] Israel's Covid-19 recession was more severe due to the more extensive shutdown. Additionally, a second shutdown led to a further dip in Q1-2021. The recession caused by the 2023-2024 Gaza war appears to be more persistent; by Q2-2024, output remained 1.4 percent below its prewar level, which is not surprising given the prolonged nature of the shock. As of June 2024, approximately

[9] Table 6 in Appendix A.4 reports the raw data.

Fig. 5: GDP in Israel and the United States



Note: Percent deviation from the 2000-2024 linear trend, normalized to 0 in Q4-2019 (Covid-19) and Q3-2023 (Gaza War). Israel's annual growth rate over this period was 3.7 percent, while the US's was 1.9 percent.

Source: Seasonally adjusted local currency GDP at constant prices from FRED (GDPC1 and NAEXKP01ILQ652S).

1 percent of the Israeli labor force was internally displaced, and another 1 percent was on army reserve duty.

We conclude this section with a brief discussion of the temporary evacuation from the Fukushima prefecture following the 2011 Fukushima Daiichi nuclear disaster. In March 2011, the Great Eastern Japanese Earthquake and Tsunami resulted in a nuclear accident at the Fukushima-Daiichi nuclear power plant. Consequently, approximately 165,000 people, or 8 percent of the prefecture's population, were evacuated. Table 1 illustrates a V-shaped decline and recovery of output and employment due to the temporary shutdown.[10] The policy response package, in this case, included support for firms' balance sheets and investments in environmental and infrastructure restoration, which involved activities such as removing radioactive topsoil, cleaning buildings, and reconstructing damaged areas.

1.1.3 Concurrent Shocks

Extensive temporary shutdowns are likely accompanied by other shocks that can significantly impact macroeconomic dynamics.

In the Covid-19 recession, consumption dynamics provide insights into the nature of concurrent shocks. Interpreting the Covid-19 shock as a large temporary decline in total factor productivity (TFP), the neoclassical growth model would predict a sharp fall in investment, reflecting households' desire to smooth consumption. However, in

[10] See, for example, Zhang et al. (2019), Carvalho et al. (2020), and Ranghieri and Ishiwatari (2014).

Table 1: Economic Activity and the Fukushima-Daiichi nuclear disaster

	$\frac{\text{GDP Fukushima}}{\text{GDP Japan}}$	Employment Fukushima
2010	1	1
2011	0.91	0.95
2012	0.98	0.99

Note: All values are normalized by the respective 2010 values.

Source: Economic and Social Research Institute, Cabinet Office of Japan (2020)

the data, aggregate consumption declined together with the GDP. The drop in consumption can be explained by the unique characteristics of the pandemic-induced recession, which disproportionately impacted contact-intensive consumption activities.[11] This observation implies the need to introduce a complementary force that counteracts consumption smoothing in order to accurately capture the dynamics of aggregate consumption. Therefore, we introduce a demand shock that reduces the marginal utility of consumption during the shutdown. Our calibration section elaborates on how we discipline this demand shock.

A second complementary shock for the Covid-19 recession is the reallocation shock discussed in the previous sections.

In the case of the Gaza war in Israel, investment fell to 25 percent below trend, government consumption increased to 15 percent above trend, and private consumption initially fell but quickly returned to trend (figure 23 in Appendix A.4). Plausible concurrent shocks include a temporary increase in military expenditures and a reduction in the labor supply of migrant workers in the construction and agriculture industries. In the case of the Fukushima nuclear disaster, a plausible concurrent shock is the depreciation of environmental and physical capital.

1.2 Literature

Even though there is a large body of work on the lockdown-induced recession during the 2020 pandemic, few papers focus on the lingering effects on the economic recovery, the policies that could expedite the recovery, or firm dynamics. The model of entrepreneurial production with labor and financial market frictions proposed in Buera et al. (2015) is a natural setup for this endeavor. We enrich their model by allowing for "rest" unemployment and recall in the period immediately following the shutdown

[11] See, for example, Aum et al. (2021b), Eichenbaum et al. (2021) and Hevia et al. (2022) for integrated epidemiological and macroeconomic models. Leibovici et al. (2020), Aum et al. (2021a), and Chetty et al. (2023) document economic activities shifting away from contact-intensive industries during the pandemic.

and by adding a reallocation shock.

Temporary layoffs play an essential role in the post-shutdown dynamics in our model. The role of the "unemployed with jobs" in the rapid recovery from the pandemic shutdown has been stressed by Hall and Kudlyak (2022a), Hall and Kudlyak (2022b), and Forsythe et al. (2022) for the US. The evidence in section 1.1 for Israel and the US supports their insight. We incorporate temporary layoffs into our model using a straightforward Diamond-Mortensen-Pissarides (DMP) framework, drawing on Alvarez and Shimer (2011)'s concept of "rest" unemployment and recall. We assume that the recall option is available only during the period immediately following the shutdown. The exercise of the recall option is influenced by the firm's balance sheet and its productivity after the shutdown-related reallocation shock to the entrepreneurial productivity. Gregory et al. (2020) explore the persistence of recessions in a more complex DMP model that accounts for heterogeneity in workers and match quality types. However, their study does not consider the shutdown-related balance sheet effects or the entrepreneurial productivity shocks that are included in our model. In their setup, "recall" unemployment is an option that is costly to maintain and exercise. For their benchmark calibration, the pandemic is modeled as a temporary drop in productivity in a subset of industries where "fickle" workers are overrepresented. They predict an L-shaped recession because the value of many of these matches does not justify the cost of the recall option. Consequently, it takes a significant amount of time for these workers to find stable employment. Bick and Blandin (2020), Cajner et al. (2020), and Lee et al. (2021) offer additional evidence on the importance of rest unemployment and recall in 2020.

Our analysis indicates that balance sheet support policies aimed at reducing firms' losses during a shutdown can significantly expedite economic recovery. There are two ways of implementing these policies. The US approach allows firms to furlough workers while providing generous unemployment insurance. Alternatively, some other countries, such as those in Europe, New Zealand, and Israel, subsidize labor hoarding by paying the wages of firms that have shut down to maintain employment matches. In our model, these two approaches are equivalent. When workers are laid off, the recall option helps preserve employment matches, and the government covers the unemployment benefits for workers who are temporarily laid off. Guerrieri et al. (2022) analyzes firms' decisions to either hoard labor or exit when faced with a temporary shutdown. In their model, firms choose to hoard labor and remain in business if the losses incurred during the shutdown are smaller than the firms' continuation value and they have sufficient liquidity to cover those losses. This condition is satisfied for most firms in our benchmark calibration, where firms do not pay wages during the shutdown. Their setup does not account for the role of temporary layoffs and the option to recall furloughed workers. Giupponi et al. (2022) examine the pros and cons of each approach in the absence of recalls, highlighting the benefit of labor hoarding for preserving labor matches and the advantage of furloughs in facilitating reallocation. Autor et al. (2022) criticize the US Paycheck Protection Program (PPP) as an inefficient initiative, arguing that it subsidized the entire universe of small businesses at a cost of $800 billion (4 percent of US GDP) instead of targeting only those that were financially constrained. Our model suggests that it is more efficient to subsidize only small young firms instead of all small firms. In our analysis, we abstract from the role of policy from the perspectives of pure insurance or aggregate demand stimulus (Guerrieri et al., 2022).

There is a literature that complements the evidence on reallocation during the Covid-19 recession discussed in section 1.1. Dinlersoz et al. (2021) and Decker and Haltiwanger (2022) provide data on business entry and exit during the Covid-19 recession. The evidence in Crane et al. (2020) suggests that firm exits have been elevated among small firms and those in industries most affected by social distancing. However, this increase in business exits did not have a significant impact on aggregate employment. Barrero et al. (2021) report that excess job and sales reallocation across firms rose sharply during the pandemic. Similarly, Bloom et al. (2021) document a shift in patent applications during 2020 toward work-from-home technologies, which is likely to lead to more permanent changes in modes of work and sectoral reallocation.

The rest of the paper is organized as follows. Section 2 develops the model. Section 3 presents the quantitative exercises using the model to understand the role of various model elements, including the nature of shocks and the policy responses. Section 4 examines the role of the reallocation shock. Finally, section 5 provides the conclusion.

2 Model of the Economy and the Shutdown

We develop a model economy with entrepreneurial production subject to financial and labor market frictions, building on the framework established by Buera et al. (2015). Our model introduces two significant new elements: the option to recall furloughed employees (rest unemployment) and the concept of a reallocation shock.

The model features a continuum of individuals who are heterogeneous in their entrepreneurial productivity, employment opportunities, and financial wealth. Access to capital is determined by entrepreneurs' wealth through a collateral constraint, which is motivated by the imperfect enforceability of capital rental contracts. Each entrepreneur can operate only one production unit in a given period. Entrepreneurial productivity is inalienable, and there is no market for managers. We assume the existence of 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, which are modeled using a simple matching function.

We model a shutdown as an unanticipated shock that impacts the economy in the first period, with each period corresponding to a quarter. The shutdown is represented as a productivity shock that affects a subset of entrepreneurs, labeled as non-essential, regardless of their individual productivity or wealth. In the context of the Covid-19 application, this productivity shock is also accompanied by a demand shock that impacts the utility derived from consumption in the first period (section 1.1.3). Firms affected by the shutdown shock are unable to produce during that period. However, it is common knowledge that the shock will disappear in the following period, allowing production to resume. Similarly, we assume that the demand shock also disappears in the following period. Given the transitory nature of the aggregate shock, we incorporate the concept of rest unemployment in the spirit of Alvarez and Shimer (2011). Laid-off workers who do not enter the centralized labor market can be recalled (or re-hired) by their previous employers in the following period without having to undergo the frictional labor matching process. Additionally, we extend the model to consider the reallocation shock. (Section 4).

2.1 Model Elements

Demographics and Heterogeneity The population size of the economy is normalized to one with no population growth. Individuals live indefinitely and are heterogeneous in their financial wealth a, entrepreneurial productivity $z \in \mathcal{Z}$, and employment opportunities. While individuals make endogenous forward-looking saving decisions to determine their wealth, their entrepreneurial productivity follows an exogenous stochastic process. Specifically, an individual retains her entrepreneurial productivity from one period to the next with probability ψ. With probability $1-\psi$, she draws 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 since $\psi > 0$, the process is 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. Employed workers earn a wage that clears the hiring market each period, while unemployed workers receive unemployment benefits and search for a job.

