

V –, U –, L – or W-shaped recovery after COVID?

Insights from an Agent Based Model

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Abstract

We discuss the impact of a Covid-like shock on a simple toy economy, described by the Mark-0 Agent-Based Model that we developed and discussed in a series of previous papers. We consider a mixed supply and demand shock, and show that depending on the shock parameters (amplitude and duration), our toy economy can display V-shaped, U-shaped or W-shaped recoveries, and even an L-shaped output curve with permanent output loss. This is due to the existence of a self-sustained “bad” state of the economy. We then discuss two policies that attempt to moderate the impact of the shock: giving easy credit to firms, and the so-called helicopter money, i.e. injecting new money into the households savings. We find that both policies are effective if strong enough, and we highlight the potential danger of terminating these policies too early. While we only discuss a limited number of scenarios, our model is flexible and versatile enough to allow for a much wider exploration, thus serving as a useful tool for the qualitative understanding of post-Covid recovery. We provide an on-line version of the code [here](#).

1 Introduction

The coronavirus pandemic has buffeted the world economy and induced one of the most abrupt drops in output ever recorded. What comes next? Will the economy recover quickly as lock-down measures are lifted, or will the damage inflicted by the massive waves of layoffs be more permanent? In pictorial terms, will the economic crisis be V-shaped, as commentators were initially hoping for, or U-shaped (prolonged drop followed by a quick recovery), or perhaps W-shaped, with a relapse due either to a second outburst of the illness, or to a premature lifting of the economic support to households and firms? The possibility of an L-shaped crisis, with a permanent loss of output, is also discussed. Or else, maybe, a “swoosh”, with a rapid drop followed by an excruciatingly slow recovery? [1]

There has been a flurry of activity to understand the consequences of the economic shock due to widespread lock-downs and loss of economic activity. While some have coupled classical economic models with SIR-like epidemic models, with the underlying assumption that the economy is somehow slaved to the dynamics of COVID [2], others have reasoned in terms of traditional economic models. There has been analytical support for both quick (V or U shaped) recoveries [3] and prolonged (L-shaped) crisis due to a stagnation trap (poor economic forecasts leading to lower consumption leading to lower investment) [4]. Given how different sectors of the economy are effected disproportionately (some completely shut, some are not), there are fears of deep recession due to a Keynesian supply shock - a deep demand shock greater in magnitude to the supply shock that cause them [5].

In this short note, we want to explore how the economic system by itself can recover from such a rapid drop of both supply and demand, even assuming quick return to normal in terms of sanitary measures. We perform numerical experiments using a prototype Agent Based Model that we have studied in depth in the past, in the context of monetary policy and inflation targeting.

Within our (highly simplified) model, we find that the length and severity of the crisis (its “typographical shape”) can be strongly affected by policy measures. We argue that, as was done in most European states, generous policies that avoid (as much as possible) bankruptcies and redundancies, allow the economy to recover rapidly, although endogenous relapses are possible (i.e. a W-shape without a second lock-down period).

In our model, U-shaped or L-shaped recoveries occur when the economy falls into what we called a “bad phase” in [6], characterized by a self-consistently sustained state of economic depression and deflation. The time needed for the “good phase” of the economy to re-establish itself when the shock is over can be extremely long (so long that it might exceed the simulation time). As a function of the parameters describing the crisis (amplitude and duration of the shock), we find that there is a discontinuous transition between V-shape recoveries and L-shape recessions. The main message of our numerical experiments is that policy should “do whatever it takes” [7] to prevent the economy tipping into such a “bad phase”, taking all measures that are seen to help the economy recover and shorten the recession period, such as “helicopter money” and easy access to credit for firms.

Although our model is not realistic on several counts and should no doubt be enriched, we believe that it offers interesting scenarios for recovery that helps sharpening one’s intuition and anticipating consequences that are often outside of the grasp of traditional approaches, where non-linear feedback effects and collective phenomena are absent. Because of heterogeneities and non-linearities, these emerging surprises are hard to anticipate and we need to develop qualitative numerical simulations, aka *telescopes for the mind* [8]. Although ABMs are spurned because they are hard (perhaps impossible) to calibrate, we have long argued [9] that one should abandon the “pretense of knowledge” and false sense of control provided by mainstream models and opt for a more qualitative, scenario driven approach to macroeconomic phenomena, with emphasis on mechanisms, feedback loops, etc. rather than on precise, but misleading, numbers. As Keynes famously said: *It is better to be roughly right than precisely wrong*. This is all the more so for policy makers in the face of a major crisis, such as the Covid shock.

Although highly stylized, our ABM generates a surprisingly rich variety of behaviour, in fact all the recovery letters listed above. Many parameters can be changed, such as those setting the “equilibrium” output and inflation levels, but also the length and severity of the shock, the amplitude of the policy response, etc. In the present note, we have only explored a small swath of possibilities. In order to allow our readers to experiment more and explore the variety of possible outcomes, we have put a version of our code on-line [here](#).

2 A short recap on Mark-0

The Mark-0 model with a Central Bank (CB) and interest rates has been described in full details in [6, 9, 10], where pseudo-codes are also provided. It was originally devised as a simplification of the Mark family of ABMs, developed in [11, 12]. We will not repeat here the full logic of the model, but only focus on the elements that are relevant for our crisis/recovery experiments.

First, we need some basic notions. The model is defined in discrete time, where the unit time between t and $t + 1$ will be chosen to be ~ 1 month. Each firm i at time t produces a quantity $Y_i(t)$ of perishable goods that it attempts to sell at price $p_i(t)$, and pays a wage $W_i(t)$ to its employees. The demand $D_i(t)$ for good i depends on the global consumption budget of households $C_B(t)$, itself determined as an inflation rate-dependent fraction of the household savings. D_i is a decreasing function of the firm price p_i , with a price sensitivity parameter that can be tuned. To update their production, price and wage policy, firms use reasonable “rules of thumb” [9] that also depend on the inflation rate through their level of debt (see below). For example, production is decreased and employees are

made redundant whenever $Y_i > D_i$, and vice-versa.¹ The model is fully “stock-flow consistent” (i.e. all the stocks and flows within the toy economy are properly accounted for). In particular, there is no uncontrolled money creation or destruction in the dynamics.² We will actually allow some money creation below, when “helicopter money” policies will be investigated.

In Mark-0 we assume a linear production function with a constant productivity, which means that output Y_i and labour N_i coincide, up to a multiplicative factor ζ : $Y_i = \zeta N_i$. The unemployment rate u is defined as:

$$u(t) = 1 - \frac{\sum_i N_i(t)}{N}, \quad (1)$$

where N is the number of agents. Note that firms cannot hire more workers than available, so that $u(t) \geq 0$ at all times – see Eq. (5) below.

We assume that the banking sector – described at the aggregate level by a single “representative bank” – sets the interest rates on deposits and loans ($\rho^d(t)$ and $\rho^\ell(t)$ respectively) uniformly for all lenders and borrowers. Therefore, the rate ρ^ℓ increases and ρ^d decreases when the firm default rate increases, in such a way that the banking sector (i.e., the representative bank) – which fully absorbs these defaults – makes zero profit at each time step (see [6, 10] for more details).

Although we have explored at length the effect of monetary policy and inflation anticipations in [10], we disregard these aspects of the problem in the present study: the baseline interest rate fixed by the central bank is set to zero, and inflation expectations of both firms and households are also zero. There is no Taylor rule coupling between inflation and interest rates either. The rationale for this choice is that we expect classical monetary policy tools to be quite ineffective as emergency measures, although they might be important to determine the long term fate of our toy economies. We leave this issue for further investigations.

