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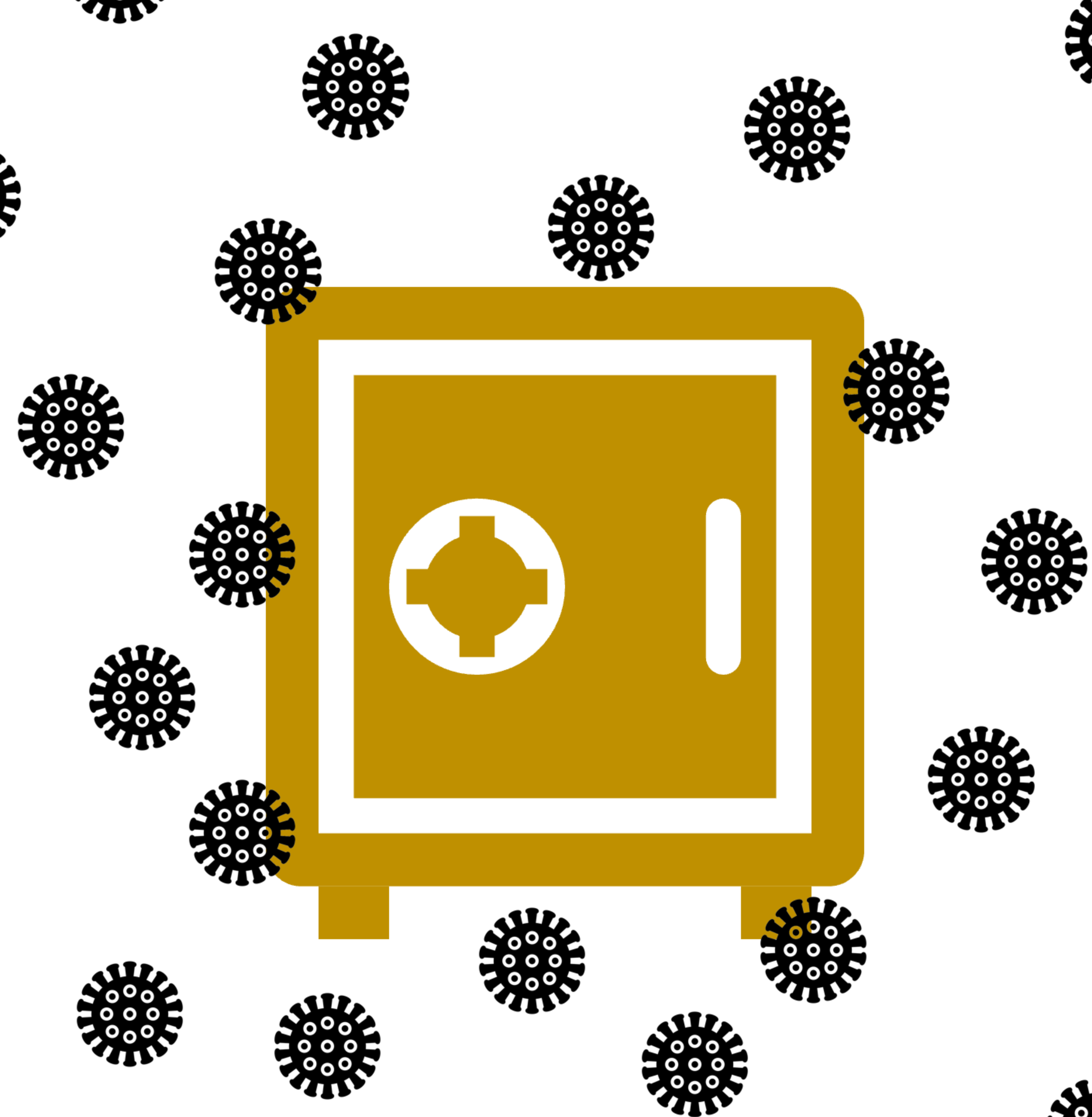

STRESS-TESTING COVID-19

AN EXPLORATORY STRESS-TEST SCENARIO FOR THE NEXT 36 MONTHS

DISCUSSION PAPER

MARCH 2020

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The report benefited from review and inputs by Mark Fulton (Energy Transition Advisors) as well as a series of stakeholders across financial supervisory authorities.

Note: Given the speed of the crisis, this paper is being disseminated as a discussion paper. It has not undergone 2° Investing Initiative's typical internal and external review process applied in the context of publishing reports. As a result, the paper may contain errors that would normally have been identified in such a process. The reader is asked to advise the author in case they identify any such errors.

The modelling in this report builds on the scenario analysis concept and toolbox developed for climate stress-test scenarios, previously developed in partnership with the California Insurance Commissioner, the Bank of England, and the European Insurance and Occupational Pensions Authority (EIOPA). It also builds on two discussion papers published in 2019 on mechanisms to develop long-term supervision frameworks.

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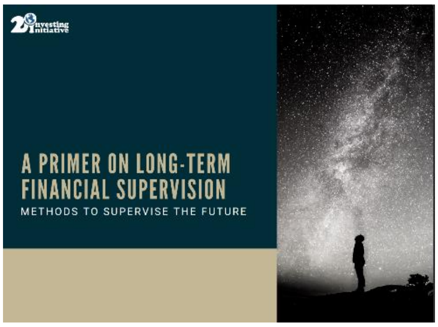

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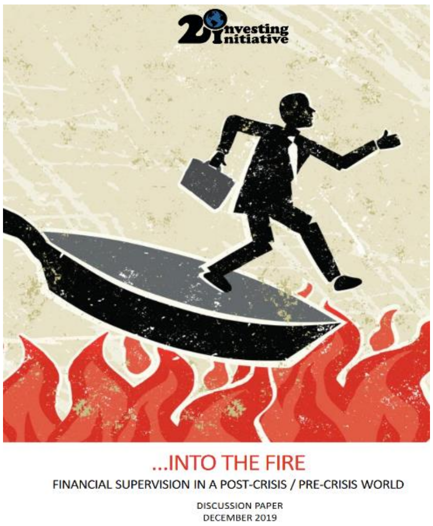


INTO THE FIRE: FINANCIAL SUPERVISION IN A POST-CRISIS / PRE-CRISIS WORLD (LINK)

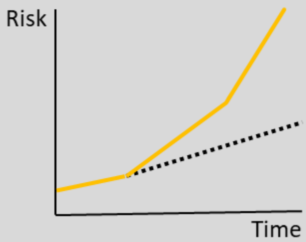
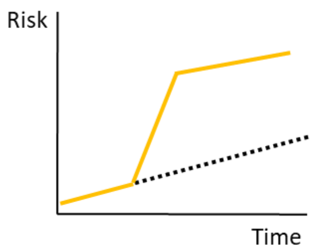
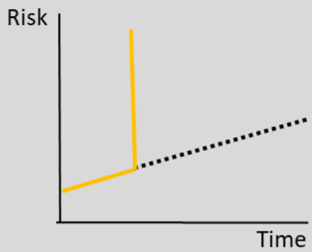
2° Investing Initiative (2°II) is a non-for-profit think-tank working to integrate long-term risks and societal goals into financial markets. With offices in Paris, London, Berlin and New York, the Initiative engages a global network of over 50 partners and members, including financial institutions, investment researchers, asset managers, policymakers, research institutions, academics and NGOS. Our work primarily focuses on three pillars of finance – metrics and tools, investment processes, and financial regulation.

I. Introduction

This paper provides a stress-test template for financial supervisors to simulate potential losses on banks' and insurers' balance sheets under 6 different COVID-19 pandemic scenarios over the next 36 months. It develops the nature of these scenarios and provides loss estimates that can be used as inputs to analysis of banks' and insurers' balance sheets. While valuation losses and credit spreads have already moved dramatically in the past month, this paper is not designed to recalculate what is already modelled but rather provide a toolkit for financial supervisors and institutions to scenario plan the next 36 months.

The stress-test scenarios cannot unfortunately enjoy a back office of a team of modellers developing scenarios over time and testing and calibrating them to ensure stress-test scenarios for this pandemic are ready and off the shelf. Unfortunately, financial supervision by and large still remains wedded to traditional stress-test formats without ensuring preparedness to existential and 'long-term risks', of which pandemic is one. Long-term risks in this context are in the "point in time" category (see Fig. below), which relates to 1 in 1000 type events which are very unlikely to happen at any given point but very likely to happen *at some point*.