We note that $1-\psi$, the probability of redrawing entrepreneurial productivity, is not the firm exit rate. The firm exit rate is slightly smaller than $1-\psi$. This is because some of the entrepreneurs who draw new productivity choose to continue operating their business with the new productivity level, which can be higher or lower than their previous productivity.

The unanticipated shutdown shock in period $t = 1$ temporarily shuts down a fraction ϕ of the entrepreneurs, labeled as non-essential. This shock is orthogonal to their wealth or entrepreneurial productivity. Following the unanticipated shutdown shock, unemployed workers have the option to rest and wait to be recalled by their previous employers in the next 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 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. Expectations are taken over the realizations of entrepreneurial productivity z, but not over the unanticipated shutdown or preference shocks. These shocks are completely unanticipated; however, once they occur, their future paths are completely deterministic.

Technology An entrepreneur with productivity z produces using capital k and labor l according to a decreasing-returns-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 $\alpha + \theta < 1$. Entrepreneurial input is a fixed factor, each entrepreneur can operate only one firm at a time, and entrepreneurs income share is $1 - \alpha - \theta$.

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 $a \geq 0$ represents 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 must be self-financed by entrepreneurs. The same λ applies to everyone.[12]

Labor Markets We first describe the workings of the labor market without rest unemployment, which becomes relevant only after the unanticipated temporary shutdown shock arrives. Entrepreneurs hire workers in a competitive centralized hiring market. We assume that (i) all employed workers must be paid the wage that clears the centralized hiring market in each period, and (ii) employers may terminate the employment relationship at any time.

Unemployed workers, whether due to being laid off or voluntarily exiting entrepreneurship, must re-enter the hiring market before becoming employed again. This re-entry process is subject to frictions. Specifically, a matching function determines the fraction of currently unemployed workers who re-enter the centralized hiring market. It is assumed that all unemployed workers face the same probability of re-entering the hiring market.[13]

Formally, let M_t represent the number of unemployed workers who enter the hiring market in period t. The matching function is given by:

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

where U_t denotes the number of unemployed workers at the end of the previous period, and JD_t represents job destruction at the beginning of the current period.[14]

The job destruction can be written as:

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

where l_t is the 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 join the pool of unemployed workers. The employees of these exiting entrepreneurs are

[12] 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).

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

[14] For the dynamic stability of U_t, it is crucial that a fraction of laid-off workers and exiting entrepreneurs enter the hiring market and find employment within the period, as reflected in the inclusion of the JD_t term on the right-hand side of equation (2).

accounted for in the first term of the integral.

The law of motion for the unemployment rate is:

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

where the term UB_t represents the measure of new entrepreneurs in period t who were unemployed workers at the end of period $t-1$. Combining equations (2) and (3), we have:

$$U_{t+1} = (1-\gamma)\,(U_t + JD_t) - UB_t\ . \tag{4}$$

Rest Unemployment We enrich the model of the labor market by allowing employers affected by the temporary shutdown shock to recall or rehire their laid-off workers as soon as the shock is over. This recall option enables employers to bypass the frictional labor market represented by the matching function. Alvarez and Shimer (2011) referred to this state of the labor market as rest unemployment, while Hall and Kudlyak (2022a) called it unemployment with jobs.

In our model, the ability of employers to recall resting workers is endogenously determined by the interaction between the duration of the shutdown and the financial frictions faced by the firms. During the shutdown, firms must continue to make capital rental payments, which depletes their financial assets. Consequently, the extent to which firms can rehire and resume operations after the shutdown depends on their external financing needs and the extent of asset depletion relative to the collateral requirements. Any resting workers who cannot be recalled when the shutdown ends will join the regular unemployment pool.[15]

Let R_2 be the measure of workers laid off in period 1 (when the unanticipated shock occurs) and recalled by their previous employers in period 2 (when the shutdown ends). Then:

$$R_2 = \int \min\left\{l_2(a,z), l_{1-}\right\} dG_2^{NE}\left(a, l_{1-}, z\right), \tag{5}$$

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 (NE for "non-essential"), with $G_2^{NE}(\infty,\infty,\infty) = \phi$, the fraction that was shut down. Only continuing firms, those with $l_2(a,z) > 0$ and $l_{1-} > 0$, have the option to recall their former employees who are unemployed.

[15] Although this option is not available in the initial stationary equilibrium, it would not be very relevant even if it were. This is because our entrepreneurial productivity shock process implies that a firm laying off workers is unlikely to increase employment in the immediately following period. For a similar reason, extending the recall period will not have a quantitatively significant effect. Those unemployed workers who are not immediately recalled are mostly accounted for by the exit and downsizing of their former employer. In such cases, extending the recall period will not generate many additional recalls after the first period.

An inspection of equation (5) reveals that the key equilibrium object determining the ripple effects of a shutdown shock is the joint distribution $G_2^{NE}(a, l_{1-}, z)$. While wages and interest rates also influence the labor demand of an entrepreneur with a given productivity and wealth after the shutdown, $l_2(a, z)$, it is the joint distribution of individuals across these dimensions that ultimately determines the fraction of laid-off workers who are recalled. The asset depletion experienced by non-essential entrepreneurs during the shutdown is reflected in the wealth distribution of continuing entrepreneurs. Due to the collateral constraint, an increase in the number of entrepreneurs with a worsened financial position undermines the capital and labor demand of firms after the shutdown, thereby weakening the recovery. The deterioration of balance sheets may even prompt some entrepreneurs to endogenously exit the market when the shutdown ends. This is captured by entrepreneurs transitioning to a wealth level where $l_2(a, z) = 0$, indicating zero labor demand, which means they either become workers or join the unemployed.

Given the measure of recalled unemployed workers (R_2), the measure of workers entering the hiring market in period 1 (M_1) and the unemployment rate in period 2 (U_2) are:

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

and

$$U_2 = U_1 + JD_1 - M_1 - UB_1 - R_2\ . \tag{6}$$

Unemployment Benefits We assume that unemployed workers in a given period t receive a transfer b_t equal to the period wage w_t, which is partially financed with debt that will 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 satisfies the government's budget constraint:

$$\tau^B + B_{t+1} - B_t = w_t U_{t+1} + r_t B_t,\ 1 \leq t < T, \tag{7}$$

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 tax τ^B such that it fully repays its debt by period T.[16] For $t \geq T$, the government reverts to a balanced budget with no debt. This means that lump-sum taxes are determined by the following

[16] Appendix B explores two alternative debt financing schemes: (i) a full adjustment of the lump-sum tax to balance the budget every period, and (ii) a more relaxed repayment option where taxes remain unchanged for 12 quarters, followed by a fixed increase thereafter to repay the debt in 12 years. As shown in the appendix, our main finding on output is robust to these fiscal policy variations. Consumption and investment are more affected by these alternative assumptions. We will revisit this discussion when presenting the baseline results in section 3.

equation:

$$\tau_t = w_t U_{t+1},\ t \geq T, \tag{8}$$

where the right-hand side is the product of the wage w_t that clears the hiring market in each period (given that 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}.

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

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

Assuming that the shock impacts the economy in period 1 and dissipates by the next period, the following is the recursive formulation of an individual's problem in all periods, except for the problem faced by non-essential entrepreneurs in period 1.

$$\begin{aligned} v_t\left(z,a\right) = \max_{c,a' \geq 0}\ & \xi_t \frac{c^{1-\sigma}}{1-\sigma} + \beta \mathbb{E}_t v_{t+1}(z',a') \\ \text{s.t.}\ \ & c + a' = \max\left\{w_t, \pi_t\left(z,a;r_t,w_t\right)\right\} + \left(1+r_t\right)a - \tau_t \end{aligned} \tag{9}$$

where

$$\begin{aligned} \pi_t\left(z,a;r,w\right) = \max_{k,l}\ & zk^{\alpha}l^{\theta} - \left(r_t+\delta\right)k - w_t l \\ \text{s.t.}\ \ & k \leq \lambda a \end{aligned}$$

The occupation choice of an individual is denoted by $o_t\left(a,z\right) \in \{0,1\}$. Individuals choose entrepreneurship ($o=1$) if and only if the period's profit exceeds the hiring market wage (which is equal to the unemployment benefit): $w_t < \pi_t\left(z,a;r_t,w_t\right)$. The capital input of entrepreneurs is subject to a collateral constraint, $k \leq \lambda a$. 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 faced by entrepreneurs who are unexpectedly classified as non-essential and shut down in period 1 is as follows.

$$v_1^{NE}\left(z_1, a_1, k_{1-}\right) = \max_{c_1, a_2 \geq 0} \ \xi_1 \frac{c_1^{1-\sigma}}{1-\sigma} + \beta \mathbb{E}_1 v_2\left(z_2, a_2\right) \quad (10)$$

$$\text{s.t.} \quad c_1 + a_2 = -\left(r_1 + \delta\right) k_{1-} + \left(1 + r_1\right) a_1 - \tau_1.$$

The timeline is such that the unanticipated shutdown shock occurs *after* the occupational choice and capital rentals have been made, based on the expectation of factor prices prior to the shock. Non-essential entrepreneurs still pay for the capital rental, denoted by $k_{1-} = k(z_1, a_1)$, even though no output is produced. In our baseline quantitative exercise, we assume that non-essential entrepreneurs temporarily lay off all their employees, who then enter rest unemployment.[17] Once the shutdown shock disappears in period 2, there is no longer a distinction between essential and non-essential entrepreneurs, so the continuation value no longer carries the superscript NE.

2.3 Competitive Equilibrium

Given an initial distribution $G_1\left(a, l_{-1}, z\right)$ of wealth a, the previous period's labor input l_{-1}, and entrepreneurial productivity z, the initial and period-T government debt $B_1 = B_T = 0$, a competitive equilibrium comprises prices $\{w_t, r_t\}_{t=1}^{\infty}$, allocations $\{c_t\left(a, z\right), a_{t+1}\left(a, z\right), k_t\left(a, z\right), l_t\left(a, z\right), o_t\left(a, z\right)\}_{t=1}^{\infty}$, the measure of unemployed workers $\{U_t\}_{t=1}^{\infty}$, the period-1 rest unemployed R_2, lump-sum taxes $\left\{\tau_t = \tau^B\right\}_{t=1}^{T-1}$ and $\{\tau_t = w_t U_{t+1}\}_{t=T}^{\infty}$, and government debt $\{B_t\}_{t=2}^{T-1}$ such that:[18]

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 (9) and (10) for all $t \geq 1$;

2. The measure of unemployed workers follows the equilibrium law of motion (3) and (6);

3. The government budget constraints given by (7) and (8) are satisfied for all $t \geq 1$;

4. Capital markets clear for all $t \geq 1$:

$$K_t \equiv \underbrace{\int k_t\left(a, z\right) G_t\left(da, dl_{-1}, dz\right)}_{\text{capital demand}} = \underbrace{\int a G_t\left(da, dl_{-1}, dz\right) - B_t}_{\text{capital supply}}; \quad (11)$$

[17] In section 3.4, we also consider the scenario where non-essential entrepreneurs are required to pay the wage bill despite not producing any output.