2.1 Households

We assume that the total consumption budget of households $C_B(t)$ is given by:

$$C_B(t) = c [S(t) + W(t) + \rho^d(t)S(t)], \quad (2)$$

where $S(t)$ is the savings, $W(t) = \sum_i W_i(t)N_i(t)$ the total wages, and $\rho^d(t)$ is the interest rate on deposits, and c is the “consumption propensity” of households. If c is chosen to increase with increasing inflation [6, 10], then Eq. (2) describes a feedback of inflation on consumption similar to the standard Euler equation of DSGE models (see e.g. [13]). However, we neglect this effect in the present note. The total household savings evolve according to:

$$S(t+1) = S(t) + W(t) + \rho^d(t)S(t) - C(t), \quad (3)$$

where $C(t) \leq C_B(t)$ is the actual consumption of households, determined by the matching of production and demand, see [9].

2.2 Firms

2.2.1 Financial fragility

The model contains N_F firms (we chose $N_F = N$ for simplicity [9]), each firm being characterized by its workforce N_i and production $Y_i = \zeta N_i$, demand for its goods D_i , price p_i , wage W_i and its cash balance $\mathcal{E}_i$ which, when negative, is the debt of the firm. We characterize the *financial fragility* of the firm through the debt-to-payroll ratio

$$\Phi_i = -\frac{\mathcal{E}_i}{W_i N_i}. \quad (4)$$

¹As a consequence of these adaptive adjustments, the economy is on average always ‘close’ to the global market clearing condition one would posit in a fully representative agent framework. However, small fluctuations persists in the limit of large system sizes giving rise to a rich phenomenology [9], including business cycles.

²In our baseline simulation, the total amount money in circulation is set to 0 at $t = 0$. This choice is actually irrelevant in the long run, but may have important short term effects.

Negative Φ 's describe healthy firms with positive cash balance, while indebted firms have a positive Φ . If $\Phi_i < \Theta$, i.e. when the flux of credit needed from the bank is not too high compared to the size of the company (measured as the total payroll), the firm i is allowed to continue its activity. If on the other hand $\Phi_i \geq \Theta$, the firm i defaults and the corresponding default cost is absorbed by the banking sector, which adjusts the loan and deposit rates ρ^ℓ and ρ^d accordingly. The defaulted firm is replaced by a new one at rate φ , initialised at random (using the average parameters of other firms). The parameter Θ controls the maximum leverage in the economy, and models the risk-control policy of the banking sector.

2.2.2 Production update

If the firm is allowed to continue its business, it adapts its price, wages and production according to reasonable (but of course debatable) “rules of thumb” – see [6, 9]. In particular, the production update is chosen as follows:

$$\begin{aligned} \text{If } Y_i(t) < D_i(t) &\Rightarrow Y_i(t+1) = Y_i(t) + \min\{\eta_i^+(D_i(t) - Y_i(t)), \zeta u_i^*(t)\} \\ \text{If } Y_i(t) > D_i(t) &\Rightarrow Y_i(t+1) = Y_i(t) - \eta_i^-[Y_i(t) - D_i(t)] \end{aligned} \quad (5)$$

where $u_i^*(t)$ is the maximum number of unemployed workers available to the firm i at time t , which depends on its wage (see [10, Appendix A]). The coefficients $\eta^\pm \in [0, 1]$ express the sensitivity of the firm's target production to excess demand/supply. We postulate that the production adjustment depends on the financial fragility Φ_i of the firm: firms that are close to bankruptcy are arguably faster to fire and slower to hire, and vice-versa for healthy firms. In order to model this tendency, we posit that the coefficients $\eta_i^\pm$ for firm i (belonging to $[0, 1]$) are given by:

$$\begin{aligned} \eta_i^- &= \llbracket \eta_0^-(1 + \Gamma\Phi_i(t)) \rrbracket \\ \eta_i^+ &= \llbracket \eta_0^+(1 - \Gamma\Phi_i(t)) \rrbracket, \end{aligned} \quad (6)$$

where $\eta_0^\pm$ are fixed coefficients, identical for all firms, and $\llbracket x \rrbracket = 1$ when $x \geq 1$ and $\llbracket x \rrbracket = 0$ when $x \leq 0$. The factor $\Gamma > 0$ measures how the financial fragility of firms influences their hiring/firing policy, since a larger value of Φ_i then leads to a faster downward adjustment of the workforce when the firm is over-producing, and a slower (more cautious) upward adjustment when the firm is under-producing. Since the “dangerous” level of fragility is $\Phi = \Theta$, we assume that $\Gamma = \Gamma_0/\Theta$, where Γ_0 is an adjustable parameter. However, we neglected this effect in the present work and set $\Gamma_0 = 0$.

2.2.3 Price update

Following the initial specification of the Mark series of models [11], prices are updated through a random multiplicative process, which takes into account the production-demand gap experienced in the previous time step and if the price offered is competitive (with respect to the average price). The update rule for prices reads:

$$\begin{aligned} \text{If } Y_i(t) < D_i(t) &\Rightarrow \begin{cases} \text{If } p_i(t) < \bar{p}(t) &\Rightarrow p_i(t+1) = p_i(t)(1 + \gamma\xi_i(t)) \\ \text{If } p_i(t) \geq \bar{p}(t) &\Rightarrow p_i(t+1) = p_i(t) \end{cases} \\ \text{If } Y_i(t) > D_i(t) &\Rightarrow \begin{cases} \text{If } p_i(t) > \bar{p}(t) &\Rightarrow p_i(t+1) = p_i(t)(1 - \gamma\xi_i(t)) \\ \text{If } p_i(t) \leq \bar{p}(t) &\Rightarrow p_i(t+1) = p_i(t) \end{cases} \end{aligned} \quad (7)$$

where $\xi_i(t)$ are independent uniform $U[0, 1]$ random variables and γ is a parameter setting the relative magnitude of the price adjustment, chosen to be 1% (per month) throughout this work.³

³In [10], we introduced a factor $(1 + \hat{\pi}(t))$ in the price and wage update rules, to model the fact that firms also factor in an anticipated inflation $\hat{\pi}(t)$ when they set their prices and wages. This effect is neglected here, as it plays a minor role in the present discussion.

Number of firms	N_F	10000
Consumption propensity	c	0.5
Price adjustment parameter	γ	0.01
Firing propensity	η_-^0	0.2
Hiring propensity	η_+^0	$R\eta_-^0$
Hiring/firing ratio	R	2
Bankruptcy threshold	Θ	3
Rate of firm revival	φ	0.1
Productivity factor	ζ	1
Financial fragility sensitivity	Γ_0	0

Table 1: Parameters of the Mark-0 model that are relevant for this work, together with their symbol and baseline values. For a comprehensive list of parameters, see [10].