The work on climate change stress-testing and scenario analysis has been a welcome exception to this rule, although these exercises have struggled to break through and into mainstream frameworks. Moreover, outside of climate change, save for a few think pieces and notes,[1] work on supervising long-term risks has been limited to non-existent.

Type of Risk	Definition	Risk Profile
Slow-Building	• Risks are slow to build at first but gain momentum over time so the expected impact of an event risk grows at a greater-than-linear rate over time. • Linear cash flow projections neglect the non-linear trajectory of the risk.	
De-Anchoring	• Status quo relies on artificial or regulatory safeguards or barrier(s) to competition. If barriers are removed, the risk to the future cash flows of incumbents spikes dramatically. • Linear cash-flow projections assume an artificial 'risk anchor', and thus do not account for the potential that it could be removed.	
Point-in-Time	• Probability of a high-impact event occurring in the short-term is low, but almost certain to materialize at some unforeseen point-in-time over the long-term. • Linear cash flow projections do not take such high-impact events with low immediate probability into account.	

[1] https://www.dnb.nl/en/binaries/QuartBullMar06_tcm47-147068.pdf

The pandemic stress-test scenario developed in this paper should be read in light of a reality that sophisticated models don't exist to develop such scenarios. As a result, the scenarios largely build on 'guesstimate' modelling using historical relationships identified in the academic and financial literature[2] and applying them to a series of scenarios for the further evolution of COVID-19. It builds on these historical scenarios, but seeks when possible to use forward-looking modelling of potential cash flows to identify valuation effects of this pandemic. Instead of a full-fledged macroeconomic model, it uses simple assumptions around the supply shock to labour due to mortality and sick days, as well as the demand shock due to mortality, to arrive at GDP effects. It augments these effects using simple assumptions around changes in sentiment and policy interventions – positive or negative.

The pandemic stress-test scenarios presented here lack a number of key indicators, notably exchange rates, sovereign spreads (and potential defaults), as well as unemployment. It thus is for all intents and purposes an incomplete exercise. However, to the extent that it does provide indicators, it represents the first attempt at developing a stress-test scenario specific to the type of pandemic currently under way in the form of COVID-19.

The paper should be read with an appreciation for the unchartered territory it seeks to enter. There are of course a range of studies on the potential financial effects of a pandemic in general.[3] The past few weeks have also seen a range of reports, blogs, or op-eds define potential effects to different markets, whether it be credit,[4] housing,[5] or equity, to cite just a few examples.[6] Here, a first attempt is made to represent, as close as seems currently realistic, an attempt at understanding what a COVID-19 stress-test should or could look like.

The stress-test scenarios in this report are organized according to a series of archetypes (Section 2) yielding 24 potential stress-test scenarios, of which 6 are presented in further detail in Section 3. The reality is that a stress-test like a pandemic must always anticipate an Armageddon scenario, which could be dramatically worse than anything modelled in this paper, a scenario explored in Section 4. And finally, it is important to understand the lessons for designing financial supervision moving forward, notably the need to graduate from short-term to long-term supervision as a way to prepare for risks like pandemics, climate change, and other mega risks before they materialize (Section 5).

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[2] Both the literature on pandemics and the broader stress-testing and economics literature.
[3] https://www.economics.ox.ac.uk/materials/working_papers/paper431.pdf & Lloyds "Pandemic insurance impact"
[4] https://www.ft.com/content/4455735a-63bc-11ea-b3f3-fe4680ea68b5
[5] https://www.nytimes.com/2020/03/13/business/buying-a-home-coronavirus.html
[6] https://emergingmarkets.blog.franklintempleton.com/2020/01/28/coronavirus-and-the-implications-for-emerging-markets/

II. Scenario archetypes

When designing a scenario archetype for a pandemic stress-test, there are three key elements to the simulation:

- The actual evolution of the virus itself in terms of its effect on public health and the subsequent implications for economic activity **(‘health effect’)**;
- The **‘sentiment effect’** of the virus in terms of investment and consumption patterns;
- The **‘policy response’** both in terms of monetary and fiscal policy that either offsets or aggravates the first and second component.

In total, this paper outlines 24 different outcomes for the global economy and financial markets over the next 36 months, based on four different health trajectories, two different sentiment responses, and three different types of policy responses. Section 3 will then go on to model 6 variations of these 24 possible combinations.

i) Health Effects

The stress-test scenario involves four potential health outcomes for the virus over the next 24-36 months:

Under a normal stress-test scenario, the least dramatic outcome would not be simulated (e.g. low penetration, low mortality). However, in the context of a pandemic, this scenario might still have a material effect that should be managed.

Globally, health effects are considered from the perspective of

1) How many individuals will be infected at which stage of the pandemic (“penetration”)?
2) How severe will the infection be in terms of loss of productivity, measured here in sick days (“severity”)?
3) What mortality rate will be associated with the pandemic (“mortality)?

These different factors are of course inter-related and may be mutually reinforcing. Higher levels of the pandemic penetration will likely increase mortality as healthcare services cannot sufficiently response to critical cases. Higher mortality will also likely be related to higher degrees of severity.

When thinking about these factors in a stress-test scenario, the key critical additional question is the timeline. Traditional stress-tests will frequently assume some level of bounce back at the end of the stress-test period. For the particular case of the pandemic, a similar dynamic seems likely, either as a result of a vaccination solution or higher immunity levels. However, the presence / deployment of these two aspects remains uncertain.

One critical choice that had to be made is whether mortality and penetration is dynamic in the sense of increasing / decreasing over time.

The health effects have a number of implications in terms of modelling their effects on the economy.

- **Loss of demand due to mortality**: The mortality rate will drive a short-term ‘demand shock’. Mortality seems to be focused in particular on the older population, which in some cases has higher and in other parts of the world lower purchasing power. In developed markets, the older population (“Baby boomers”) tend to have higher purchasing power, so a 3% mortality rate – assuming it is concentrated in the older generation – would be expected to have a higher than 3% effect on demand.[7] On the other hand, the demand of these individuals is driven by fixed assets rather than income in many cases, which would suggest that there may be a positive

[7]https://revelsystems.com/resources/generational-breakdown-purchasing-patterns/

wealth effect as these fixed assets get transferred, potentially offsetting some of the demand shock. To avoid over-complication, the first order demand shock will be calculated based on mortality, by simply assuming that the negative effect on GDP is one-to-one correlated with the loss in demand from victims of the virus.

- **Loss of labour supply due to illness**: Given the concentration of mortality among older people, mortality is likely to have a limited effect on the overall supply of labour, albeit not zero. For this exercise, we assume that only about 20% of mortality is among individuals working – given the current evidence of the distribution of mortality rates.[8] However, it is likely to have a more pronounced effect on the availability of labour as a result of illness. While at the moment the virus appears mild in the majority of cases, quarantine action and potential future mutations may change that. The "low mortality" scenario assumes an overall lower effect on labour availability given the assumption that lower mortality implies lower number of sick days. Nevertheless, given the need to quarantine and general uncertainty around the flu, as well as the objective to frame this as a stress-test, the scenarios developed here assume a 5 days labour loss for every ill patient under a low mortality scenario and a 10 day loss under a high mortality scenario. The 10 day loss would be truly dramatic, effectively doubling the average number of sick days in most jurisdictions.[9]

  Concretely, that means that a high mortality, high penetration scenario will lead to a loss of roughly 13% in labour supply. A low penetration, low mortality scenario in turn only leads to a labour supply loss of roughly 2.7%. Crucially, this 'supply shock' from labour does not translate one-to-one into GDP losses. First, labour is only one input into the production function, and as outlined below, it seems unlikely that capital and land will see a commensurate negative shock, although of course some capital may be stranded in the context of supply chain disruption and temporary under-utilization. Second, while the literature on this is limited, "sick days" do not translate one to one into loss in output as quantified through GDP. In some cases, it may reduce the quality of a good (e.g. a report written by a think tank builds on a lower number of research days), or the availability of a good not captured in GDP indicators (e.g. certain types of public services, household functions). A study by the Institute of Labour Economics suggests that a 1% percentage point increase in sick days translates to a 0.25% loss in output.[10] This percentage loss is applied to the total labour supply loss to derive GDP effects.