[18] To be precise, we need to define a binary variable j which takes the value of zero if an 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 assumed to be always equal, trivially, $G_t(a, l_{-1}, z, j = 0) = U_t G_t(a, l_{-1}, z)$ and $G_t(a, l_{-1}, z, j = 1) = (1 - U_t) G_t(a, l_{-1}, z)$.

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

$$L_t \equiv \underbrace{\int l_t(a,z)\, G_t(da, dl_{-1}, dz)}_{\text{labor demand}} = \underbrace{1 - \int \mathbb{I}\{o_t = 1\} G_t(da, dl_{-1}, dz) - U_{t+1}}_{\text{workers in hiring market}}, \tag{12}$$

where the left-hand side is the demand for workers 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;

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 equilibrium mapping:

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

In the capital and labor market clearing conditions, one can integrate out the previous period's employment from aggregate capital and labor demand. This is because, generally, the previous period's employment does not influence firms' current capital and labor demand, $k_t(a,z)$ and $l_t(a,z)$. In the period immediately following the shutdown, the previous period's employment does constrain firms' labor and capital choices, as firms that were shut down cannot recall more workers than they employed when the shock occurred. We carry l_{-1} as a state variable in every period, instead of writing separate equations for $t = 2$ and $t > 2$.

2.4 Calibration

Our model is parameterized so that the stationary equilibrium matches relevant aggregate and firm-level moments in the US economy.

We set the length of a time period to one quarter. The coefficient of relative risk aversion σ is set to 1.5, the annual depreciation rate is set to 0.06, or $(1-\delta)^4 = 0.94$, and the ratio $\alpha/(\alpha+\theta)$ is set to 0.33 to match the aggregate capital income share—α and θ are the output elasticity with respect to capital and labor, respectively. For the parameter of the hiring market matching function, we set $\gamma = 0.32$ in order to obtain an unemployment rate of 4 percent in the stationary equilibrium.

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

The remaining parameters to be calibrated are $\alpha + \theta$, η, ψ, discount factor β and the collateral constraint parameter λ. We target the following moments from the US data: the employment share of the top decile of firms by size (measured by the number of employees), the top 5 percent earnings share, the annual exit rate of firms, the real interest rate, and the ratio of total liabilities to total non-financial assets in the non-financial, non-corporate business sector.

Table 2: Calibration

	US Data	Model	Parameter
Top 10% Employment Share (Firms)	0.78	0.76	$\eta = 3$
Top 5% Earnings Share (Individuals)	0.36	0.35	$\alpha + \theta = 0.75$
Firm Exit Rate (Annual)	0.08	0.08	$\psi = 0.98$
Real Interest Rate (Annual)	0.04	0.04	$\beta = 0.97$
Credit Market Instruments to Non-Financial Assets	0.59	0.57	$\lambda = 7.5$

Note: The employment share of the top 10 percent of firms and the firm-based exit rate are from the Business Dynamics Database for the year 2007 (U.S. Census Bureau, U.S. Department of Commerce, 2022). The top 5 percent earnings share is from Survey of Consumer Finance for the year 2013.

Table 2 presents the moments from the US data and their counterparts in the calibrated model. In 2007, the top 10 percent of firms in terms of employment accounted for 78 percent of total employment. The earnings share of the top 5 percent of individuals was 36 percent in 2013. The annual firm exit rate was 8 percent in 2007, according to the Business Dynamics Statistics from the US Census. We assume an annual interest rate of 4 percent. Additionally, the ratio of total liabilities to total non-financial fixed assets in the non-financial, non-corporate business sector averaged 0.59 over the five years prior to Q4-2019.[19]

Although all parameter values are jointly determined in the model equilibrium, we can identify which empirical moments are most sensitive to each parameter. The tail parameter η of the Pareto distribution of entrepreneurial productivity, holding other parameters constant, primarily influences the fraction of employment accounted for by the top decile of the largest firms. Similarly, the sum $\alpha + \theta$ can be mapped to 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 a direct link between the parameter ψ, which governs the persistence of entrepreneurial productivity, and the probability that an entrepreneur exits production, thereby influencing the annual firm exit rate observed in the data. In the model's stationary equilibrium, entrepreneurs constitute

[19] Specifically, we use the ratio of total liabilities (FL114190005.Q), net of foreign direct investment in US real estate business (LM115114103.Q), to non-financial assets (LM112010005.Q), also net of foreign direct investment in US real estate business (LM115114103.Q). All these variables pertain to the non-financial, non-corporate business sector in the Flow of Funds.

5 percent of the population. Thus, the probability that a firm continues operating over four quarters is $[1 - (1 - \psi) \cdot 0.95]^4 = 0.92$, implying $\psi = 0.98$.

Using equation (4), which governs the dynamics of unemployment, we can verify the calibration of the labor market friction parameter γ with a back-of-the-envelope calculation. The equation implies $\gamma = \frac{JD-UB}{U+JD}$. Considering each variable as a fraction of the population, UB is the unemployed who become entrepreneurs. Given that the steady-state fraction of entrepreneurs is 0.05 and the unemployment rate is 0.04, UB is negligible, leading to $\gamma \approx \frac{JD}{0.04+JD}$. Notably, $JD \approx (1 - \psi) \times L_t$, the fraction of entrepreneurs receiving the entrepreneurial productivity shock times the fraction of employed workers (or employed non-entrepreneurs). Substituting the values yields $\gamma = \frac{(1-0.979)(1-0.05)(1-0.04)}{(0.04+(1-0.979)(1-0.05)(1-0.04))} \simeq 0.32$, confirming the calibrated value of the labor market friction parameter γ.

The discount factor, naturally, 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, given by

$$\frac{\int \max\left\{k_t\left(a,z\right) - a, 0\right\} G_t\left(da, dl_{-1}, dz\right)}{K_t}, \tag{13}$$

which corresponds to the ratio of total liabilities to total non-financial assets in the data.

Although the collateral constraint parameter is calibrated by targeting an aggregate measure of external finance dependence, it is instructive to examine the extent to which constrained and unconstrained firms drive economic activity under the resulting calibration. This characterization is particularly valuable considering the highly developed nature of the US financial markets, where barriers to accessing external finance may not represent the most binding constraint for firms.[20] To this end, table 3 reports the fraction of unconstrained firms in the entire economy, among young and old businesses, as well as the fraction of employment accounted for by these firms. Reassuringly, the table shows that more than 80 percent of employment is within unconstrained businesses, which make up about 40 percent of all firms. Additionally, most constrained firms are young, and these young constrained firms account for the vast majority of employment in constrained firms within the economy. As will be discussed in section 3.2, the disproportionate exposure of young firms to financial frictions is crucial for understanding the aggregate response of the economy to a shutdown shock.

Lastly, as for the calibration of the shutdown shock ϕ, we target the decline in US GDP in Q2-2020, resulting in $\phi = 0.1$, which means that 10 percent of firms are

[20] Indeed, the calibrated value for the collateral constrained, $\lambda = 7.5$, implies a ratio of external finance to capital of 0.57, which is very close to the value in an economy with perfect credit market, $\lambda = \infty$, which equals 0.58.

	Total	Young	Old
Fraction of Employment in Unconstrained Firms	0.83	0.45	0.95
Fraction of Unconstrained Firms	0.38	0.09	0.53

Table 3: Unconstrained Firms and Employment in Stationary Equilibrium

Note: The first column presents the fraction of employment in financially unconstrained firms and the fraction of such firms in the entire economy. The second column shows these fractions specifically among young firms, defined as those five years old or younger. The third column provides the same fractions among old firms. All figures are derived from the stationary equilibrium of the model prior to the shutdown shock.

classified as non-essential and are shut down for one quarter. The concurrent demand shock ξ_1 is set so that the ratio of the fall in consumption to the fall in investment in $t = 1$ in the model matches that observed in US data for Q2-2020—see figure 22, where $I_1/I_0 = 0.92C_1/C_0$.[21] Finally, we assume that the debt issued during the shutdown is fully repaid over $T = 48$ quarters.[22]

3 The Ripple Effect of a Shutdown

In this section, we illustrate the transition dynamics following an unexpected shock that shuts down 10 percent of firms for one quarter. In our baseline exercise, the shutdown shock is accompanied by an unexpected demand shock that lowers the marginal utility of consumption. This concurrent demand shock captures the behavioral and policy-induced decline in consumption observed during the early stages of the pandemic. In an alternative scenario, we abstract from the unique forces that restricted consumption at the onset of the pandemic and focus on the aggregate effects of a pure shutdown shock. In both exercises, we assume that workers who become unemployed due to the shutdown receive full unemployment insurance benefits, financed by government debt, and can be reemployed directly by their previous employers without going through the frictional matching process in the next period.[23] During the shutdown, non-essential entrepreneurs are required to pay the rental cost of capital, which can be seen as a fixed cost. They must also decide how much of their asset to draw down and how much

[21] The October 2024 revision gives a ratio of 0.935. The calibrated value of the demand shock is virtually unaffected by the revised data.

[22] The calibration of the reallocation shock is discussed in section 4.