2.2.4 Wage update

The wage update rule follows the choices made for price and production. Similarly to workforce adjustments, we posit that at each time step firm i updates the wage paid to its employees as:

$$\begin{aligned}
 W_i^T(t+1) &= W_i(t)[1 + \gamma(1 - \Gamma\Phi_i)(1 - u(t))\xi'_i(t)] \quad \text{if} \quad \begin{cases} Y_i(t) < D_i(t) \\ \mathcal{P}_i(t) > 0 \end{cases} \\
 W_i(t+1) &= W_i(t)[1 - \gamma(1 + \Gamma\Phi_i)u(t)\xi'_i(t)] \quad \text{if} \quad \begin{cases} Y_i(t) > D_i(t) \\ \mathcal{P}_i(t) < 0 \end{cases}
 \end{aligned} \tag{8}$$

where $\mathcal{P}_i = p_i \min(Y_i, D_i) - W_i N_i$ is the profit of the firm at time t and $\xi'_i(t)$ an independent $U[0, 1]$ random variable. If $W_i^T(t+1)$ is such that the profit of firm i at time t with this amount of wages would have been negative, $W_i(t+1)$ is chosen to be exactly at the equilibrium point where $\mathcal{P}_i(t) = 0$; otherwise $W_i(t+1) = W_i^T(t+1)$. Here, Γ is the same parameter introduced in Eq. (6).

Note that within the current model the productivity of workers is not related to their wages. The only channel through which wages impact production is that the quantity $u_i^*(t)$ that appears in Eq. (5), which represents the share of unemployed workers accessible to firm i , is an increasing function of W_i . Hence, firms that want to produce more (hence hire more) do so by increasing W_i , as to attract more applicants (see [6, Appendix A] for details).

The above rules are meant to capture the fact that deeply indebted firms seek to reduce wages more aggressively, whereas flourishing firms tend to increase wages more rapidly:

- If a firm makes a profit and it has a large demand for its good, it will increase the pay of its workers. The pay rise is expected to be large if the firm is financially healthy and/or if unemployment is low because pressure on salaries is high.
- Conversely, if the firm makes a loss and has a low demand for its good, it will attempt to reduce the wages. This reduction is more drastic if the company is close to bankruptcy, and/or if unemployment is high, because pressure on salaries is then low.
- In all other cases, wages are not updated.

The model, as presented above, has several free parameters. Some values are fixed throughout this work, using values that have been found in previous work to yield reasonable results [6, 9, 10]: their list is given in Table 1.

3 A Covid-like shock to the economy: phenomenology

The baseline values of the parameters, summarized in Table 1, allow our economy to settle in a rather prosperous state, with a low level of unemployment and, therefore, a near maximum output given the level of productivity $\zeta = 1$. The inflation level is $\approx 1.5\%$ /year and the average financial fragility $\langle \Phi \rangle$ of

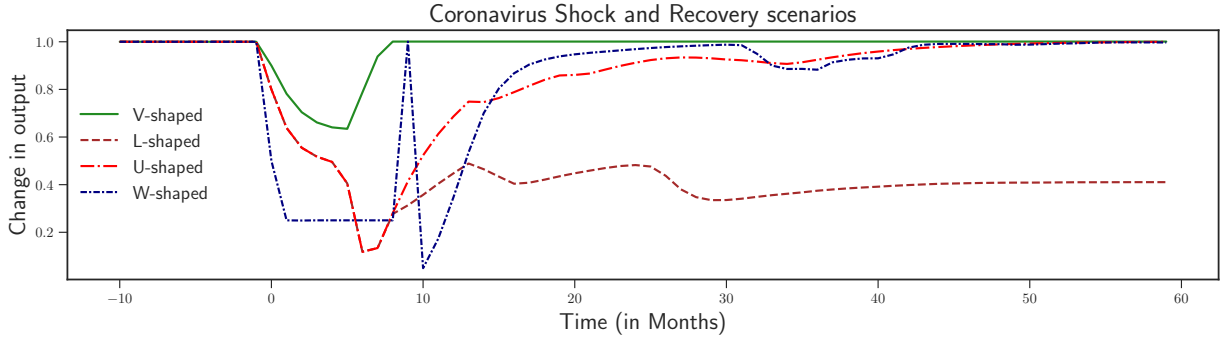


Figure 1: Some recovery patterns following the coronavirus shock, which starts at time $t = 0$. We show, as a function of time, the fall in output relative to the no-shock scenario. For mild shocks ($\Delta c/c = 0.3$, $\Delta \zeta/\zeta = 0.1$, lasting six months), the economy contracts but quickly recovers (V-Shaped recovery). For more severe shocks over the same time period ($\Delta c/c = 0.3$, $\Delta \zeta/\zeta = 0.2$), the economy contracts permanently and never recovers (at least on the time scale of the simulation). This is the dreaded L-shaped scenario, in the absence of any government policy. An increase in consumption above pre-crisis levels and a helicopter money drop at the end of the shock leads to a faster recovery (U-shaped recovery). Finally, a W-shaped scenario can also be found for stronger shocks ($\Delta c/c = 0.3$, $\Delta \zeta/\zeta = 0.5$, lasting nine months) with strong government policy and a helicopter drop (see next section).

the firms is ≈ 1 (i.e. a debt equal to one month of wages), far from the baseline bankruptcy threshold $\Theta = 3$.

The specificity of the Covid crisis is that it induced both a supply and a demand shock [14]. We can model this effect by a sudden drop of the productivity of firms, i.e. $\zeta \rightarrow \zeta - \Delta \zeta$, and of the consumption propensity of households, i.e. $c \rightarrow c - \Delta c$. These drops are meant to mimic the effect of a lock-down on the economy, that leads both to a drop of supply (employees must stay home and either not work at all or work remotely with lower productivity, while keeping their salaries) and a drop of demand (customers cannot go shopping, or are afraid to spend). It is uncertain how long the effects of the crisis would last. Hence, an important parameter describing the shock is its duration T . We will choose henceforth three benchmark values: 3 months, 6 months and 9 months. These values are meant to represent an effective length of the shock, accounting for the fact that lock-down measures can be partially lifted, which leads to an increased value of both ζ and c during the shock period and hence a shorter effective shock duration.

In Fig. 1, we show several typical crisis and recovery shapes, depending on the strength of the shock and the policy used to alleviate the severity of the crisis. For small enough Δc and/or $\Delta \zeta$, there is no drop of output at all. For larger shock amplitude or duration, one observes a V-shape recovery, as expected when the shock is mild enough not to dent the financial health of the firms. Stronger shocks can however lead to a permanent dysfunctional state (L-shape), with high unemployment, falling wages and savings, and a high level of financial fragility and bankruptcies. An L-shaped scenario can however be prevented if after the shock, consumer demand picks. To facilitate and boost consumption, a one-time policy of helicopter money can move the economy towards a path of recovery over the scale of a few years (U-shape).

For a more complete picture of the influence of these shocks, we plot the “phase diagrams” of the crises in absence of any policy, in the plane $\Delta c/c, \Delta \zeta/\zeta$, for $T = 3, 6$ and 9 months in Fig. 2. We show (a) the probability of a “dire” (L-shaped) crisis, (b) the peak value of unemployment during the shock and (c) the peak value of unemployment after the shock. Black regions indicate that the economy survives well (i.e. no dire crisis, or short crises with little unemployment). This occurs, as expected, in the lower left corner of the graphs (small $\Delta c/c, \Delta \zeta/\zeta$). These black regions shrink as T increases. We also note that mild shocks lasting only a short time ($T = 3$ months) can cause lasting damage. Indeed, we observe that low rates of unemployment during the shock are not representative of the future evolution. Interesting, there is an abrupt, first order transition line (a “tipping point” in the language of [9]) beyond which crises have a very large probability to be permanent, with high levels of unemployment (yellow regions). Because the location of such a tipping point in the real-world