- **Effect on fixed assets (capital and land).** In principle, it is unclear how capital and land would be affected by the pandemic, unless restrictions on international trade are put in place by policy actions. At this stage, the scenarios assume that the effect on fixed assets is zero, although this effect will be revisited under the 'isolationist policy response'.

It is unclear how these different factors reinforce and articulate with each other. If there is a negative supply shock and a negative demand shock at the same time, it could be argued that the market simply resets at a new equilibrium. People will purchase less, but there will also be 'less to buy'. In such a scenario, the two shocks are not cumulative. However, the different scenarios for the COVID-19 virus sometimes demonstrate a higher supply shock and sometimes a higher demand shock. Moreover, there are obviously market frictions. For example, the health care sector will likely be particularly affected by a supply shock as a labour-intensive industry highly exposed to the virus. At the same time, the

[8] This figure is derived from the distribution of COVID cases using data from Italy (https://www.statista.com/statistics/1103023/coronavirus-cases-distribution-by-age-group-italy/) and global death rate data (https://www.worldometers.info/coronavirus/coronavirus-age-sex-demographics/).

[9] https://gateway.euro.who.int/en/indicators/hfa_411-2700-absenteeism-from-work-due-to-illness-days-per-employee-per-year/

[10] http://ftp.iza.org/dp11543.pdf

demand shock for that sector should be positive in the short run. Inversely, those affected by death are likely to have a higher share of their expenditure on health care services, in turn reducing demand.

In short, the interaction and articulation of supply and demand during a pandemic is complex. The scenarios presented here represent these effects as cumulative, but the application could obviously also consider that the demand shock – given that it is lower than the supply shock in almost all cases – does not aggravate the supply shock. Of course, as has been argued by some,[11] these shocks are 'exogenous' and so one might anticipate that the economy revitalizes when they subside. On the other hand, the supply shock driven by mortality is secular in the sense that they represent an irreversible loss in productive capacity.

The figure below shows the estimated supply and demand shock respectively under the four health scenarios. As these options are applied in later sections, it is assumed that immunity and vaccination drivers don't kick in until year three of the stress-tests.

Name	**Penetration**	**Severity**	**Mortality**	**Lost output**	**Loss of demand**	***If averaged***	***If considered cumulative***
High Penetration, High Mortality	80%	High	3%	-2.8%	-1.8%	-2.3%	-4.6%
High Penetration, Low Mortality	80%	Low	1%	-1.3%	-0.6%	-1%	-1.9%
Low Penetration, High Mortality	40%	High	3%	-0.8%	-0.9%	-0.9%	-1.7%
Low Penetration, Low Mortality	40%	Low	1%	-0.7%	-0.3%	-0.5%	-1%

THIRD PARTY SCENARIO: IMPERIAL[12]

Scientist at Imperial university in an analysis of the UK and US market predict that without response, roughly 81% of the population would be infected. The stress-test scenario applied here assumes 80% as a worst-case scenario for penetration, achieved at the latest by the end of the second year.

THIRD PARTY SCENARIO: BROOKINGS[13]

The Brookings Institute develops a number of scenarios in terms of preparation, all of which are at the lower end of the scale. Their scenarios only present attack rates for China., but assume these are limited

Scenario	**Countries Affected**	**Severity**	**Attack Rate for China**
1	China	Low	1.0%
2	China	Mid	10.0%
3	China	High	30.0%
4	Global	Low	10.0%
5	Global	Mid	20.0%
6	Global	High	30.0%
7	Global	Low	10.0%

[11] Including the UK Prime Minister Boris Johnson https://www.standard.co.uk/news/uk/economy-roaring-back-coronavirus-boris-johnson-a4388901.html
[12] https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/news--wuhan-coronavirus/
[13] https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/news--wuhan-coronavirus/

ii) Sentiment effect

The first part of the stress-test scenario, the pure ‘health effect’ may be aggravated by a sentiment effect. From a stress-test perspective, there are two options in terms of modelling the sentiment effect.

1) The scenario design can assume that the sentiment effect is essentially zero, implying that any short-term ‘over-reaction’ – defined here as a reaction not commensurate with the actual impact on output and demand – will be offset or recalibrated over a time horizon with no material affect the outcomes of the stress-test.

2) The alternative is a sentiment shock where there is a “permanent” over-reaction to the fundamental drivers of the health effect over the time horizon of the stress-test (36 months). There is limited to no meaningful literature on what such an over-reaction would look like, how it would materialize, and where exactly it would have an economic effect. To use a recent example, stockpiling, one type of potential over-reaction, has had a positive effect on UK growth pre-Brexit.[14]

Modelling sentiment shock is by design subjective, there is no meaningful way to anticipate what sentiment is likely to be, at least not with the tools currently available. Future stress-test scenarios may benefit from sentiment analysis of the kind currently being piloted by a number of central banks and financial supervisors.[15]

For the purposes of the scenarios presented here, a “permanent” over-reaction – defined as an over-reaction that persists over the time horizon of the stress-test, will have three effects. First, it will depress financial market prices more than the underlying fundamentals would suggest. Second, it is likely to depress investment. Third, it may depress demand as consumers try to consolidate their balance sheet in the face of uncertainty. Each of these aspects will be briefly discussed.

In terms of fixed capital formation, there is some evidence in the literature – and of course basic intuition - that business confidence drives investment levels. Khan et al. (2017) highlight this relationship based on the OECD business confidence index and US investment levels.[16] The question then however is a) what the expected business confidence index effect will be of each health scenario and if that effect will be consistent; b) how exactly that effect will depress investment; and c) how that depressed investment will impact growth.

Without further analysis and estimations, quantifying a)-c) is currently not feasible, in particular not within the scope of the exercise suggested here. However, one option is to simply assume that effect on output is equivalent to the ‘labour effect’ identified. In this case, the supply shock from labour is doubled. Such an impact cannot reasonably be derived from existing quantitative relationships, nor is it clear whether – given that it is a ‘sentiment’ shock – it should in practice differ under different health scenarios as consumers and businesses cannot anticipate which scenario will actually materialize prior to it materializing (this is particularly the case given the potential for the virus to mutate over time). However, a commensurate shock to labour provides a neat concept for a design of an exploratory scenario analysis of the kind suggested here. Alternatively, existing shocks from standard stress-tests could be considered. For example, the EBA has a -1% shock to investment growth.

In terms of demand shock, uncertainty is similarly high and quantification similarly impossible at this stage. However, there are certain reasons to believe that consumer sentiment shock is likely to be lower than the shock for capital. First, a loss in labour supply – all other things being equal – should lead to tighter labour markets which means that negative wage effects may be limited. Second, to the extent that there are shocks in demand for labour – for example in the “gig economy” reliant on trade shows,

[14] https://www.ifs.org.uk/uploads/GB2019-Chapter-2-Recent-trends-to-the-UK-economy.pdf
[15] https://bankunderground.co.uk/2019/02/28/whats-in-the-news-text-based-confidence-indices-and-growth-forecasts/
[16] https://carleton.ca/economics/wp-content/uploads/cep17-13.pdf

conferences, or the hospitality industry, such effects may be transient. They are visible right now, but once the pandemic scenario has "settled" it seems reasonable to assume a 'bounce back' of some sort. Moreover, while there may be a more permanent shock to certain types of consumption (e.g. travel), it is unclear whether this will actually increase savings rates, in particular if – as will be discussed later – monetary policy intervention will depress interest rates. Again, the overall scale of the sentiment effect however remains unclear. In both cases, the stress-test scenario in section 3 will rely on a "low" shock of 1.5 and a high shock of 2.

Finally, the question is what the potential effects on financial market prices are and potential 'over-shoots'. Here too, quantification is impossible. A number of studies find that consumer sentiment does not drive negative stock returns.[17] However, financial market participants responses to disasters can dramatically overshoot.[18] A study looking at aviation disaster suggests that market corrections overshoot actual costs by a factor of 60 but tend to normalize relatively quickly.[19] Such "over-estimation" of the costs would suggest that if for example the "correct" shock to share prices is -20%, a sentiment shock would amplify such a shock to perhaps -40% or -60%.