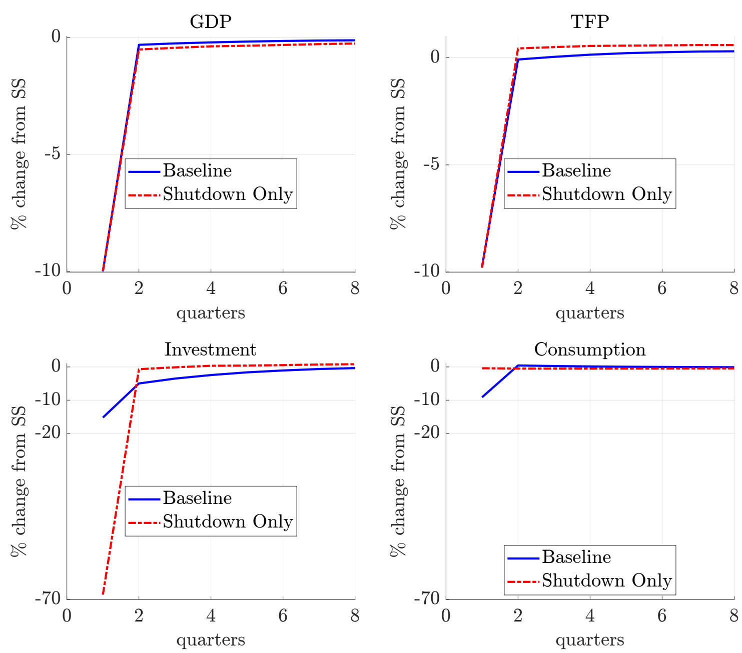
[23] An equivalent interpretation is that the government provides firms that are shut down with a 100 percent wage subsidy to cover the wage bill during the temporary shutdown, conditional on retaining their existing workers.

to consume.[24]

3.1 Aggregate Variables

The aggregate dynamics resulting from the baseline exercise and the pure shutdown shock exercise are presented in figure 6 and figure 7. The most salient feature is the swift recovery of the aggregate output. The most notable feature is the swift recovery of aggregate output. After falling by 10 percent on impact, GDP rebounds to just 0.4 percent and 0.5 percent below the initial level in the quarter following the shock. The speed of the recoveries is largely explained by the dynamics of unemployment (figure 7). In both the baseline and pure shutdown exercises, the unemployment rate jumps to 10 percent but drops back almost immediately at the end of the shutdown to less than 0.5 percent above its initial level. The decline in TFP (total factor productivity) on impact simply reflects the physical capital left unutilized by firms that are shut down. In both scenarios, TFP recovers to its initial level once the shutdown shock dissipates.

Fig. 6: Aggregate Variables

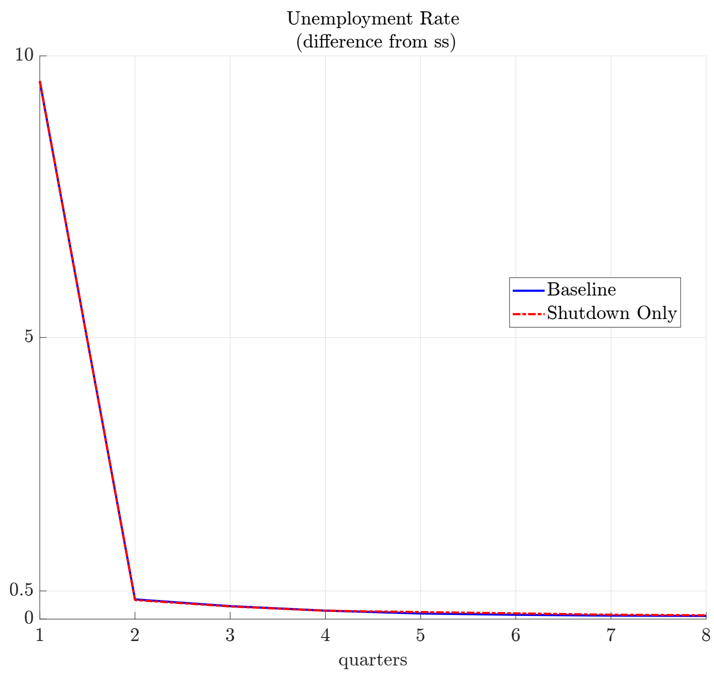


Note: The figure presents the dynamics of GDP, Total Factor Productivity (TFP), investment, and consumption for two quantitative experiments: (i) the baseline Covid-19 simulation (solid blue), which includes both a shutdown shock and an aggregate demand shock; and (ii) a pure shutdown simulation (dashed red), which isolates the effect of the shutdown by abstracting from the demand shock. All variables are expressed as percent deviations from the stationary equilibrium.

[24]In section 3.4, we consider an alternative policy arrangement where non-essential firms are required to preserve their labor force and cover the wage bill during the shutdown.

The rapid recovery in the unemployment rate indicates that most workers temporarily laid off in period 1 are recalled and rehired by their previous employers once the shutdown ends. This suggests that the negative balance sheet impact on the firms that were shut down is not substantial. Even in the non-essential sector, employment is concentrated in older, financially unconstrained firms capable of recalling most of their previous workers (table 3). In the baseline exercise, non-essential firms recall 91 percent of their resting workers once the shutdown ends, which reduces the unemployment rate to just slightly above its initial level.[25]

Fig. 7: Unemployment Rate (difference from SS)



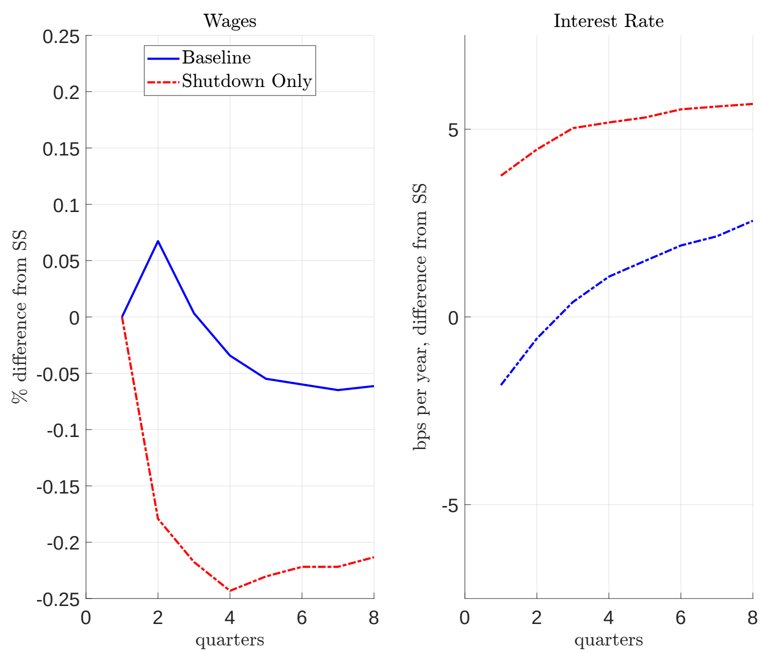
Note: The figure depicts the unemployment rate dynamics, expressed as absolute deviations from the initial period's unemployment rate. The solid blue line represents the baseline simulation, while the dashed red line illustrates the scenario with a pure shutdown shock.

Figure 6 also highlights the importance of the demand shock in generating consumption dynamics comparable to those observed in the U.S. data. In the pure shutdown exercise, the temporary nature of the shock, combined with individuals' consumption smoothing incentives, leads to a sharp contraction in investment. However, as shown in figure 22 in the appendix, consumption decreased about 10 percent in the US data, whereas investment did not experience as sharp a contraction as predicted by this exercise. With the inclusion of a demand shock, the model effectively replicates the decline

[25] Ganong et al. (2021), using data on the customers of JPMorgan Chase Bank, estimate that 75 percent of unemployment-to-employment transitions in May/June 2020 were due to recalls. This number decreased to 50 percent by October 2020.

in aggregate variables observed in the US following the shock. The subsequent dynamics of these variables are driven by the endogenous mechanisms within the model. Specifically, the quick recovery in consumption and the sluggish recovery in investment result from the interaction between the model's non-Ricardian structure and the government debt repayment scheme. In the model, due to the borrowing constraint ($a \geq 0$), workers' consumption is more sensitive to temporary changes in income and the tax profile.[26] Fiscal policy, which fully replaces wage income for the unemployed through debt financing, enables borrowing-constrained workers to maintain high levels of consumption. However, this increase in government debt crowds out private investment. Due to the extended repayment path of government debt, investment remains depressed for a longer period compared to aggregate output. As further discussed in Appendix B, raising lump-sum taxes to balance the government budget every period reverses this pattern.

Fig. 8: Factor Prices



Note: The figure illustrates the dynamics of the wage (left panel) and interest rate (right panel), in the baseline-covid shock combining a lockdown and a demand shock (solid blue) and in the lockdown shock only (dashed red). The wage rate is expressed as % difference from the steady state, whereas the interest rate is reported basis point differences from the steady-state level.

Figure 8 illustrates the behavior of factor prices. The primary observation from

[26] 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, being in the lowest income state, let their wealth converge to zero over a finite period. Consequently, workers with low wealth tend to consume a large portion of any transfer that is financed with taxes deferred far into the future.

the figure is the minimal movement in both wages and interest rates, which can be largely attributed to rest unemployment. Despite the significant fluctuations in unemployment, wages remain relatively unchanged because the newly unemployed workers remain in rest status and are directly recalled by the reopening non-essential firms without undergoing the frictional labor matching process. Wages move slightly more in the pure lockdown shock exercise and remain lower for a longer period compared to the benchmark exercise. This is due to the drop in investment, which leads to a decline in the capital stock and, consequently, depresses the marginal returns to labor. Interest rates, in turn, decrease slightly upon impact in the baseline exercise but increase slightly in the pure shutdown exercise. Two forces interact to shape these responses. On the one hand, non-essential entrepreneurs demand less capital due to their weakened balance sheet and more binding credit constraints, which pushes the interest rate downwards. On the other hand, the increase in government debt to finance unemployment insurance requires additional savings and reallocates net worth away from physical capital and into government securities, thereby pushing the interest rate upwards. In the baseline exercise, the increase in the marginal utility of consumption from period 1 to period 2 induces more saving in period 1. As a result, the declining demand for capital dominates, causing the interest rate to fall. In the pure shutdown exercise, however, a higher return on savings is required to clear the asset market because individuals dis-save to smooth their consumption in period 1.[27]

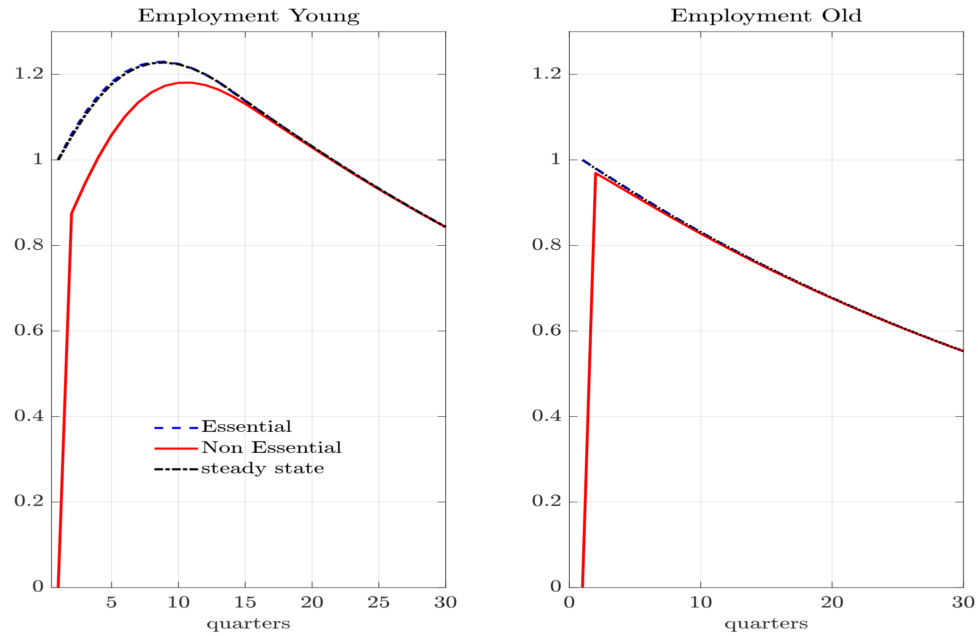
3.2 Micro-Level Implications

The rapid recovery of aggregate variables obscures significant differences in the pace of recovery across firms. The shutdown shock exclusively affects non-essential firms, leaving essential firms unaffected by design. Within the non-essential sector, the shock has a more prolonged impact on young firms, which are more likely to be financially constrained even before the shock and suffer more from the negative effects on their balance sheets when shut down.