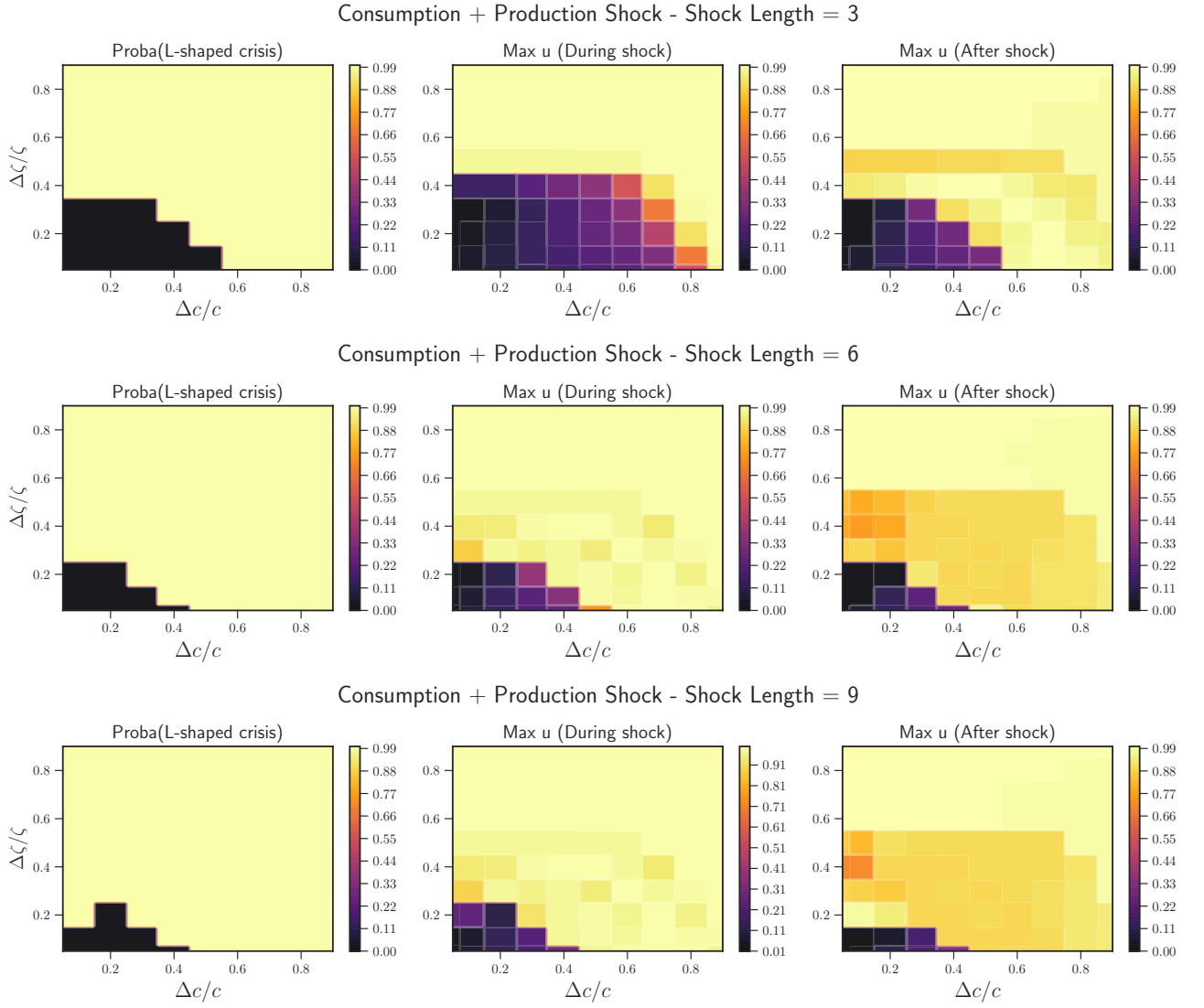


Figure 2: Phase diagrams in the $\Delta c/c$ - $\Delta \zeta/\zeta$ plane for different shock lengths. As the length of the shock is increased, the probability of having a long-crisis increases even for mild shocks. *Top Row:* Shock lasting for 3 months. The region of parameter space with no L-shaped crisis is quite large allowing for strong consumption shocks ($\Delta c/c \lesssim 0.5$) and mild productivity shocks ($\Delta \zeta/\zeta \lesssim 0.3$). Note that for such a short shock, the effects on unemployment are seen after the shock has passed. *Middle Row:* Shock lasts for 6 months. A decrease in the region of no-crisis is observed. Mild shocks ($\Delta c/c \sim 0.4$) can also lead to prolonged crises. During the shock itself, extremely high rates of unemployment can be seen. *Bottom Row:* Shock lasts for 9 months. Only for extremely mild shocks does the economy not undergo a prolonged crisis.

economy is extremely hard to estimate⁴, our results suggest that governments should be very cautious and do as much as possible to prevent a possible collapse of the economy.

It is useful to focus on the line $\Delta \zeta = 0$ of these two-dimensional plots, corresponding to a consumption shock without productivity shock. We show in Fig. 3 the same three quantities as in Fig. 2. An abrupt transition between no dire crises and dire crises can be seen for $\Delta c/c \sim 0.4$ when $T = 9$ months.

We now implement, within our model, some emergency governmental policy inspired from those that are actually currently in place in different countries. From now on, we choose $\Delta c/c = 0.3$ and $\Delta \zeta/\zeta = 0.5$ as reasonable values to represent the severity of the Covid shock [15, 16], and let T again take the values 3, 6 and 9 months. In the absence of any active policy, the economy collapses into a deep recession, with an output reduced by 2/3 compared to pre-shock levels.

⁴In physics, it is well known that there is no way to know that one is approaching a first order transition between two phases, just looking from within a single phase. Hence, no simple indicator would predict the tipping point of the economy from within its “good” phase.

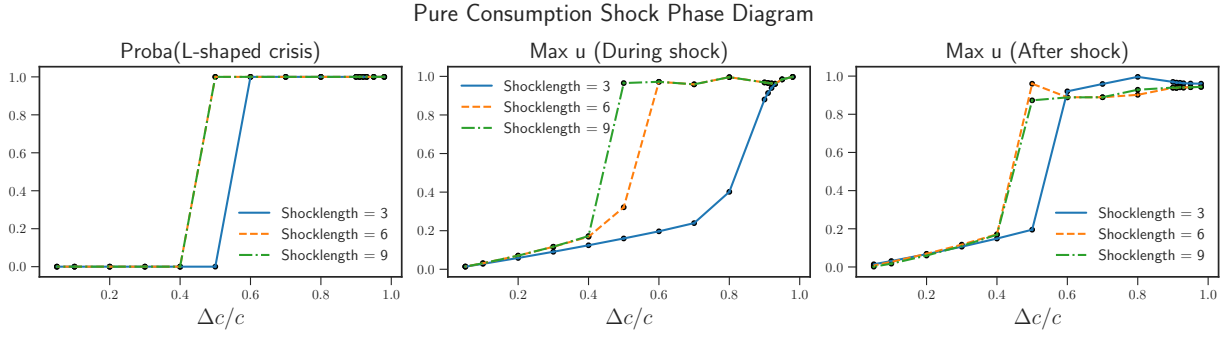


Figure 3: Phase diagram for a pure consumption shock ($\Delta\zeta/\zeta = 0$). We observe an abrupt transition to an L-shaped crisis for consumption shocks beyond $\Delta c/c = 0.5$ for $T = 3$ months, and beyond $\Delta c/c = 0.4$ for $T = 6$ or 9 months. Below these shock amplitudes, there is no prolonged crises but short-lived crises are observed. This can be seen by observing the maximum unemployment rate during the shocks: for $\Delta c/c = 0.4$, we reach about 15% unemployment.