The existing academic literature on this topic is wildly inconsistent, with some studies finding no evidence of over-reaction,[20] others – like the "aviation" study described above finding over-reaction by a factor of 60. A scenario with no over-reaction would then be consistent with a 'no sentiment shock' concept. A somewhat date, if seminal contribution the literature by Thaler et al. (1985) finds an 'over-reaction' to loser stocks of around 20%. This reference point will be used for the scenario where a sentiment shock amplifies losses.

[17] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.471.8901&rep=rep1&type=pdf

[18] https://reader.elsevier.com/reader/sd/pii/S1062976910000840?token=70A2BE860E07C5A28D1443015AC92BDCD079ECDDBE79F2C5A425C184D4E1AE3A494F8A5471C7ABCE9CDA9F0FA99CEC84

[19] https://www.sciencedirect.com/science/article/abs/pii/S0304405X09002086

[20] https://www.imes.boj.or.jp/cbrc/cbrc-12.pdf

iii) Policy responses

The policy response is the third component of the pandemic stress-test. In principle, three types of scenarios can be envisioned for a policy response, which can act individually or in some combination:

1. **Isolation response.** An isolation response will involve creating barriers to the flow of people as well as goods and services. This response is likely to amplify the stress-test scenario results, given that it will increase costs, reduce supply given breakdown of supply chains, and more broadly inhibit the efficient trade of goods and services. The isolation response effect is likely to be primarily felt as a result of potential barriers to trade of goods and services. It is unclear what exact effect a reduction of travel will have. A study sponsored by the Global Business Travel Association focused on the Canadian market suggests a 1.5% effect on GDP, although this study is obviously part of an industry marketing effort.[21] Moreover, we don't expect to a see a 100% shock to business travel. For this exercise, a third of that effect may be reasonable as a baseline (0.5% loss of GDP).[22] In terms of trade of goods and services, analysis of more recent introduction of trade barriers tends to suffer from the fact that much of these trade barriers relate to standards (e.g. protection of intellectual property, licensing) rather than concretely quotas, and try to understand the economic effects of the dismantling of such trade barriers. As a result, analysis of the economic effects tends to suggest that trade liberalization is limited. Very recent US policy interventions on trade are likely too recent to draw meaningful conclusions and the analysis on Brexit trade barriers tends to conflate both trade and other effects associated with the departure of the United Kingdom from the European Union. One interesting role model for 'isolation policy' – albeit a somewhat dated one - may be the Great Depression. Recent analysis suggests a negative effect of the Smooth-Hawley Tariff Act, the defining policy intervention by the US government as way of erecting trade barriers, of around 1.2% reduction total factor productivity.[23] The isolation policy will thus assume an additional negative shock to GDP of 1.2%.

2. **Limited response.** A limited to no response scenario essentially assumes that there is no policy intervention. The results of such a scenario then are zero in terms of their effect on the health and sentiment outcomes described above. It seems unlikely that such a response leads to low mortality rates. Of course, even in a limited response, 'automatic stabilizers' of the social welfare system would be expected to offset some of the effects.[24]

3. **Aggressive response.** An aggressive policy response implies fiscal policy offsetting a negative demand shock through government expenditures and / or a negative supply shock through various bailouts or credit lines that allow business to survive. Government policies of course will determine or at the very least influence the direction of the health effect and the sentiment effect, as well as effects on credit defaults and stock prices. The case could be made that a high penetration, high mortality outcome in the context of an aggressive policy response is – based on what we know now, not a realistic scenario. In terms of GDP, there is no meaningful way to forecast a stimulus that does not exist. However, using the assumption that roughly 40% of aggregate demand is the public sector, the scenario around an aggressive policy response provides a simplistic assumption that 40% of the demand shock is offset by government fiscal policy. Of course, more ambitious scenarios could assume that the government offsets an even larger proportion.

[21] https://www.gbta.org/membership-and-communities/chapters-and-regions/canada/pressreleases/pages/rls_042215
[22] Of course, business travel will be affected independent of the policy response in the short-term, as evidenced now. However, the overall 'shock' to business travel is likely to abate once the pandemic dynamic 'normalizes'.
[23] https://cdn.vanderbilt.edu/vu-my/wp-content/uploads/sites/276/2011/09/14093131/2012-w18034-BCPR.pdf
[24] http://faculty.haas.berkeley.edu/arose/FM599.pdf

iv) Scenario combinations

The stress-test scenario framework suggested here involves four different components (penetration, mortality, sentiment, policy). It assumes essentially that the stress-test scenario stems from a health effect consisting of the penetration of COVID-19 and its mortality, amplified or mitigated by a sentiment effect and a policy response.

In theory, this framework generates 24 different scenario combinations. In practice however, it seems reasonable to assume that certain combinations are unlikely. For example, it seems unlikely that a 'benign' outcome of the pandemic – benign in inverted commas – will be coupled with an isolationist policy or a high sentiment effect.

That is not to say it is impossible that such a combination may materialize, simply that it seems more likely that isolationist policies will be coupled with a malign outcome of the pandemic. Similarly, based on current available evidence, high mortality seems unlikely in the context of low penetration, given the extent to which mortality will be a function of over-burdened health care systems.

For this paper, the shocks will be modelled based on five potential outcomes. These outcomes are classified as either 'benign', involving low penetration and low mortality, or 'malign', involving high penetration and high mortality. The second type of label is managed, involving low sentiment effects and aggressive policy responses, unmanaged, involving high sentiment effects and limited policy response, and aggravated, involving high sentiment effects and isolationist policy responses. The table below summarizes the six scenario combinations.

	Benign & managed	**Benign & unmanaged**	**Malign & managed**	**Maligned & managed – Low Mortality**	**Malign & unmanaged**	**Malign & aggravated**
Penetration	Low	Low	High	High	High	High
Mortality	Low	Low	High	Low	High	High
Sentiment	Low	High	Low	Low	High	High
Policy	Aggressive	Limited	Aggressive	Aggressive	Limited	Isolation

1. **Benign & managed.** Virus penetration remains low, with 20% penetration by December 2020 and 40% by December 2021 and the wide deployment of vaccines keeping penetration at 40% until 2022. Health care services – despite some early disruptions – ultimately are able to cope with the outbreak, ensuring mortality is contained at 1% on an annual basis. Despite some short-term disruptions – largely addressed through governmental intervention – sentiment effects are limited, amplifying the 'fundamentals' of the health effect by only 50%. Policy intervention is able to offset roughly 50% of the loss in demand. This mitigates some stock market effects and reduces credit default.

2. **Benign & unmanaged.** This scenario largely reflects the benign & managed health effect, albeit with a high sentiment shock and limited policy response.

3. **Malign & managed.** Virus penetration cannot be meaningfully contained, reaching 40% by December 2020 and 80% by December 2021. The benefit of the high penetration is higher degrees of immunity, ensuring a reduction to 40% of cases by 2022 at 1% mortality, potentially partly supported by the deployment of vaccines. A structured and efficient policy response – despite the severity of the outbreak – mitigates sentiment effects to a degree, keeping them at

roughly the level of a benign & managed outbreak. Policy response also ensures some offset of demand losses and broader support of credit and stock markets. This scenario will actually be split into two categories, one where mortality rate is high (3%), and a second one where it is assumes that a managed policy response helps contain mortality at "benign" levels of 1%.

4. **Malign & unmanaged.** The malign & unmanaged scenario largely mirrors that of the malign & managed scenario, except policy intervention remains limited or – to the extent that it does take place – provide ineffective. Sentiment shocks are high, doubling the expected GDP effects of the virus. Monetary policy is in place, but can only mitigate credit default and support asset prices to a point.