Employment Dynamics The employment dynamics across different groups of firms are illustrated in Figure 9. The left panel shows the employment dynamics of a cohort of young firms, defined as those five years old and younger, while the right panel depicts the dynamics for older firms, defined as those older than five years. The average employment is computed over surviving firms only. In each panel, the

[27]In the baseline exercise, the lower interest rate in period 2 and the subsequent reallocation of capital to the essential sector explain the temporary rise in wages. Essential firms with access to cheaper funding attempt to hire more workers, but the reallocation of non-essential workers who are not recalled is impeded by the frictional labor matching process. Consequently, the wage rate in the hiring market is temporarily elevated.

Fig. 9: Micro-Level Implications: Employment Dynamics



Note: The figure illustrates the employment dynamics of cohorts of young and old firms in both the non-essential and essential sectors. The left panel presents the employment dynamics of firms that are five years old or younger at the time of the shutdown shock. The dashed blue line represents the employment of young firms in the essential sector, which remain operational during the shutdown. The solid red line shows the employment of the non-essential firms, which are shut down for one quarter. The dot-dashed black line shows the life-cycle dynamics in the absence of the shock. The right panel shows the dynamics for firms older than five years. All employment magnitudes are reported relative to each cohort's average employment before the shutdown.

employment dynamics are separately presented for essential firms (dashed line) and non-essential firms that are shut down (solid line), alongside their common life-cycle in the absence of the shutdown shock (dash-dot line). In all cases, employment is normalized to its value in the initial period before the unanticipated shutdown shock.

Starting with each cohort's life-cycle in the absence of the shutdown shock, Figure 9 demonstrates the importance of financial frictions in shaping the life-cycle dynamics of young and old cohorts. Many young firms are run by productive but relatively poor entrepreneurs, and their scale is limited by collateral constraints. As time passes and net worth accumulates, these young firms gradually overcome their constraints, leading to a period of employment growth. In contrast, older firms have largely overcome their financial constraints. Their average employment declines over time because, on average, these firms draw lower productivity levels, even when the new productivity is above the exit threshold, given the shape of the Pareto distribution from which they draw new productivity. In other words, the average employment declines due to mean reversion in the surviving firms' productivity. This also explains the downward-sloping part of the younger cohort's average employment in the left panel.

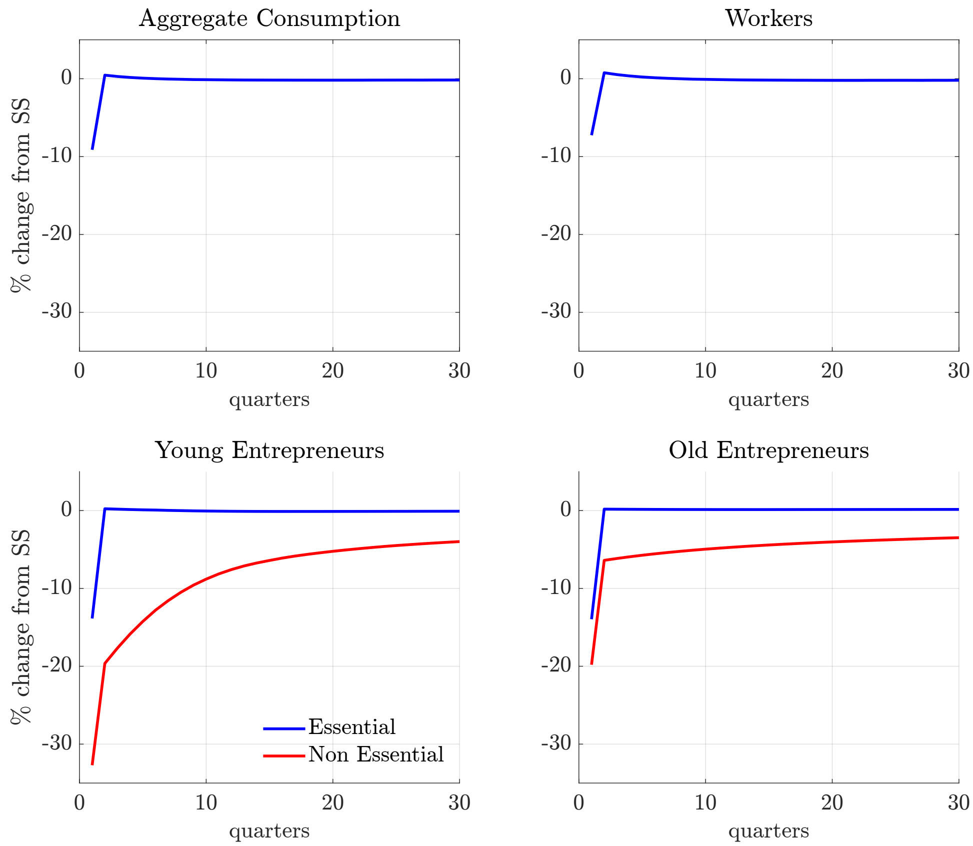
Next, we examine the dynamics of essential and non-essential firms in the aftermath of the shutdown. Following the drastic initial drop due to the shutdown, the average employment of young non-essential firms falls 20 percent below trend and fails to catch up with their essential counterparts, which were not shut down, over the subsequent 15 quarters (left panel). This persistent effect occurs because the net worth of young firms is already low before the shock and is further diminished by the need to pay for capital rental without generating any revenue during the shutdown. In contrast, the employment of old non-essential firms almost fully recovers in the period after the shock (right panel). This is because older entrepreneurs are typically less financially constrained and can more easily overcome financial constraints, even after being shut down for a quarter.

Consumption Dynamics The heterogeneous employment responses across firms have a close parallel in the differential consumption responses among workers and entrepreneurs, as shown in figure 10. For workers and essential entrepreneurs, their consumption drop in period 1 are primarily driven by the preference shock that temporarily reduces the marginal utility of consumption. For non-essential entrepreneurs, whose firms are shut down for a quarter, the decline in consumption is two to three times larger and much more persistent. In particular, entrepreneurs running young non-essential firms (bottom left panel) typically have low net worth and are financially constrained even before the shutdown shock. Consequently, they experience a larger and more prolonged decline in consumption as they rebuild their wealth to overcome these financial constraints over time. In comparison, Non-essential entrepreneurs running older firms tend to be wealthier and less financially constrained, allowing them to better smooth out their consumption once the shutdown and preference shocks pass (bottom right panel).

3.3 Effect of the Size and Duration of the Shutdown

In the benchmark exercise, 10 percent of firms are classified as non-essential and shut down for a quarter. This section examines the effects of varying the magnitude and duration of the shutdown. We find that the size of the shutdown has little impact on the aggregate dynamics, but longer shutdowns significantly slow the recovery. A larger shutdown affects more firms; however, the impact on each individual firm's balance sheet remains nearly the same. Consequently, the recovery of aggregate variables mirrors the pattern observed in the benchmark exercise. In contrast, the duration of the shutdown has a more pronounced effect, as a longer shutdown weakens firms' balance sheets more severely due to prolonged losses. This results in a delayed recovery.

Fig. 10: Micro-Level Implications: Consumption Dynamics

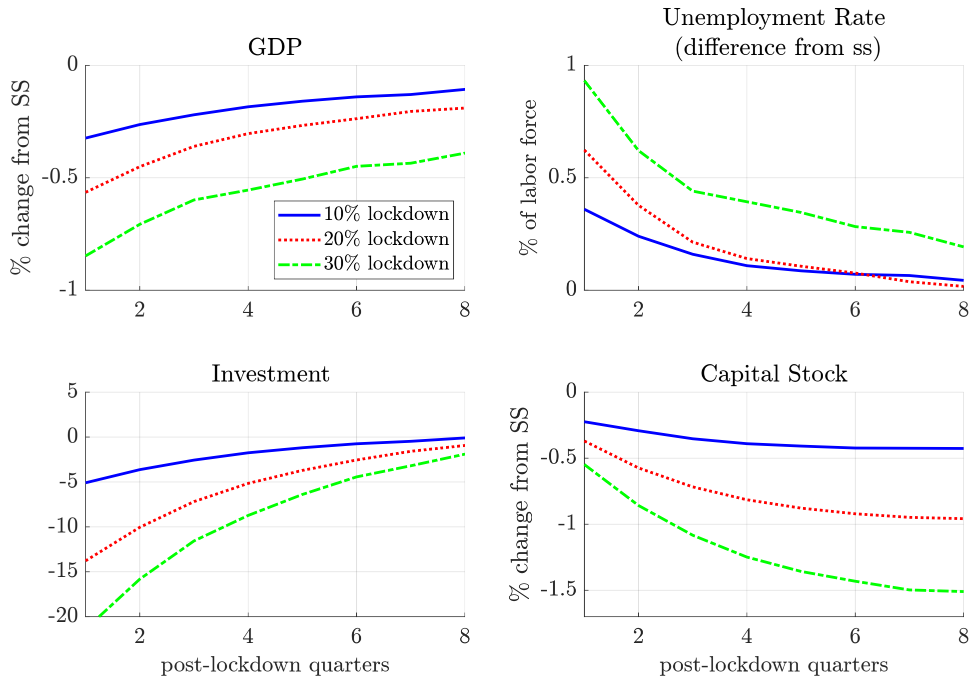


Note: The figure illustrates consumption dynamics across different types of individuals in the economy, expressed as percentage deviations from the initial period before the shock. The top left panel displays aggregate consumption, while the top right panel shows the consumption response among wage earners, including those unemployed and receiving unemployment benefits. The bottom left panel presents the consumption of entrepreneurs running young firms (five years old and younger) in both the essential and non-essential sectors at the time of the shutdown shock. The bottom right panel depicts the consumption of entrepreneurs running older firms at the time of the shutdown shock.