4 Securing a quick recovery?

The toolbox developed in the aftermath of the Global Financial Crisis (GFC) of 2008 puts monetary policy in the center of economic crisis management. This takes the form of either direct interest rate cuts or, as was seen recently for the GFC interventions, even stronger measures such as quantitative easing. Our Agent Based Model provides several channels through which the economy can be propped up, including interest rate cuts [10]. However, given that the interest rates are already very low, the interest-rate channel itself might not be effective, and might lead to a stagnation trap and a L-shaped recovery [4]. Hence, in this work, we disregard the interest-rate channel, since it cannot be used as an emergency measure in the face of a collapsing supply sector. We focus on two possible channels: easy credit for firms, and “helicopter money” for households.

A way to loosen the stranglehold on struggling firms is to give them easy access to credit lines, independently of their financial situation. In our model, this amounts to a significant increase of the bankruptcy threshold Θ . So the policy we investigate is the following: during the whole duration of the shock, we set $\Theta = \infty$, i.e. all firms are allowed to continue their business and accumulate debt. When the shock is over, the value of Θ is taken back down. This can be done in several ways. One extreme possibility (that we call naive below) is to set Θ to its pre-shock value as soon as the shock is over. Intuitively, when the shock is short enough, allowing endangered firms to survive might be enough. For long shocks however, such a naive policy is not going to be very helpful as firms that have muddled through the shock have become much more fragile at the end of the shock. So in this case, many will fail when credit is tightened, and the economy plunges into recession as if no policy was applied. This is precisely what is shown in Figs. 4, 5, second column (“Naive Policy”), where we plot (as in Fig. 6 below) a dashboard of the state of the economy: output and unemployment, financial fragility and default rate, inflation and wages, savings and interest rates. Note that we only show the results corresponding to $T = 3$ months and $T = 9$ months. For the shock amplitude that we have chosen, the case $T = 6$ months is qualitatively similar to the case $T = 3$ months and is therefore not shown. Recent data indeed points to this scenario bearing out with bankruptcies set to soar in the coming months [17].

Another possibility, that we call “adaptive”, is to reduce Θ progressively, in a way that is adapted to firms’ average fragility. We assume that the government measures the instantaneous value of $\langle \Phi \rangle$ over firms still in activity, weighted by production, $\langle \Phi \rangle = \sum_i \Phi_i Y_i / \sum_i Y_i$, and sets Θ as:

$$\Theta = \max(\theta \langle \Phi \rangle, 3), \quad (t > T), \quad (9)$$

where θ is some offset that we chose to be $\theta = 1.25$. This means that only the most indebted firms, whose fragility exceeds the average value by more than 25%, will go bust as the effective threshold Θ is progressively reduced. As shown in Figs. 4, 5 fourth column (“Adaptive Policy”), this scheme is very successful: the economy recovers 100% of its pre-shock output at the end of the shock, for all three durations $T = 3, 6, 9$ months. As can be seen from the plot of the average fragility, this comes at the

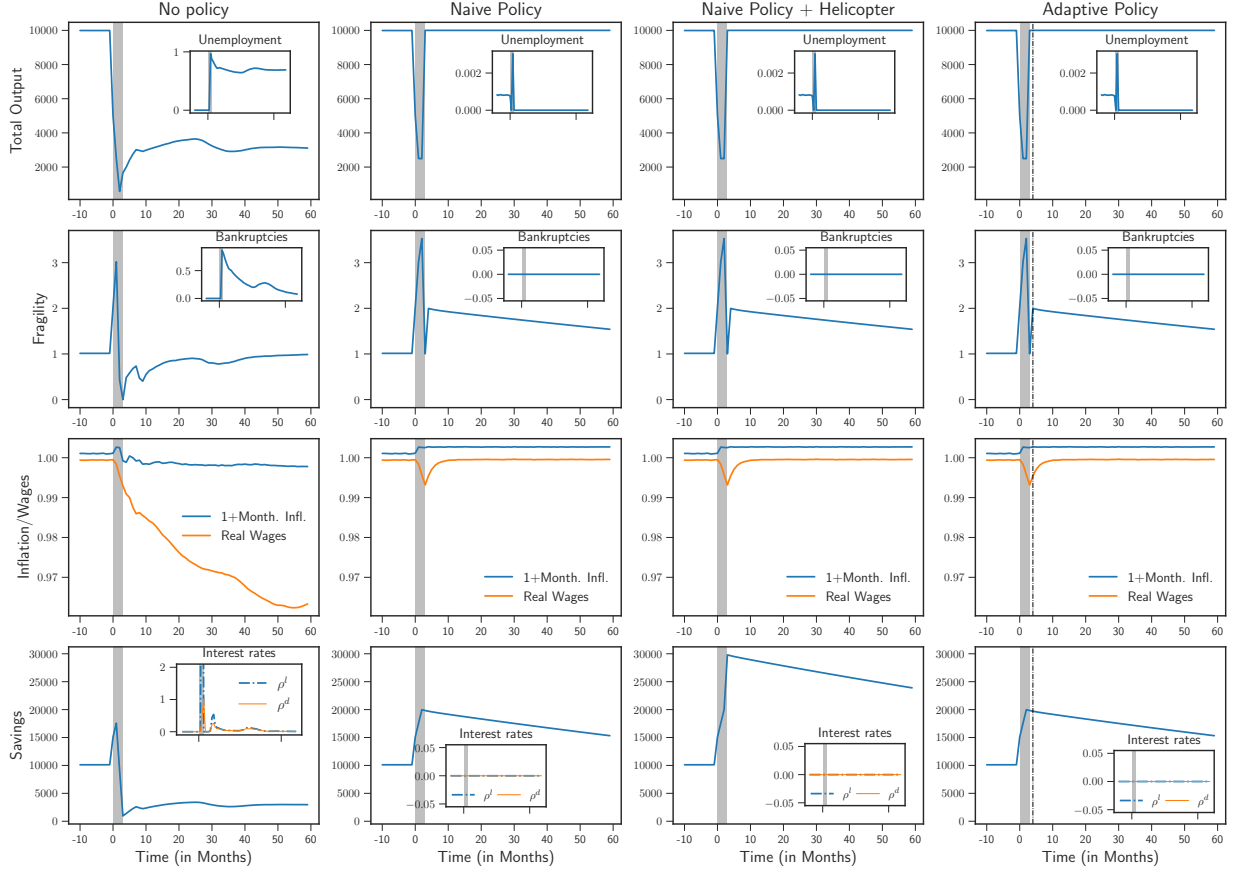


Figure 4: Scenarios for shock length of 3 months (marked in grey) with and without policy. *First column:* Without a policy intervention, the economy suffers a deep contraction with extremely high rates of unemployment and a subsequent loss in wages. A large number of firms go bankrupt and household savings reduce permanently after a brief increase during the shock. Permanent deflation and drop of real wages are also observed. A rapid increase in the interest rate on loans ρ^l following firms going bankrupt. *Second Column:* A policy of extending the credit limits for all firms is introduced, which lasts the duration of the crisis. This improves the situation of the economy. A temporary contraction in output can not be avoided but the policy is able to prevent bankruptcies and hence keep unemployment during and beyond the crisis very low. *Third Column:* The situation with the naive policy followed by a helicopter drop of money is shown. Since the naive policy by itself was enough to prevent a crisis, the helicopter drop does not change the outcome, apart from increasing the savings of households. Note that the money injected into the economy by the helicopter drop quickly disappears due to inflation. *Fourth Column:* An adaptive policy which reduces the bankruptcy threshold Θ gradually is essentially equivalent to the naive policy in this case. The vertical dotted line marks the end of this policy.

price of $\langle \Phi \rangle$ reaching very high values for a while (for example $\langle \Phi \rangle \approx 6$, i.e. six times its pre-shock value, when $T = 9$ months). But the slow removal of the easy credit policy allows the economy to smoothly revert to its pre-shock state, with a limited number of bankruptcies.