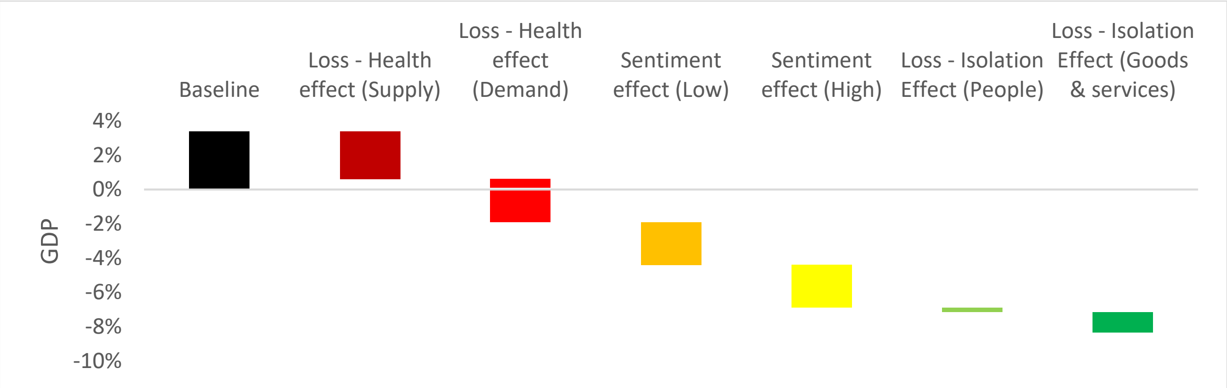
5. **Malign & aggravated.** This scenario largely mirrors the malign & managed scenario, however with policy response aggravating the health effects through the implementation of barriers to the flow of goods, services, and people across borders on a permanent level. This scenario is also supported by high sentiment effects.

IV. Stress-test scenario indicators

i) GDP

The worst-case scenario modelled in this report – except for the "Armageddon" scenario outlined in the next section – is a global drop of real GDP from a baseline value of 3.3% (based on IMF forecast) to minus 2.6%, for a total decline of 5.9%. Such a scenario assumes a pandemic with a high mortality and penetration rate, a significant sentiment aggravation of the adjustment and an isolationist policy response. The real GDP decline of such a pandemic is lower than the 8.3% shock anticipated in the EBA 2020 Adverse Growth Scenario stress-test[25] for example, as well as the shock of the Federal Reserve stress test scenario.[26] The equivalent scenario with a "limited policy response" assumption would yield a negative shock of 4.6%.

Crucially, these effects are specific to the pandemic. They may be compounded by reinforcing additional mechanisms, notably wealth effects depressing demand. By extension, the exact ramifications of a secular shock to output in the context of a stress-test scenario versus the cyclical nature of shocks is unclear.



The following table highlight the GDP effects in terms of GDP reduction relative to baseline growth under the 5 scenario combinations selected above.

	2020	2021	2022	Cumulative loss of output
Benign & managed	-0.7%	-1.4%	-1.4%	-3.5%
Benign & unmanaged	-1.1%	-2.1%	-2.1%	-5.3%
Malign & managed	-3.4%	-6.8%	-1.4%	-11.6%
Malign & managed – Low mortality	-1.4%	-2.9%	-1.4%	-5.7%
Malign & unmanaged	-5.2%	-10.3%	-2.1%	-17.6%
Malign & aggravated	-6.6%	-11.8%	-3.6%	-22.0%

THIRD PARTY SCENARIO: ECB[27]
While not publishing specific forecasts, the ECB Governor Lagarde has communicated to heads of state estimates of GDP effects of between 2 to 10% in 2020, with 10% being an extreme outlier, and a more likely range of 2-5%. These estimates are consistent with the GDP shocks in this paper, although a 10% shock does materialize in 2021 as the pandemic exacerbates.

[25] https://www.esrb.europa.eu/mppa/stress/shared/pdf/esrb.stress_test200131~09dbe748d4.en.pdf
[26] https://www.federalreserve.gov/newsevents/pressreleases/files/bcreg20200206a1.pdf
[27] https://www.faz.net/aktuell/wirtschaft/coronavirus-ezb-chefin-erwartet-konjunktureinbruch-von-5-prozent-16684805.html?GEPC=s5&premium=0x793244b1e977d613c82ebe0d472e199b

THIRD PARTY SCENARIO: BROOKINGS[28]

The Brookings Institute provides shocks to consumption demand, which are driven by both mortality and other factors (notably unemployment). The worst case scenarios modelled in this paper most closely adhere to the SO5 scenario (see table below) and are significantly lower than the SO6 scenario shocks.One primary driver of the difference is that the scenarios only consider a sentiment multiplier to the 'health' related demand shocks and not the extent to which unemployment drivers aggravate these effects. On the other hand, this paper also assumes that first we have a supply shock and then the demand shock is 'additional' to the supply shock, without clarifying how these two drivers articulate and will in practice be additional. When taking the supply and demand shock together, the worst case scenarios presented in this paper are roughly consistent with the SO6 scenario below, although this paper also then adds other negative drivers to GDP.

Meanwhile the aggregate GDP effects of the paper are similar to the ranges of this report.

Table 7 – Shocks to consumption demand

Region	S04	S05	S06	S07
Argentina	- 0.83	- 2.09	- 3.76	- 0.83
Australia	- 0.90	- 2.26	- 4.07	- 0.90
Brazil	- 0.92	- 2.31	- 4.16	- 0.92
Canada	- 0.90	- 2.26	- 4.07	- 0.90
China	- 1.00	- 2.50	- 4.50	- 1.00
France	- 0.93	- 2.31	- 4.16	- 0.93
Germany	- 0.95	- 2.36	- 4.25	- 0.95
India	- 0.91	- 2.29	- 4.11	- 0.91
Indonesia	- 0.86	- 2.15	- 3.86	- 0.86
Italy	- 0.93	- 2.32	- 4.18	- 0.93
Japan	- 1.01	- 2.51	- 4.52	- 1.01
Mexico	- 0.89	- 2.22	- 4.00	- 0.89
Other Asia	- 0.95	- 2.38	- 4.28	- 0.95
Other oil producing countries	- 0.92	- 2.31	- 4.16	- 0.92
Republic of Korea	- 0.89	- 2.23	- 4.01	- 0.89
Rest of Euro Zone	- 0.98	- 2.45	- 4.40	- 0.98
Rest of OECD	- 0.92	- 2.31	- 4.16	- 0.92
Rest of the World	- 0.98	- 2.45	- 4.42	- 0.98
Russia	- 0.92	- 2.31	- 4.16	- 0.92
Saudi Arabia	- 0.74	- 1.86	- 3.35	- 0.74
South Africa	- 0.82	- 2.05	- 3.69	- 0.82
Turkey	- 0.88	- 2.19	- 3.95	- 0.88
United Kingdom	- 0.94	- 2.34	- 4.22	- 0.94
United States of America	- 1.06	- 2.66	- 4.78	- 1.06

[28] https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/news--wuhan-coronavirus/

ii) Inflation & oil prices

All four health scenarios are likely to have a negative effect on inflation, although the policy efforts may offset that. Negative effects on inflation will be driven by reduction in growth putting less pressure on prices, and the high sensitivity of commodities to growth. The already apparent drop in oil prices is testament to that effect. At the same time, it seems likely that health care goods for example will see a positive effect on inflation, as already evidenced anecdotally for hand sanitizer and face mask products. Without a macroeconomic inflation model, the best that can be done at the moment is to provide educated guesses as to the sensitivity of inflation.

The ‘direct’ health effect on inflation is likely to primarily effect commodity prices given the sensitivity of commodities to demand and the volatility of prices. Oil prices in particular will be affected given the reduction in transport demand. Already, oil prices have dropped around 50% (see Fig. below). Using a relationship of 0.17 between oil prices and agricultural commodities identified by Baffes (2007),[29] the immediate inflation effect of an oil price shock on agricultural commodities for example is 0.17. Depending on the consumer basket used to measure inflation, the exact shock of commodities and its pass-through across a broad set of sectors, this effect will obviously be different.

Moreover, this still leaves unresolved the broader relationship between inflation and growth. Modelling the sentiment and policy effect on inflation is again less intuitive. A number of aspects are likely to mitigate deflationary pressures, notably price increase in the health sector, the expected limited effect on housing prices (discussion below), and potential offsets through government demand. Again however, an inflation model would be required to fully map these effects.

[29] Baffes, John (2007, Aug.) ‘Oil spills on other commodities’. World Bank Policy Research Working Paper4333 [Accessed: 15.03.2012]. Available from: <http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2007/08/28/000158349_20070828090538/Rendered/PDF/wps4333.pdf>.