3.3.1 The Size of the Shutdown

We analyze the consequences of shutting down 10, 20 and 30 percent of the economy for one quarter. In each exercise, the demand shock is re-calibrated to achieve the same relative decline of investment and consumption as seen in the benchmark. Figure 11 illustrates the dynamics of GDP, unemployment rate, investment, and capital stock. We exclude the effects during the shutdown, as they are primarily mechanical, and instead focus on the ripple effects of the shocks in the post-shutdown quarters. The main takeaway from Figure 11 is that the ripple effects from larger shutdowns are approximately additive. In the period following a 10-percent shutdown, GDP is 0.3 percent below trend. After a 20-percent shutdown, GDP is 0.6 percent below trend, and following a 30-percent shutdown, it is 0.9 percent below trend. A similar pattern is observed for the unemployment rate and capital stock.

Fig. 11: Aggregate Variables: Alternative Size of Shutdown

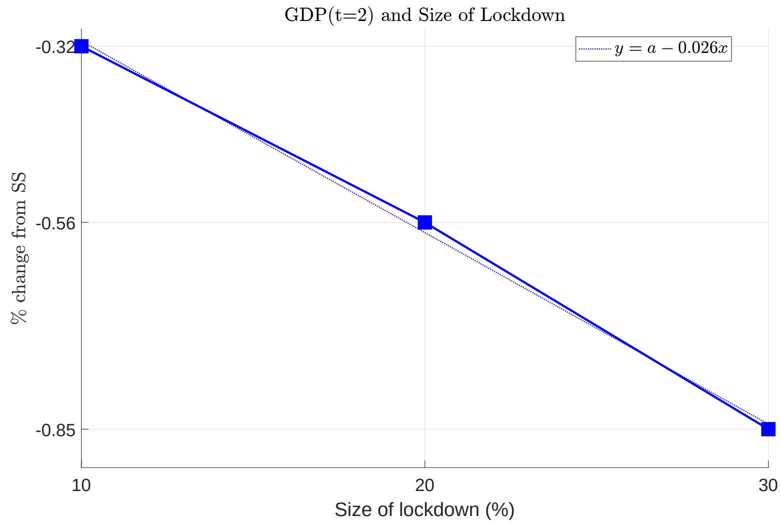


Note: The figure illustrates the dynamics of GDP, unemployment rate, investment, and capital stock when 10 (blue, the baseline), 20 (red), and 30 percent (green) of firms in the economy are shut down for one quarter. To emphasize the post-shutdown recovery, the shutdown period itself is omitted from the figure, with the first points in each graph corresponding to the first quarter after the shutdown.

Figure 12 illustrates the loss in output (in percentage deviations) immediately after the shutdown ends (period 2) relative to the size of the shutdown. It reveals a nearly linear relationship. This occurs because larger shutdowns, while affecting a greater number of firms, do not further deteriorate the balance sheets of individual non-essential firms.

Figure 13, which illustrates the life-cycle dynamics of different groups of firms across various shutdown sizes, provides further insight into the near linearity of the output effect observed in figure 12. The life-cycle dynamics are nearly indistinguishable across shutdowns of different magnitudes, confirming that the amplification of aggregate ripple effects from larger shutdowns arises not from a heightened impact on individual affected firms, but from the higher number of firms affected. It is important to note that larger shutdowns do result in larger declines in wages and interest rates, which benefits essential firms that are not shut down. However, this general equilibrium response is relatively weak, resulting in an aggregate output response that remains nearly linear with respect to the size of the shock.

Fig. 12: Size of Shutdown and the Impact on GDP



Note: The figure reports the percentage decline in GDP in the first period after the shutdown as a function of the shutdown size. The decline is measured relative to the level of GDP in the stationary allocation.

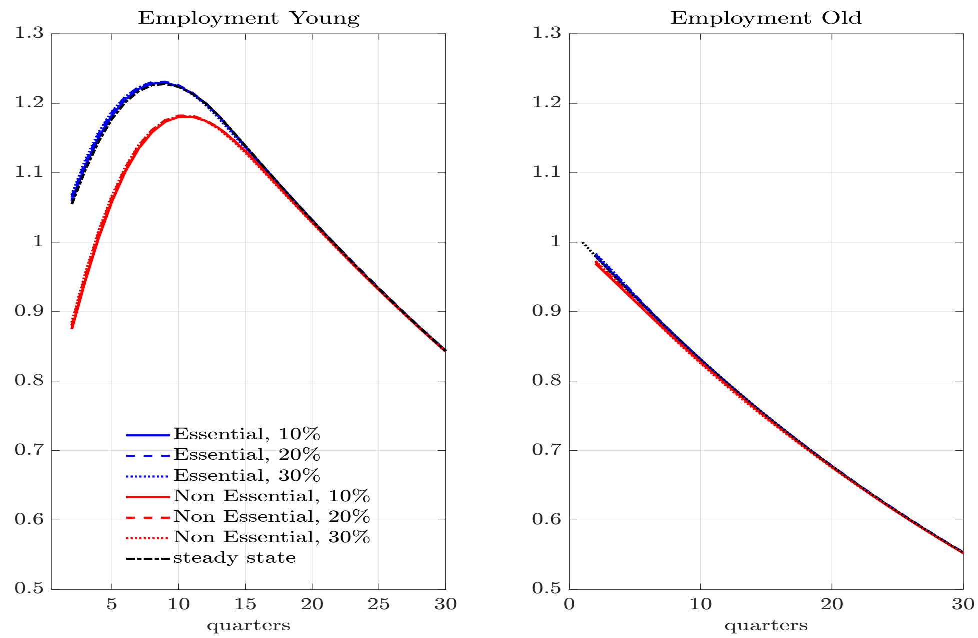
3.3.2 The Duration of the Shutdown

We now examine the macro and micro-level implications of longer shutdowns. We maintain the size of the shutdown at 10 percent of all firms and investigate the effects of one, two, and three-period shutdowns of non-essential firms. We assume that these firms furlough their workers, who remain in rest unemployment and receive unemployment benefits for the duration of the shutdown. Once the shutdown ends, the re-opening non-essential firms can recall their former employees without undergoing the frictional labor matching process. We assume that non-essential entrepreneurs are required to pay the rental cost for the non-depreciated portion of their rented capital, unless they choose to exit during the shutdown. This condition can be interpreted as a form of irreversibility in capital. Depreciation and exit generate capital reallocation from the non-essential sector to the essential sector during the shutdown period. Entrepreneurs who exit and the workers they lay off join the regular unemployment pool and are consequently subject to labor market frictions when re-entering the hiring market. We analyze the effects of shutdown duration within the context of a pure shutdown shock, abstracting from the concurrent demand shock present in the benchmark.[28]

We begin by presenting the dynamics of the aggregate variables in figure 14. The

[28]One motivation for excluding the demand shock is computational simplicity, as it avoids the potential complication that multiple combinations of the demand shock sequence during the shutdown periods can match the relative decline in investment and consumption. As observed in figure 6, the demand shock plays a negligible role in shaping the dynamics of output and unemployment, although it affects the dynamics of consumption and investment.

Fig. 13: Micro-Level Implications: Alternative Size of Shutdown

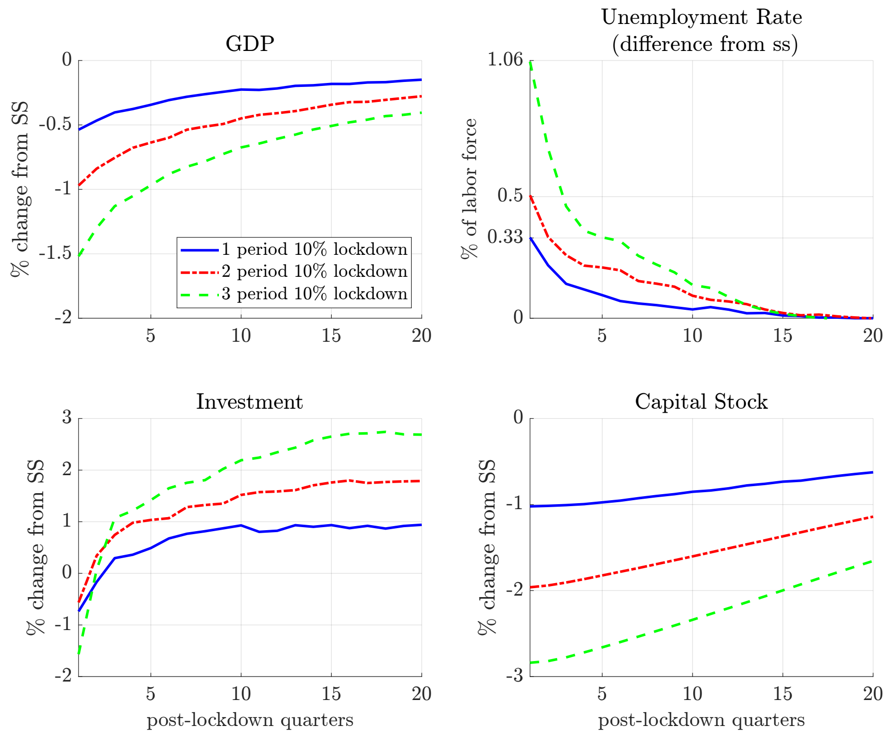


Note: The figure illustrates the employment dynamics of cohorts of young firms (five years old and younger at the time of the shutdown shock, left panel) and older firms (right panel). The blue lines represent the employment dynamics of essential firms, which are not shut down. The red lines depict the employment dynamics of non-essential firms, which are shut down for one quarter. The solid lines represent the baseline where 10 percent of firms are shut down, while the dashed and dotted lines correspond to exercise where 20 and 30 percent of firms are shut down for a quarter, respectively. The dot-dashed black line shows the life-cycle dynamics in the absence of the shutdown shock. All employment figures are normalized by each group's average employment before the shutdown.

horizontal axis represents the number of quarters following the shutdown, with the first points of each panel corresponding to period 2 for the one-period shutdown, period 3 for the two-period shutdown, and period 4 for the three-period shutdown. The top right panel shows that the unemployment rate immediately following the shutdown increases nonlinearly with the duration of the shutdown. Specifically, the unemployment rate is 0.33 percent higher that the pre-shutdown level at the end of the one-period shutdown, 0.5 percent higher at the end of the two-period shutdown, and 1.06 percent higher at the end of the three-period shutdown.