Consumption + Production Shock - Shocklength = 9, $\Delta c/c = 0.3$, $\Delta \zeta/\zeta = 0.5$

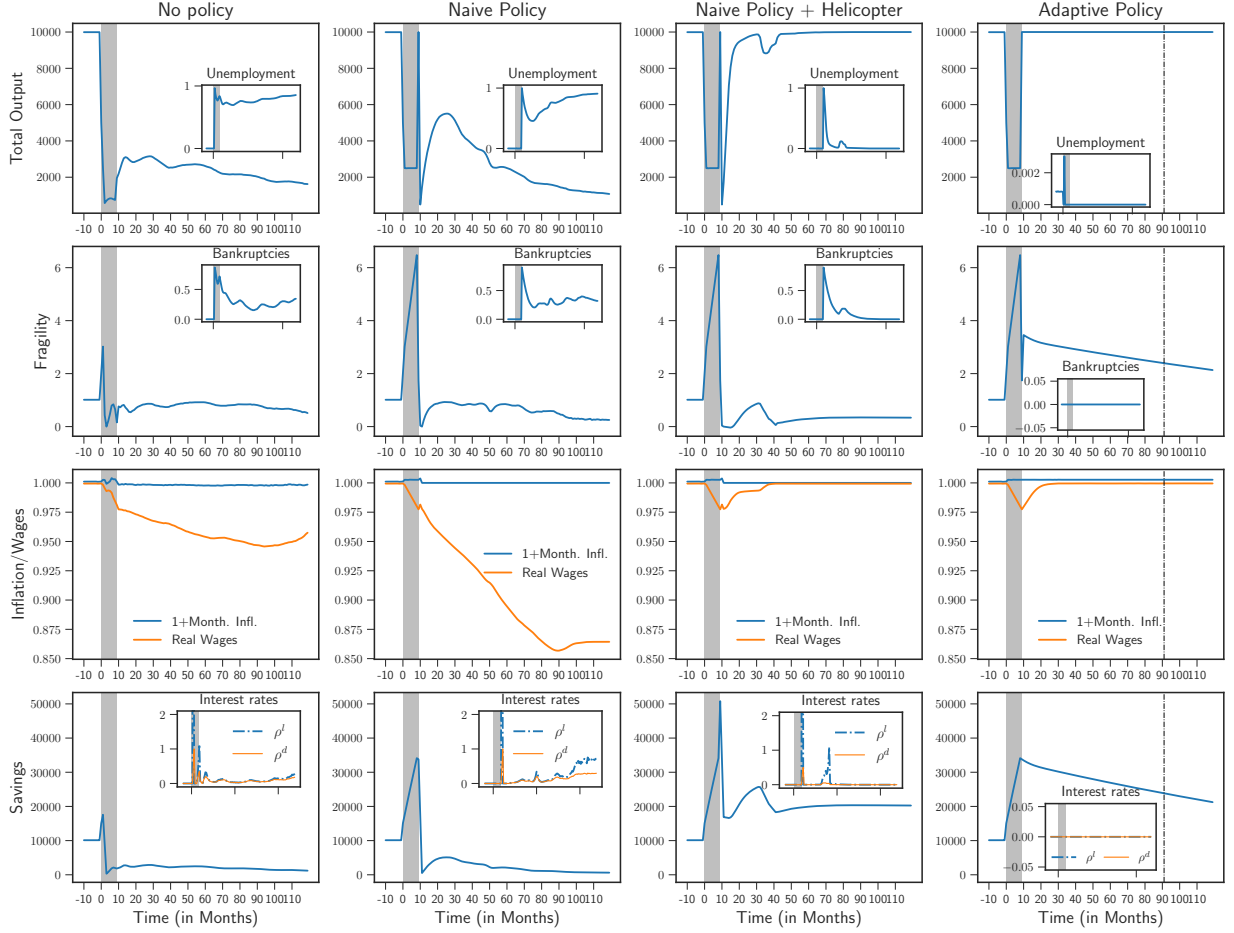


Figure 5: Scenarios for shock length of 9 months (marked in grey) with and without policy. *First column:* Similar to Fig. 4, the economy undergoes a severe and prolonged contraction. However, given the length of the shock, there is a deeper fall in the level of real wages with firms continuing to go bankrupt far after the shock has occurred. *Second Column:* The presence of the naive policy in this case is unable to rescue the economy and in turn exacerbates the situation. Given the already fragile nature of the firms, removing the easy credit policy abruptly leads to a further spate of bankruptcies. This leads to wages being depressed further and unemployment remaining high. *Third Column:* The introduction of helicopter money improves upon the naive policy intervention at the expense of the economy undergoing another endogenous crisis. This is the W-shaped scenario from Fig. 1. *Fourth Column:* The adaptive policy in this situation drastically improves the economic outcomes. The contraction in output is inevitable but by providing firms the support they need for as long as possible (for more than 6 years here), the policy is able to keep unemployment low and prevent any bankruptcies due to the shock. The vertical dotted line marks the end of this policy.