THIRD PARTY SCENARIO: BROOKINGS[30]

The Brookings scenario does not explicitly model inflation, but does provide indication for increased production costs which reach up to 0.5%. The higher bound is used in this stress-test scenario as the inflation above 0% reference point for all other sectors.

The following approaches could be considered, mapped to the health scenarios described above, although of course – given the uncertainty – either outcome or a different outcome may be associated with these dynamics. The estimates are based on the HICP basket of the European Union and would of course be different in different markets:

- **The zero-inflation outcome under a low penetration scenario.** The pandemic essentially causes inflation to go to 0% across all sectors except for the health care sector, where pressure on prices creates significant inflation of around 10%. While some short-term inflationary pressures on certain goods (e.g. groceries) may materialize, these do not persist in the scenario. Prices are prevented from going into deflation territory by government and monetary policy intervention, as well as a low penetration scenario ultimately mitigating some of the GDP effects. Under such a scenario, overall inflation is likely to drop 50%. In Europe, this would imply a drop of inflation from 1.4% to 0.7% and globally from 3.4% to 1.7%.

- **The deflation outcome under a high penetration scenario.** The high penetration scenario shock to growth, coupled with a collapse in agricultural commodity and oil prices, and price wars in the hotel and transport sector create a deflationary dynamic. A 10% price drop in air transport and 0% inflation for transport more generally, a 10% drop in agricultural commodities, coupled with a 25% price drop in fuel prices, partially offset by a 10% price increase in health care services, with all other inflation drivers staying constant, would – for the European Union – imply deflation of roughly -1.8%.

Name	Health costs	Food & beverage	Air transport	Fuels	Other transport	Other	Baseline (EU)	Scenario
Malign (“Deflation outcome”)	+10%	-10%	-10%	-25%	0%	Unchanged	1.4%	-1.8%
Benign (“O Inflation outcome”)	+10%	0.5%	0.5%	0.5%	0.5%	0.5%	1.4%	1%

[30] https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/news--wuhan-coronavirus/

iii) Unemployment effects

A limited set of existing studies suggest a medium-term positive effect of pandemics on employment and wages. This is intuitive, since pandemics at differing scales represent a negative shock to labour supply. That is why the core modelling work presented here does not focus on employment effects, both in the previous and subsequent sections. That is not to suggest short-run negative and positive fluctuations, but rather over 1-3 year periods.

However, there are potential negative shocks accruing from social isolation and distancing may have significant negative employment effects in service sectors affected by these practices (tourism, restaurants, etc.). In Europe the relevant sector (ETOVG_I: Distrib. trade, repairs; transp.; accommod., food serv. activ.) represents about 25% of total employment.

For simplicity and given that certain sub-sectors under this category are not affected, we assume a 10% shock to the employment in that sector under a benign scenario and a 20% shock under a malign scenario, multiplied by the standard 1.5 and 2x sentiment factors. It is assumed that policy offsets 40% of the unemployment shock under a managed scenario. No additional unemployment aggravation is assumed under the aggravated scenario.

	2020	2021	2022
Benign & managed	1.4%	1.4%	0.0%
Benign & unmanaged	4.8%	4.8%	
Malign & managed	2.9%	2.9%	
Malign & managed – Low Mortality	2.9%	2.9%	
Malign & unmanaged	9.6%	9.6%	
Malign & aggravated	9.6%	9.6%	

iv) Real estate prices

The empirical evidence on the relationship between real estate prices and pandemics – limited as it is – suggests a very limited effect of pandemics and related health events on housing markets. The price elasticity of housing demand is relatively limited and given the incredible pressure on housing in many jurisdictions, this analysis suggests that 'at best' the pressures will lead to a reduction in price increases, but not a shock to housing prices.

At the same time, the potential economic dislocation engineered by policy-mandated or consumer and employer driven social distancing policies and actions may generate an additional disruption to housing markets in response to employment effects. This section will first present housing price shocks focusing on the pure supply-demand dynamic without material permanent employment effects,[31] and then provide an additional scenario which takes into account employment effects from the social isolation & distancing policy.

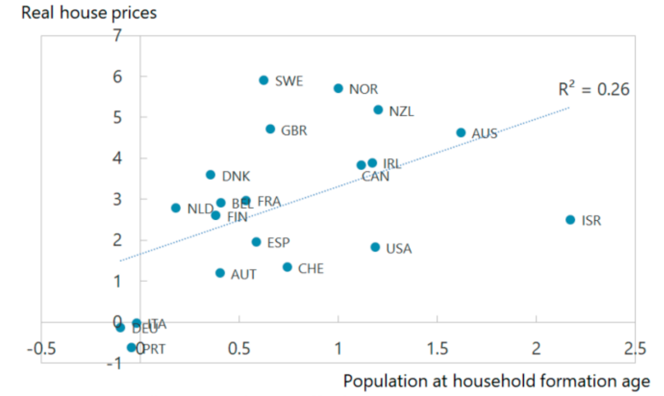
The particular nature of how a pandemic affects GDP suggests that other typical drivers depressing housing prices are not in play neither. Reduction in the supply of labour – all other things being equal – is likely to have a positive effect on wages. Of course, the only real role model at the scale under consideration here is the Spanish Flu or going back further, events like the Bubonic Plague, for which data is scarce and comparability unclear.

The two most striking effects why the immediate health effect should have limited effects on real estate prices are the following:

III. With the exception of the Global Financial Crisis, where the crisis was a result of a housing downturn, real estate prices tend to be relatively resilient to recessions.

IV. While mortality will depress demand given a reduction of supply, the statistical relationship will be limited. An 80% penetration, 3% mortality rate implies an eventual reduction in demand of 1.8%. If we take the statistical relationship as given, every 1% reduction in population growth reduces housing prices by about 1.6%.[32] The challenge here is that the analysis from the IMF involves almost exclusively examples with positive population growth so it remains unclear if the relationship holds at negative levels. Moreover, the statistical fit is relatively poor, suggesting a range of different outcomes.

Figure 8. House Prices and Population
(Average annual percent change from 1995: Q1 to 2016: Q4)



Sources: OECD, Dallas FED, and IMF staff calculations.

[31] Permanent, defined here as elsewhere as existing over the time horizon of the stress-test scenario.
[32] https://www.imf.org/en/Publications/WP/Issues/2018/07/13/Fundamental-Drivers-of-House-Prices-in-Advanced-Economies-46053

Policy interventions, notably by supervisors and central banks, would be expected to mitigate some of these effects, if they are not of isolationist nature. Sentiment effects on the other hand may amplify shocks to housing. However, it is difficult to mitigate effects from a policy perspective when driven by fundamentals of the kind a pandemic generates at the basis of supply and demand. At best, policy intervention can likely impact sentiment effects.

The table below provides the stress-test indicators for housing prices. The shocks are calibrated based on the assumption of 0% population growth at long-run price housing price growth at that level of 1.8%. Obviously, they would need to be recalibrated based on specific jurisdictions baselines.

	2020	**2021**	**2022**
Benign & managed	1.3%	0.8%	0.8%
Benign & unmanaged	1.2%	0.5%	0.5%
Malign & managed	-1.1%	-4.0%	1.1%
Malign & managed – Low Mortality	0.8%	-0.1%	0.8%
Malign & unmanaged	-2.0%	-5.9%	0.5%
Malign & aggravated	-2.0%	-5.9%	0.5%

There is really no meaningful empirical reference point we could identify on the question of how unemployment might affect housing prices. While there is some understanding of the relationship between default rates and home prices (see next section), the broader dynamic remains unclear. The empirical literature on the relationship between employment and housing prices is mixed, with a lot of the literature actually focusing on the impact of housing prices on employment[33][34] or - when looking at both variables – find a stronger relationship from housing prices to unemployment.[35]

One challenge is the lack of panel and time series data that meaningfully captures that relationship, with the Global Financial Crisis being usually the dataset of choice when looking at this question. The challenge of course is that the unique dynamic of inflated housing prices and subprime mortgages somewhat potentially confuses the picture when using that reference point.

For the moment, the stress-test scenario provided here is thus unable to simulate aggravated effects through unemployment.