The worsening economic contraction with increasing shutdown duration results from the interaction between the deterioration of non-essential firms' balance sheets and their financial constraints. As firms are forced to shut down for longer periods, prolonged asset depletion causes more firms to become financially constrained, further tightening already binding constraints. Consequently, some firms are forced to exit. Overall, fewer workers will be recalled by their previous employers.

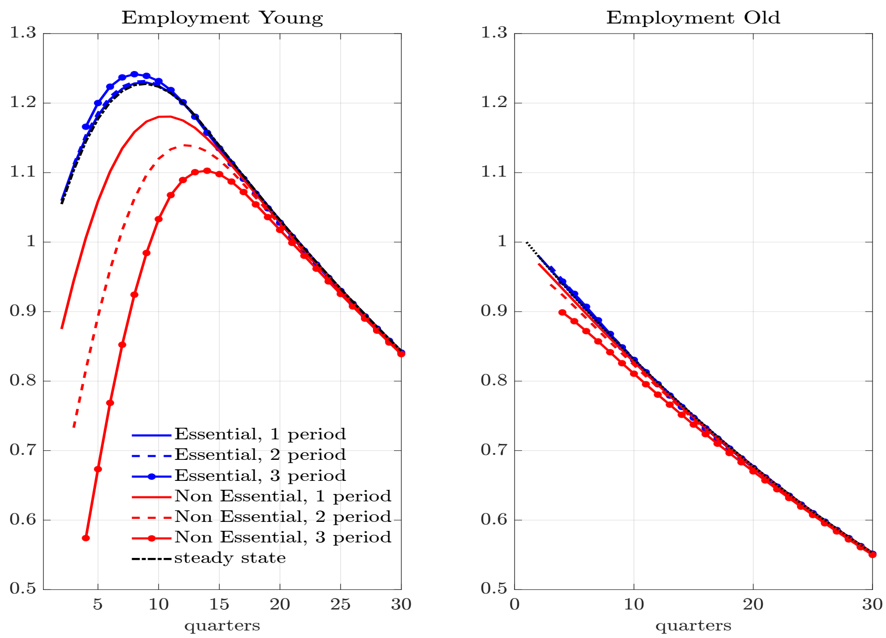
Fig. 14: Aggregate Variables: Longer Shutdowns



Note: The figure illustrates the dynamics of GDP, unemployment rate, investment, and capital stock in response to shutdown shocks lasting one quarter (blue), two quarters (red), and three quarter (green). To emphasize the post-shutdown responses, the shutdown periods are excluded from the figure. Consequently, the first points in each panel correspond to periods 2, 3, and 4 for each respective duration.

Exploring how the life-cycle dynamics of different groups of firms vary with shutdown duration helps clarify why the unemployment responses are non-linear with respect to the shutdown duration. As shown in Figure 15, young non-essential firms would resume operations after the shutdown approximately 13 percent below their pre-shutdown scale for a one-period shutdown, 27 percent for a two-period shutdown, and 44 percent for a three-period shutdown. Additionally, older non-essential firms, most of which are financially unconstrained in normal times, employ an average of 10 percent fewer workers after a three-period shutdown. These dynamics contrasts with the effects of varying the size of the shutdowns. In those exercises, the cohort dynamics of non-essential firms remained unaffected by the size of the shutdown. However, longer shutdowns deepen the recession by worsening the balance sheets of a given number of non-essential firms. General equilibrium forces help mitigate the negative effects, as the lower factor prices benefit essential firms, particularly older and less financially constrained ones. Nevertheless, longer shutdowns result in larger and more prolonged recessions.

Fig. 15: Micro-Level Implications: Employment Dynamics, Longer Shutdowns



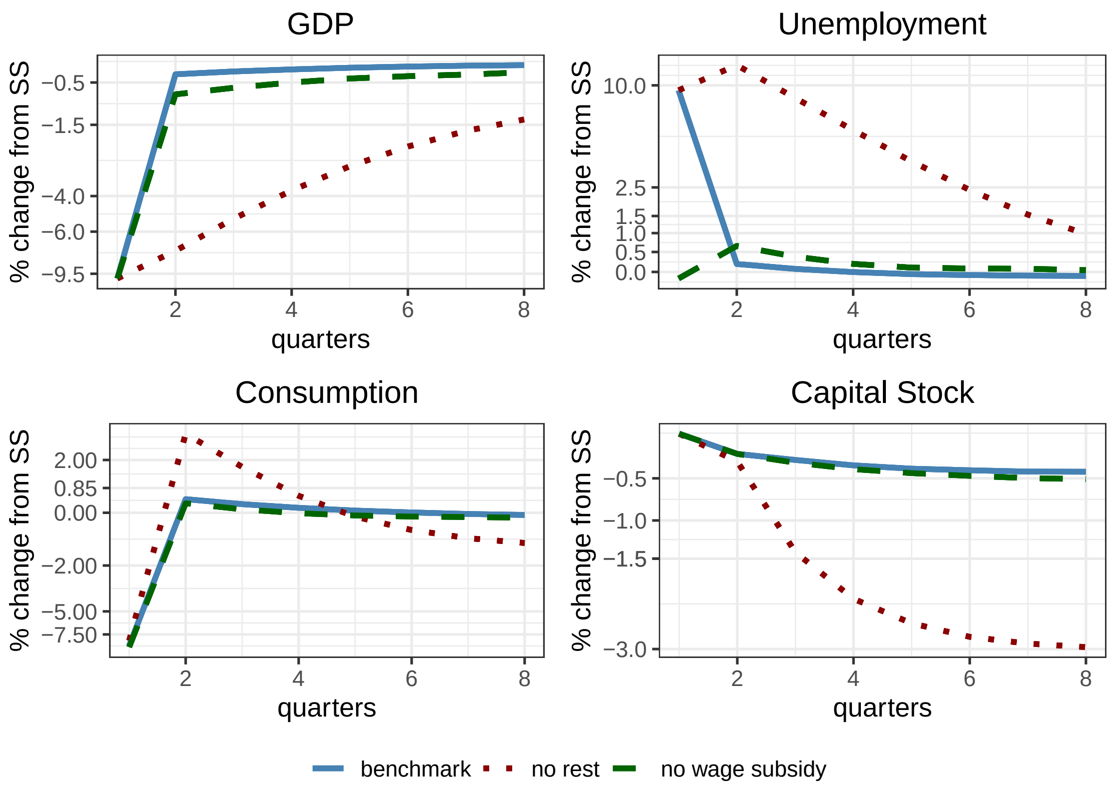
Note: The figure illustrates the employment dynamics of cohorts within essential and non-essential firms. The left panel shows the employment dynamics of young firms (5 years old and younger at the time of the shutdown shock), while the right panel presents the dynamics of older firms. The blue lines represent the employment of firms in the essential sector, which are not shut down. The red lines depict the employment of non-essential firms, which are shut down. The solid lines correspond to a one-period shutdown, whereas the dashed and dotted lines represent two-period and three-period shutdowns, respectively. The dot-dashed black line indicates what the employment dynamics would have been in the absence of the shutdown shock. Employment levels are normalized by each group's average employment before the shutdown.

3.4 Unpacking the Ripples: Policies and Mechanisms

This section isolates the contribution of two key factors in our baseline characterization of the economy's response to a shutdown: (i) full payment to workers laid off by non-essential firms during the shutdown, financed by taxpayers, and (ii) rest unemployment with the possibility of a frictionless recall. We achieve this by simulating the economy's response to a 10-percent shutdown lasting one quarter under two alternative scenarios: one where rest unemployment is not permitted, requiring the unemployed and the reopening non-essential businesses to navigate the frictional labor matching process; and the other where non-essential entrepreneurs are obliged to retain their employees during the shutdown and cover the wage bill themselves. In both scenarios we activate the concurrent demand shock. The results are presented in figure 16.

In the scenario without rest unemployment ("no rest"), reopening non-essential firms and temporarily laid-off workers must navigate matching frictions, which slows the recovery of the aggregate unemployment rate to its pre-shutdown level. Although

Fig. 16: Shocks, Policies, and Mechanisms



Note: The figure illustrates the dynamics of GDP, unemployment, consumption, and capital stock in three scenarios: the benchmark (blue), a version without rest unemployment (dotted red), and a scenario where non-essential firms are required to cover their employees' wages during the shutdown (dashed green).

non-essential firms' labor demand rebounds quickly after the shutdown, the matching frictions hinder the re-entry of unemployed workers into the central hiring market, thereby delaying the recovery of the aggregate economy. Rest unemployment and recalls help the economy avoid transforming temporary negative shocks into persistent recessions.

We now analyze the role of costless layoffs and debt-financed unemployment insurance.[29] In the "no wage subsidy" scenario shown in figure 16, non-essential firms are required to retain their employees and cover their wages while being shut down. This forced labor hoarding keeps the unemployment rate low during the shutdown period.[30] After the shutdown, the unemployment rate is one percentage point higher than in the benchmark scenario and remains persistently elevated. Similarly, GDP remains

[29] In our baseline scenario, non-essential firms can lay off their workers during the shutdown without incurring severance payments or firing costs. The government issues new debt to provide full wage replacement to the unemployed.

[30] In this scenario, the decline in GDP is fully attributed to a reduction in measured TFP, which reflects the underutilization of capital and labor by the firms that are shut down.

consistently lower than in the benchmark. The excess unemployment results from the interplay between the negative balance sheet impact caused by greater shutdown losses of non-essential firms and financial constraints. Weaker balance sheets reduce the capital and labor demand of financially constrained firms.

An alternative policy intervention designed to further mitigate the ripple effects of a shutdown is the introduction of a capital rental subsidy for non-essential firms, in addition to the wage subsidy. Our findings indicate that this policy has a minimal impact on aggregate dynamics. There are two reasons for this minimal impact. First, capital rental subsidies compensate for only a portion of non-essential entrepreneurs' revenue losses net of labor costs.[31] Secondly, entrepreneurs running young firms, who are typically financially constrained, use part of the capital rental subsidy to smooth their personal consumption. In other words, capital rental subsidies are only partially utilized to support the balance sheets of young firms that have been shut down (figure 25 in the appendix). However, these subsidies have a significant impact on the welfare of financially constrained entrepreneurs in the non-essential sector (figure 26 in the appendix).