Consumption Shock - Shocklength = 9, $\Delta c/c = 0.7$

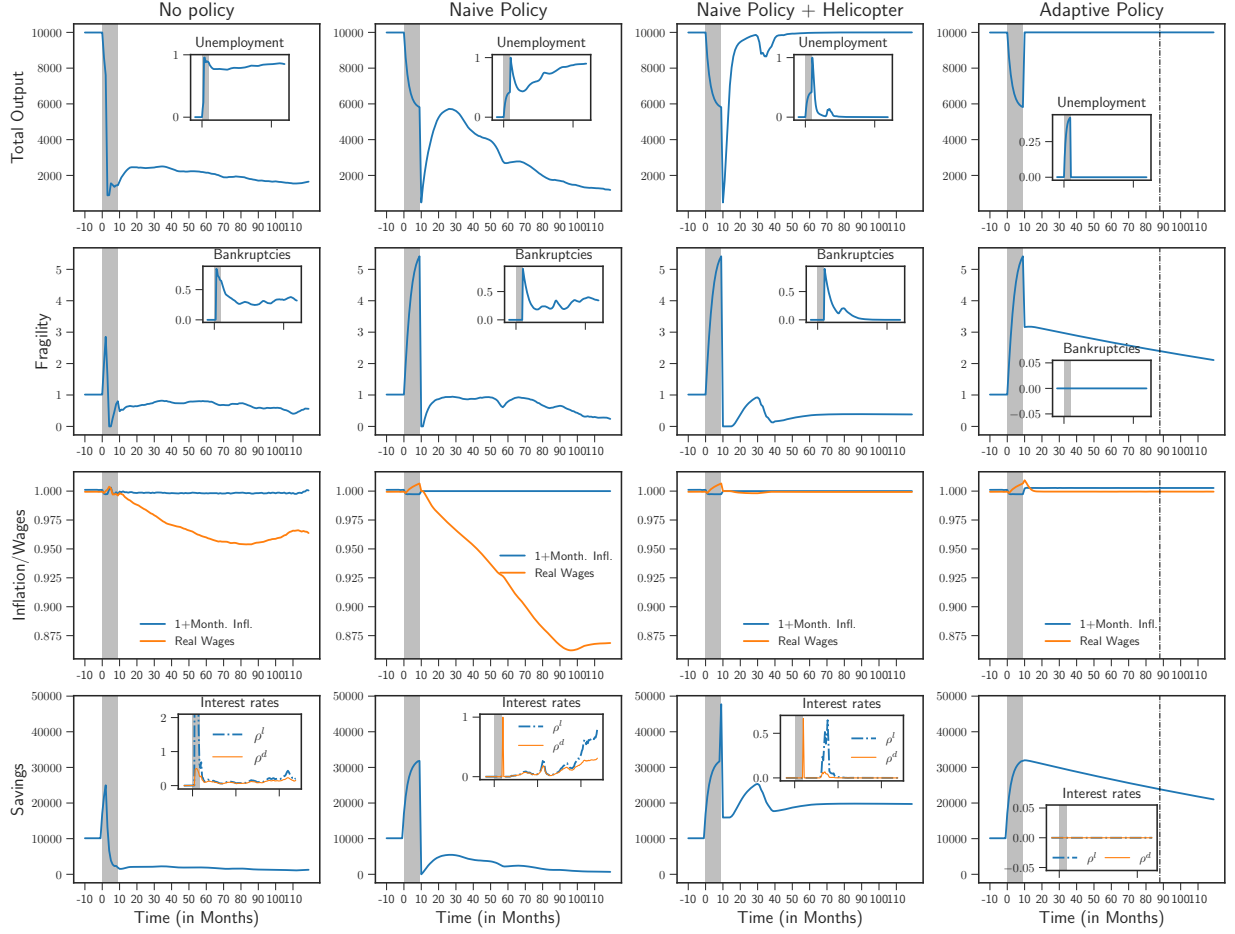


Figure 6: Scenarios for a severe consumption shock $\Delta c/c = 0.7$ of length of 9 months (marked in grey) with and without policy for a pure consumption shock. *First column:* A prolonged crisis with a deep contraction is observed similar to the situation shown in Fig. 5. *Second column:* The naive policy is not sufficient to mitigate the crisis. In fact, removing the policy as the shock ends leads to further contraction and higher rate of bankruptcies. *Third column:* With the presence of helicopter money to boost spending, we observe a rapid recovery. However, another short-lived crisis is observed after the initial shock-induced crisis (W-shape recovery). *Fourth column:* With an adaptive policy, we are able to prevent bankruptcies and keep unemployment in control as well.

Note that at the end of the shock, when c returns to its original value, households start to over-spend with respect to the pre-crisis level, because their savings increase during the shock (mirroring the increase of firms' debt) and they want to spend a fixed fraction of them, see Eq. (2). However, this over-spending can be insufficient to drive back the economy to its pre-crisis state.

Another possible policy is thus to inject cash in the economy to boost consumption and facilitate recovery. This is often nicknamed “helicopter money”. This involves the expansion of the money supply by the central bank and has multiple transmission channels: the central bank transfers cash directly to its citizens or it can transfer it directly to the government which in turn would spend it on healthcare or infrastructure projects. This policy has been considered radical due to the fear that an expansion in money supply might lead to runaway inflation. In normal times, there might be support for such a view, but it has been shown that a helicopter drop may not always be inflationary [18]. Given the enormity of the crisis, there have been calls from all corners for central banks to break “taboos” [7, 19, 20] and do what is necessary.

In this work, we implement a helicopter-money drop by assuming that the government distributes money to households multiplying their savings by a certain factor $\kappa > 1$: $S \rightarrow \kappa S$. The distribution takes place at the end of the shock, and we study here how the “naive policy” (for which Θ goes back to its baseline value immediately after the shock) can be improved by some helicopter money.

Results for $\kappa = 1.5$ are shown in Figs. 4, 5 in the third column (“Naive Policy + Helicopter Money”). We indeed see that in the case $T = 9$ months, for which the naive policy was not sufficient to prevent a prolonged recession, increasing the consumption budgets of households does allow the economy to recover. However, a quite interesting effect appears, in the form of a W-shape, or relapse of the economy, *even in the absence of a second lock-down period*. This “echo” of the initial shock is due to financially fragile firms that eventually have to file for bankruptcy when credit has tightened. This second blip is however temporary and the economy manages to settle back on an even keel. This experiment shows the importance of boosting consumption when the shock is over. A similar effect would be obtained if instead of the savings S , the consumption propensity c was increased post-lock-down. This echoes pleas from policy makers, wooing households into over-spending once the shock period is over. A combination of the two might indeed lead the economy to a faster recovery as shown in the U-shape recovery in Fig. 1.

We also studied the case of a pure, rather severe consumption shock $\Delta c/c = 0.7$ lasting $T = 9$ months in Fig. 6. We observe that a prolonged drop in consumption, without any loss in production, can still lead to long-lived crisis. The “naive” policy in this case is not enough to hasten the recovery. Direct cash transfer to households via helicopter money drop helps the economy recover faster but leads to a slow, W-shape recovery. Finally, the “adaptive” policy again works best in keeping unemployment low and ensures a rapid recovery.

5 Discussion & Conclusion

In this paper, we have discussed the impact of a Covid-like shock on the toy economy described by the Mark-0 Agent-Based Model developed in [6, 9, 10]. We have shown that, depending on the amplitude and duration of the shock, the model can describe different kind of recoveries (V-, U-, W-shaped), or even the absence of full recovery (L-shape). Indeed, as we discussed in [9], the non-linearities and heterogeneities of Mark-0 allow for the presence of “tipping points” (or phase transitions in the language of physics), for which infinitesimal changes of parameters can induce macroscopic changes of the economy. The model display a self-sustained “bad” phase of the economy, characterized by absence of savings, mass unemployment, and deflation. A large enough shock can bring the model from a flourishing economy to such a bad state, which can then persist for long times, corresponding to decades in our time units⁵.

We have then studied how government policies can prevent an economic collapse. We considered

⁵Whether such a bad phase is truly stable forever or would eventually recover (via a nucleation effect similar to metastable phases in physics) is an interesting conceptual point. It could also have practical implications because if recovery happens via nucleation, one could imagine triggering it via the artificial creation of the proper “nucleation droplet”, in the physics parlance. We leave this discussion for future studies.

two policies that are currently being implemented in several countries: helicopter money for households and easy credit for firms. We find that some kind of easy credit is needed to avoid a wave of bankruptcies, and mixing both policies is effective, provided policy is strong enough. We also highlight that, for strong enough shocks, some flexibility on firm fragility might be needed for long time (a few years) after the shock to prevent a second wave of bankruptcies [17]. Too weak a policy intervention is not effective and can result in a “swoosh” recovery or no recovery at all. Again, a threshold effect is at play, with potentially sharp changes in outcome upon small changes of policy strength.

Our results then suggest that governments should try to be on the safe side and do “whatever it takes” to prevent the economy to fall in a bad state, and stimulate a rapid recovery.

There are, however, some major limitations of our study. For example, in our model money is conserved and is essentially equal to zero (in real value) in the good phase of the economy, because any initial amount of money is washed away by inflation. Hence, total savings equal total debt (unless some helicopter money is injected). The interest rates on both deposits and loans are determined by a central bank via a zero-profit rule, in order to absorb the costs of defaults [6, 10]. Mark-0 thus correctly describes the firm bankruptcies due to excessive debt, and the resulting increase of the interest rate on loans (and decrease of the interest rate on deposits). However, in Mark-0 there is no splitting of debt into a “public” and a “private” sector, hence no competition between investments in corporate bonds and in government bonds. As a result, within the current framework we cannot model possible “panic” effects that would result from a ballooning public debt, which could potentially lead to an increase of the yield of government bonds, possibly resulting in runaway public debt, confidence collapse and hyperinflation. This is indeed the major objection currently being raised against a stronger governmental response.