[33] http://www.centreformacroeconomics.ac.uk/Discussion-Papers/2015/CFMDP2015-07-Paper.pdf
[34] http://www.centreformacroeconomics.ac.uk/Discussion-Papers/2015/CFMDP2015-07-Paper.pdf
[35] https://www.um.edu.mo/fba/irer/papers/forthcoming/IR170105R2%20Asymmetric%20Causality%20Unemployment%20&%20House%20Price%20in%20USA%20(Bahmani-Oskooee%20&%20Ghodsi).pdf

v) **Mortgage default**

Again, assuming a benign employment and house price trajectory, mortgage default rates will likely be constrained. However, more dramatic employment effects at semi-permanent levels are likely to meaningfully elevate mortgage defaults.

One of the most relevant studies for the exercise of interest here is from 2014 looking at micro data and housing price movements.[36] It finds that a 1% increase in unemployment increases the monthly default risk by 3.6 to 6.3 basis points. Using 50 basis points as a baseline, that implies roughly a 6-12% increase in defaults relative to the baseline, assuming this relationship gets translated into actual defaults. The baseline default rates for a series of jurisdictions is provided below.[37]

Market Forecasts

		Page	Nominal Home Prices (% Change Yoy)			Arrears (%)			Gross New Mortgage Lending (% Change Yoy)			Overall Market Evaluation	
	Country		2018 estimate	2019 forecast	2020[e] forecast	2018 estimate	2019 forecast	2020[e] forecast	2018 estimate	2019 forecast	2020[e] forecast	Outlook[f]	Change vs 2018[g]
North America	USA	11	5.6	4.1	▲	1.8[c]	1.8[c]	▶	-9.0	0.0	▲	Stable	▶
	CAN	12	3.0	0.5	▲	0.3[c]	0.3[c]	▲	2.9[d]	1.5[d]	▲	Stable/ Negative	▶
Europe	UK	13	2.5	2.0	▲	0.9[c]	1.1[c]	▲	0.0	-12.5	▲	Stable/ Negative	▶
	GER	14	8.9	3.5	▲	0.1[c]	0.1[c]	▶	2.5	2.0	▲	Stable	▼
	NLD	15	10.0	7.0	▲	0.2[h]	0.2[h]	▲	1.0	1.0	▲	Stable	▶
	FRA	16	2.8	1.5	▶	1.2[b]	1.2[b]	▶	-35.0	-15.0	▼	Stable	▼
	BEL	17	2.0	2.0	▲	1.1[c]	1.1[c]	▶	-10.0	-10.0	▼	Stable	▶
	DEN	18	3.5	3.0	▲	0.2[c]	0.2[c]	▲	2.0	1.4	▲	Stable	▶
	SWE	19	-4.0	-3.0	▲	n.a.	n.a.	n.a.	5.8[d]	2.4[d]	▲	Stable/ Negative	n.a.
	NOR	20	1.5	1.0	▲	0.2[c]	0.2[c]	▲	6.1[d]	4.9[d]	▲	Stable	▲
	IRL	21	8.0	9.0	▲	9.5[b]	8.8[b]	▼	24.0	18.1	▲	Stable/ Positive	▼
	ESP	22	6.0	5.0	▲	6.4[b]	6.0[b]	▶	10.0	7.5	▲	Stable/ Positive	▶
	ITA	23	-0.1	0.0	▶	8.0[b]	7.7[b]	▶	3.0	3.0	▲	Stable	▼
	PRT	24	6.5	6.0	▲	5.2[b]	5.0[b]	▶	20.0	15.0	▲	Stable/ Positive	▶
	GRC	25	0.5	1.0	▲	33.2[c]	33.2[c]	▶	-5.0	0.0	▶	Stable	▼
	AUS	26	-6.1[a]	-5.0	▶	0.6[b]	0.6[b]	▲	5.0[d]	3.5[d]	▲	Stable/ Negative	▼
	CHN	27	2.0[a]	0.0[a]	▶	0.3[c]	0.3[c]	▶	17.0[d]	15.0[d]	▲	Stable	▶

As outlined above, the immediate unemployment effects of the pure health effect are expected to be limited and depending on the exact nature of the pandemic, could even be positive as a function of a negative labour supply shock. We thus assume very limited effects to mortgage defaults, which are not further modelled here. However broader economic disruption through social distancing / isolation policies may generate more pronounced unemployment effects, in particular in specific sectors. As outlined above, measuring and modelling such effects is unchartered territory. However, the results of such estimates can be considered in how they might affect default rates.

[36] https://faculty.wharton.upenn.edu/wp-content/uploads/2017/05/Reconciling-theory-and-empirics-on-the-Role-of-Unemployment-in-Mortgage-Default.pdf
[37] https://www.lma.eu.com/application/files/4215/5066/7567/Global_Housing_and_Mortgage_Outlook_-_2019.pdf

Using the higher end of the spectrum and based on the unemployment shock assumptions described above for EU-28, this would imply the following increases in defaults, using a baseline of 1.2% default for a "low default baseline" country and a 6% "high baseline" country.[38] The defaults are modelled using that defaults peak in 2021 with a halfway increase reached in 2020, a peak in 2021, and a return to baseline levels by 2022. The peaks are calculated based on the unemployment shocks from the social isolation / distancing policy explored previously multiplied by the sentiment multiplies for the managed and unmanaged variations.

	Type	2020	2021	2022
Benign & managed	Low default rate (1.2%)[39]	1.3%	1.4%	1.20%
Benign & unmanaged		1.5%	1.9%	1.20%
Malign & managed		1.4%	1.6%	1.20%
Malign & managed – Low Mortality		1.4%	1.6%	1.20%
Malign & unmanaged		1.9%	2.6%	1.20%
Malign & aggravated		1.9%	2.6%	1.20%
Benign & managed	High default rate (6%)[40]	6.5%	7.0%	6.00%
Benign & unmanaged		7.7%	9.5%	6.00%
Malign & managed		7.0%	8.1%	6.00%
Malign & managed – Low Mortality		7.0%	8.1%	6.00%
Malign & unmanaged		9.5%	12.9%	6.00%
Malign & aggravated		9.5%	12.9%	6.00%

[38] The default rate baseline is based on France https://www.lma.eu.com/application/files/4215/5066/7567/Global_Housing_and_Mortgage_Outlook_-_2019.pdf
[39] Ibid.
[40] The default rate baseline is based on Spain https://www.lma.eu.com/application/files/4215/5066/7567/Global_Housing_and_Mortgage_Outlook_-_2019.pdf

vi) Stock market prices

The stock market shocks are simulated using a discount cash flow model simulation. The exact articulation and calibration of such a simulation involves a number of choices exogenous to the health effect, including assumptions around risk premiums, potential over-reactions, and the extent to which the GDP effects (the fundamentals) translate into alternative prices. Ultimately, all that to say that such a simulation can be designed in multiple different ways and formats.

The simulations designed here involve the following assumptions:

	Baseline	**Stress-test scenario**
Cash flow growth	3.4%	Estimated corporate profit growth assuming that the GDP shocks accrue 100% to the private sector, with the government sector continuing to grow at global growth rate. Profit margins move pro-cyclically[41] and are assumed to drop by 20% under the benign scenarios and 40% under the malign scenarios over the next 3 years, after which they recover to pre-crisis levels. Drop in profit margin are based on a 50% or "full" replication of drops in profit margin during the financial crisis.[42]
Discount rate	5%	7.5% for the first 5 years,[43] then 5%, assuming a 50% increase in the risk premium.
"Over-reactions"	NA	20% over-reaction relative to fundamentals.
Time horizon	2050	2050
Terminal value	0	0

The results of modelling a 'rational' run-through of a stress-test can be seen below. To put this number into context, the FTSE100 has lost about 28% since the beginning of the COVID-19 crisis, suggesting – based on the stress-test figures below, a market anticipation somewhere between a benign and malign scenario. Of course, these effects may be amplified by a broader market correction driven by other business cycle dynamics. Another crucial factor is that the model – given the extent to which a pandemic represents a permanent and irreversible destruction of demand – does not involve a recovery.

The table below represents valuations relative to the 2019 baseline.