4 Complementary Impulse: Reallocation Shock

The shock underlying the temporary shutdown may lead to lasting changes in preferences or accelerate technological advancements, to which different entrepreneurs or firms adapt with varying degrees of effectiveness. For instance, the pandemic-induced shutdown shifted preferences towards work-from-home arrangements and online shopping. Some firms adapted better to these changes, prompting further reallocation within the economy. Figure 1 and figure 2 in section 1.1 illustrate increased firm turnover and labor reallocation across industries.

Since all firms produce the same good in our model, a manageable way to simulate this reallocation shock is to temporarily adjust the persistence parameter ψ that governs the evolution of entrepreneurial productivity. Specifically, we impose a higher-than-normal fraction of non-essential entrepreneurs to re-draw their entrepreneurial productivity in period 1, independent of their wealth or previous entrepreneurial productivity. In other words, we set $1 - \psi_1^{ne} > 1 - \psi$ for the period $t = 1$ and $\psi_t^{ne} = \psi$ for all $t > 1$. We calibrate the reallocation shock based on the establishment exit rate reported in figure 1d. In Q2-2020, the establishment exit rate was 1.1 percentage points higher than previous periods' average, translating into an excess firm exit rate of 0.825 percentage points.[32] Adding the steady-state exit rate of 2 percent per quarter results

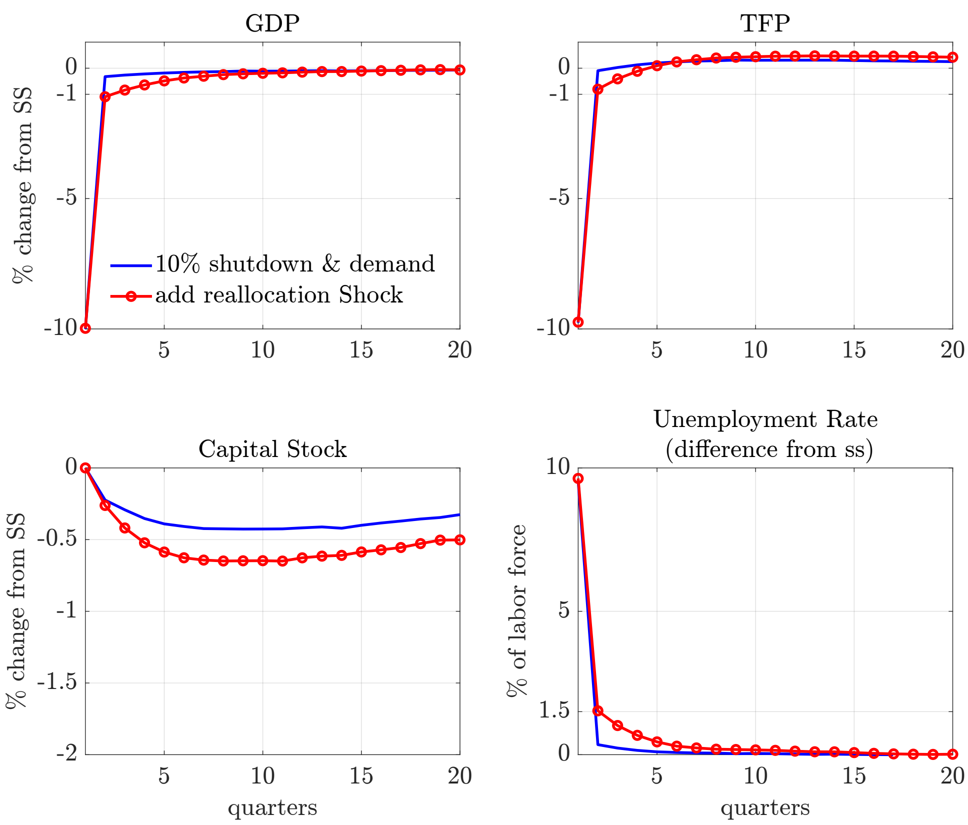
[31] In our calibration, capital rental costs and payments to the entrepreneurial fixed factor are approximately equal fractions of revenue net of labor costs: $\alpha/(1-\theta) \approx 1 - \alpha/(1-\theta) \approx 0.5$.

[32] The average ratio of firms to establishments between 2012 and 2022 was 0.75. Using this ratio, we

in an exit rate of 2.825 percent for Q2-2020. Considering that 5 percent of entrepreneurs who re-draw their productivity remain as entrepreneurs, the quarterly firm exit rate for Q2-2020 is calculated as $(1 - \psi_1^{ne})(1 - 0.05) = 0.02825$. Thus, $\psi_1^{ne} = 0.9703$, as opposed to $\psi = 0.98$ in other periods. Our reallocation shock is modest in magnitude.

Before discussing the results, two important comments are in order. First, in a perfect-credit benchmark with frictionless labor markets, the reshuffling of entrepreneurs, who re-draw idiosyncratic productivity from the same distribution, has no impact on aggregate quantities. The aggregate effects of the reallocation shock presuppose financial and labor market frictions. Second, these same frictions cause the one-time reallocation shock to have persistent effects. It takes time for the frictional labor market to reallocate workers to productive firms and for firms that newly become productive to build up their net worth and overcome financial constraints.

Fig. 17: Shutdown, Demand, and Reallocation Shocks



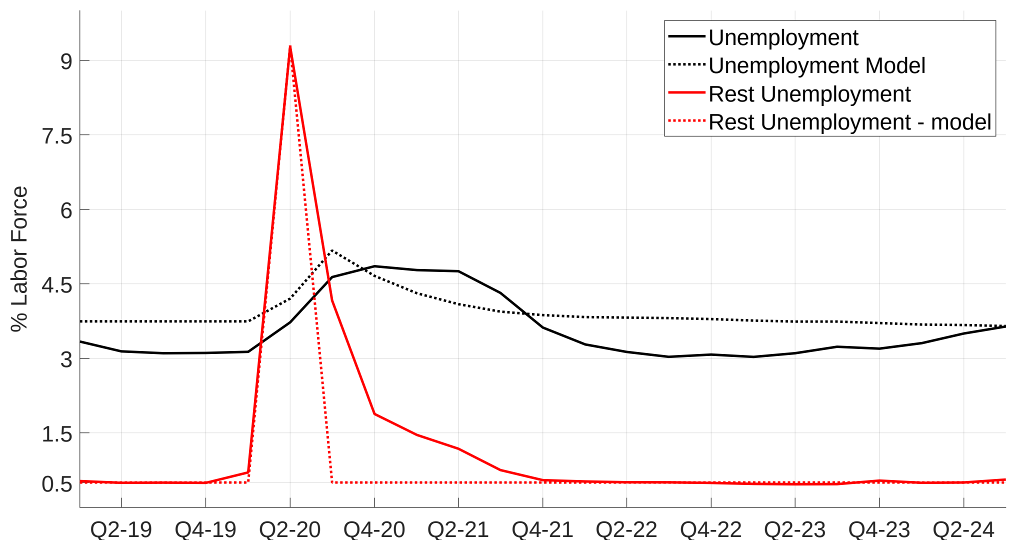
Note: The figure presents the baseline with shutdown and demand shocks (blue) alongside an economy experiencing an additional reallocation shock (red circle). At the time of the shutdown shock, the probability of entrepreneurs re-drawing their productivity temporarily increases. These new draws are independent of existing productivity and entrepreneurial wealth.

In Figure 17, the solid lines represent the benchmark with the shutdown and demand

calculate $0.75 \times 1.1 = 0.825$.

shocks, and the lines with circles represent the results of adding the reallocation shock. Initially, there is no difference between the two exercises because the reallocation shock impacts the transition of non-essential entrepreneurs from the shutdown period to the next. However, we observe a significantly weaker recovery with this modest reallocation shock thereafter. The unemployment rate remains more than one percentage point higher than its period 2 value in the benchmark and decreases slowly. TFP remains depressed for a longer period, and the capital stock lags the benchmark trajectory for more than 20 quarters. Financial and labor market frictions are at the core of the slower recovery. As firms impacted by the reallocation shock exit and are replaced by new ones, financial frictions hinder the growth of these productive entrants, who are not yet wealthy enough to overcome financial constraints. Additionally, as workers leave the exiting firms and tries to be hired by the new firms, the labor market experiences congestion due to matching frictions. As a result, the unemployment rate remains high even after the initial shocks dissipate.

Fig. 18: Taking the model with all shocks to the data.



Note: Total unemployment is decomposed into rest unemployment and unemployment. The data for unemployment and rest unemployment (solid lines) are the same as those presented in figure 3. We assume that 0.5 percent of the labor force is in rest unemployment in the model's stationary equilibrium.

Figure 18 compares the US unemployment rate data from figure 3 with the simulated time series of unemployment from the model. We differentiate rest unemployment from unemployment, so that their sum is the headline unemployment rate in the data. In the model, rest unemployment corresponds to unemployed individuals on temporary layoffs. By design, rest unemployment in the model lasts only one quarter, whereas unemployed individuals on temporary layoffs during Covid-19 decline at a slower pace in the data. The model's equilibrium unemployment rate captures the general pattern observed in U.S. data: Unemployment peaks when the economy reopens and gradually returns to pre-shutdown levels for two key reasons: financially constrained firms are unable to recall all previous employees who are in rest unemployment after the shutdown, and the frictional labor matching process causes delays in new firms absorbing unemployed workers.

5 Concluding Remarks

This study highlights the significant economic ripple effects of temporary shutdowns, such as those experienced during the Covid-19 pandemic. The model developed demonstrates that the mitigation of these ripple effects largely depends on the possibility of recalling furloughed workers without undergoing frictional labor matching process and on the strength of firms' balance sheet positions. While the overall economy can recover swiftly under these conditions, young non-essential firms face more severe and persistent impacts due to financial constraints. The research underscores the importance of *targeted* balance sheet support policies to accelerate the recovery.

Large temporary shutdowns are a response to underlying shocks, such as pandemics, natural disasters, wars, or cyber-attacks/outages, which also impact the economy in other ways. With such triggers for additional reallocation, the recovery tends to be slower. A computational experiment incorporating a shutdown and a reallocation shock calibrated to the US economy in Q2-2020 can replicate the dynamics of the US economy emerging from the shutdown.

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