Similarly, there is no coupling, in the current version of Mark-0, between a firm financial fragility and the interest rate on its debt (i.e. no extra risk premium for fragile firms). This could again lead to a run away mechanism and a collapse of the corporate sector. Modeling all these effects is possible within Mark-0, but we leave these important extensions for future work. We note that in any case our results show that the excess debt accumulated during the crisis decays (via excess inflation) over the scale of a few years, provided economic recovery is achieved.

Despite these limitations, we believe that our model is flexible enough and captures enough of the basic phenomenology to be used as an efficient “telescope of the mind” [8]. One can play with the parameters to investigate qualitatively the different scenarios that can arise under different policies and shocks. For instance, one could impose a different shock on the economy by reducing the value of R (the ratio of firms’ hiring and saving propensity), either by increasing the speed at which firms fire their employees, or by reducing the hiring rate.⁶ A low enough value of R indeed drives the Mark-0 economy to a bad state [9]. A different policy, which we did not consider here, is that the government pays the wages directly, allowing firms to keep their financial health unscathed. This can also easily be implemented in Mark-0, but should be roughly equivalent to an increase of Θ .

In this work, we did not investigate the feedback channels modeled by the awareness parameter Γ [see Eqs. (6) and (8)], which was set to zero throughout our work. A positive Γ means that firms’ hiring/firing propensity and wage policy depend on their financial fragility, which could lead to interesting effects. We again leave this for a future investigation.

As we have emphasized above, we have not investigated in this study the standard monetary policy tool, namely interest rate cuts. Whereas such cuts are not expected to play a major role in the short term management of the crisis, their effect on the long-term fate of the economy (in particular when the recovery is L-shape) can be important and should be examined as well. Readers interested in this issue can use the code available on-line [here](#).

Yet another direction for future investigations would be to consider the effect of successive lockdowns due to subsequent spikes of Covid infections. It would be interesting to study the different recovery patterns that can arise in this case and assess which policy strategy is the most effective, perhaps coupling Mark-0 with SIR-like models.⁷

Finally, we believe that one of the most needed extension of Mark-0 is to allow the role of inequalities

⁶This actually happened during the lock-down, as most hires were frozen.

⁷Note again, however, that W-shape recoveries can be observed in our model even in absence of a second wave of infections.

(of firm sizes and of household wealth and wages) to be discussed. One of the peculiarities of the Covid shock has been the asymmetry in the way the crisis has affected households, with lower spending by high-income households compounding the situation for low-income households [21]. Taking into account heterogeneities in income and effects of the shock would bring our ABM closer to reality, while addressing one of the most pressing issues of our current times.

References

- [1] Paul Hannon and Saabira Chaudhuri. Why the Economic Recovery Will Be More of a ‘Swoosh’ Than V-Shaped. *Wall Street Journal*, May 2020. Retrieved 12 June 2020.
- [2] Martin Eichenbaum, Sergio Rebelo, and Mathias Trabandt. The Macroeconomics of Epidemics. *National Bureau of Economic Research, Working Paper Series*, Mar 2020.
- [3] Warwick J. McKibbin and Roshen Fernando. The Global Macroeconomic Impacts of COVID-19: Seven Scenarios. *SSRN Electronic Journal*, pages 1–43, March 2020.
- [4] Luca Fornaro and Martin Wolf. Covid-19 Coronavirus and Macroeconomic Policy. *Barcelona GSE Working Paper Series*, March 2020.
- [5] Veronica Guerrieri, Guido Lorenzoni, Ludwig Straub, and Iván Werning. Macroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages? *National Bureau of Economic Research Working Paper Series*, 53(9):1689–1699, April 2020.
- [6] Stanislao Gualdi, Marco Tarzia, Francesco Zamponi, and Jean-philippe Bouchaud. Monetary policy and dark corners in a stylized agent-based model. *Journal of Economic Interaction and Coordination*, 12(3):507–537, Oct 2017.
- [7] Richard Baldwin and Beatrice Weder di Mauro. *Mitigating the COVID Economic Crisis: Act Fast and Do Whatever It Takes*. Vox CEPR Policy Portal, 2020.
- [8] Mark Buchanan. This Economy does not compute. *New York Times*, 2008. Retrieved 12 June 2020.
- [9] Stanislao Gualdi, Marco Tarzia, Francesco Zamponi, and Jean Philippe Bouchaud. Tipping points in macroeconomic agent-based models. *Journal of Economic Dynamics and Control*, 50:29–61, 2015.
- [10] Jean-Philippe Bouchaud, Stanislao Gualdi, Marco Tarzia, and Francesco Zamponi. Optimal inflation target: insights from an agent-based model. *Economics: The Open-Access, Open-Assessment E-Journal*, pages 1–19, Sep 2018.
- [11] Edoardo Gaffeo, Domenico Delli Gatti, Saul Desiderio, and Mauro Gallegati. Adaptive Microfoundations for Emergent Macroeconomics. *Eastern Economic Journal*, 34(4):441–463, Oct 2008.
- [12] Domenico Delli Gatti, Saul Desiderio, Edoardo Gaffeo, Pasquale Cirillo, and Mauro Gallegati. *Macroeconomics from the Bottom-up*. Springer Science & Business Media, 2011.
- [13] Frank Smets and Raf Wouters. An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association*, 1(5):1123–1175, Sep 2003.
- [14] R. Maria del Rio-Chanona, Penny Mealy, Anton Pichler, Francois Lafond, and Doyne Farmer. Supply and demand shocks in the COVID-19 pandemic: An industry and occupation perspective. *Covid Economics*, (6), Apr 2020.
- [15] Mark Carney and Ben Broadbent. Bank of England Monetary Policy Report May 2020. Technical Report May, Bank of England, 2020.

- [16] Pierre Aldama, Raphaël Cancé, Marion Cochard, Marie Delorme, William Honvo, Yannick Kalantzis, Guy Levy-Rueff, Emilie Lor-Lhommet, Jean-François Ouvrard, Simon Perillaud, Béatrice Rouvreau, Paul Sabalot, Katja Schmidt, Antoine Sigwalt, Camille Thubin, Youssef Ulgazi, Paul Vertier, and Thao Vu. Macro-economic projections June 2020. Technical report, Banque de France, June 2020.
- [17] Mary Williams Walsh. A tidal wave of bankruptcies is coming. *New York Times*, 2020. Retrieved 19 June 2020.
- [18] Willem H. Buiter. The Simple Analytics of Helicopter Money: Why It Works — Always. *Economics: The Open-Access, Open-Assessment E-Journal*, 8(1), 2014.
- [19] Sony Kapoor and Willem H. Buiter. To fight the COVID pandemic , policymakers must move fast and break taboos. *Vox CEPR Policy Portal*, 2020. Retrieved 12 June 2020.
- [20] Jordi Gali. Helicopter Money: the time is now. *Vox CEPR Policy Portal*, 2020. Retrieved 12 June 2020.
- [21] Emily Badger and Alicia Parlapiano. The rich cut their spending. that has hurt all the workers who count on it. *New York Times*, 2020. Retrieved 19 June 2020.