	2020	**2021**	**2021**
Benign & managed	-23.0%	-22.9%	-22.5%
Benign & unmanaged	-24.1%	-24.0%	-23.7%
Malign & managed	-35.2%	-34.5%	-33.4%
Malign & managed – Low mortality	-34.9%	-34.3%	-33.4%
Malign & unmanaged	-36.3%	-35.6%	-34.4%
Malign & aggravated	-38.4%	-37.7%	-36.5%

[41] https://www.researchgate.net/profile/Stephen_Millard/publication/253135790_Working_Paper_No_351_The_cyclicality_of_mark-ups_and_profit_margins_for_the_United_Kingdom_some_new_evidence/links/556da5fe08aeab7772244250.pdf

[42] https://www.nasdaq.com/articles/what-relationship-between-corporate-profits-and-gdp-2015-10-30

[43] This is based on observed adjustments to the risk premium under the financial crisis. https://s3.amazonaws.com/academia.edu.documents/30681292/W97_The_equity_risk.pdf?response-content-disposition=inline%3B%20filename%3DThe_equity_risk_premium_amid_a_global_fi.pdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIWOWYYGZ2Y53UL3A%2F20200315%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Date=20200315T155147Z&X-Amz-Expires=3600&X-Amz-SignedHeaders=host&X-Amz-Signature=426b5bdf1457d0281b454e1d81ffceef81f953321ca690d51814e0982dabbf34

THIRD PARTY SCENARIO: BROOKINGS[44]

The Brookings Institute developed a range of equity risk premia across a number of different countries. These premia range from 1.111 to 2.62. The 2.5% used in this stress-test scenario thus is at the upper bound of those estimates.

Table 5 – Shock to equity risk premium for scenario 4-7

Region	S04	S05	S06	S07
Argentina	1.90	2.07	2.30	1.90
Australia	1.23	1.37	1.54	1.23
Brazil	1.59	1.78	2.03	1.59
Canada	1.23	1.36	1.52	1.23
China	1.97	2.27	2.67	1.97
France	1.27	1.40	1.59	1.27
Germany	1.07	1.21	1.41	1.07
India	2.20	2.62	3.18	2.20
Indonesia	2.06	2.43	2.93	2.06
Italy	1.32	1.47	1.66	1.32
Japan	1.18	1.33	1.53	1.18
Mexico	1.76	1.98	2.27	1.76
Republic of Korea	1.25	1.43	1.67	1.25
Russia	1.77	1.96	2.22	1.77
Saudi Arabia	1.38	1.52	1.70	1.38
South Africa	1.85	2.06	2.33	1.85
Turkey	1.98	2.20	2.50	1.98
United Kingdom	1.35	1.50	1.70	1.35
United States of America	1.07	1.18	1.33	1.07
Other Asia	1.51	1.75	2.07	1.51
Other oil-producing countries	2.03	2.25	2.55	2.03
Rest of Euro Zone	1.29	1.42	1.60	1.29
Rest of OECD	1.11	1.22	1.38	1.11
Rest of the World	2.21	2.51	2.91	2.21

[44] https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/news--wuhan-coronavirus/

vii) Corporate credit spreads / default

Modelling credit spreads and expected defaults is one of the most complex components of stress-tests – when actually modelled and not relying on historical data. Given both the complexity and uncertainty of the exercise, this scenario will use the exploratory scenario relationship used in the climate change stress-test by the Bank of England in 2019, which assumed that loss on credit portfolios would be 15% of the loss in equity value.[45] This implies a default rate – on top of baseline default rates – of the kind summarized in the table below. One question is the time lag in default rates as it can be assumed that they do not materialize immediately, unlike for equity shocks. As a result, the default rates are 'phased in', peaking at up to 5.7% additional defaults above the baseline by 2022.

The table below is the default rate for speculative grade corporate credit.

	2020	2021	2022
Benign & managed	-1.7%	-2.6%	-3.4%
Benign & unmanaged	-1.8%	-2.7%	-3.6%
Malign & managed	-2.6%	-3.9%	-5.0%
Malign & managed – Low mortality	-2.6%	-3.9%	-5.0%
Malign & unmanaged	-2.7%	-4.0%	-5.2%
Malign & aggravated	-2.9%	-4.2%	-5.5%

Applying these numbers to the European context, and using Moody's prediction as a baseline, this implies the following default rates for the European market under the different COVID-19 stress-test scenarios. The default rates compare to about 10% default rates of European speculative-grade defaults at the peak of the financial crisis.[46] From a financial stability perspective however, the difference is that at the peak of the financial only 20% of debt was speculative grade, now that number is 45%. The results provided here thus essentially imply that a malign & aggravated scenario will see roughly twice the effect of the global financial crisis in terms of defaults in credit portfolios.

	2019 (Actual)	2020 (Baseline)	2020	2021	2022
Benign & managed	1.2%	3.6%	5.3%	6.2%	7.0%
Benign & unmanaged			5.4%	6.3%	7.2%
Malign & managed			6.2%	7.5%	8.6%
Malign & managed – Low mortality			6.2%	7.5%	8.6%
Malign & unmanaged			6.3%	7.6%	8.8%
Malign & aggravated			6.5%	7.8%	9.1%

For simplicity and given the constraints of the scope of the exercise presented here, the investment grade effects are assumed to be 1/50th of the speculative grade effects, roughly consistent with the observed relationship during the financial crisis.[47]

[45] https://www.bankofengland.co.uk/prudential-regulation/letter/2019/insurance-stress-test-2019
[46] https://www.spratings.com/documents/20184/774196/2018AnnualGlobalCorporateDefaultAndRatingTransitionStudy.pdf
[47] Ibid

THIRD PARTY SCENARIO: S&P[48]

S&P has come out with estimates that US default rates may rise above 10% in 2020 and in Europe reach "high single digits". S&P estimates are thus slightly higher than those of this scenario, although 9.1% default rates are reached by 2020 in the malign and aggravated scenario. One reason for S&P higher estimates may be a more granular consideration of sector exposure and existing credit ratings and resilience of rated debt. Of course, S&P's methodology is far more sophisticated than the simple 15% relationship provided in this paper.

[48] https://www.spglobal.com/ratings/en/research/articles/200317-covid-19-credit-update-the-sudden-economic-stop-will-bring-intense-credit-pressure-11392437

viii) Sovereign spreads / default

Sovereign spreads and default are likely to be impacted – as with all financial crises – as a function of whether they are considered safe havens or not. A “flight to safety” will depress yields of countries with low debt levels and strong response to the virus.

One potential modelling approach considered here is to assess countries based on their Epidemic Preparedness Index (EPI), published by John Hopkins University.[49] However, early returns on the virus suggest a number of countries – notably the United States – are proving much less resilient and prepared as the index would suggest.

In terms of effects, the pandemic will depress tax receipts, and a policy response will put fiscal budgets under increased stress, all of which will be aggregated by the sentiment effect depressing demand and supply.

It is unclear how to reasonably model this uncertainty. The simple approach chosen here is that given the loss of fiscal resilience, it seems unlikely that a malign & unmanaged or a malign & aggravated scenario does not come with a haircut for Italian and Spanish sovereign bonds, the two countries currently most affected by the crisis with weak fiscal resilience. Of course, the other European economy primarily affected by this at the moment is France, although such a scenario is likely more appropriate for the “Armageddon” section.

As a result, the stress-test scenario assumes a 15% face value hair cut to sovereign bonds of Italy & Greece under a malign & unmanaged, a 15% cut to both Spain & Italy & Greece under a malign and managed scenario, and a ‘small’ 5% haircut under a malign & managed scenario to Italy & Greece. The 15% is slightly below the 16.7% historical mean identified in a sample of 180 cases, rounded down to the nearest 5 given the outliers of 90% write-downs in the source dataset.[50] The scenario can obviously also assume something less dramatic with perhaps a lower haircut of 5-10% even in a malign & aggravated scenario.

	Haircut	**Country affected**
Benign & managed	NA	NA
Benign & unmanaged	NA	NA
Malign & managed	5%	Italy, Greece
Malign & managed – Low mortality	NA	NA
Malign & unmanaged	-15%	Italy, Greece
Malign & aggravated	-15%	Italy, Spain, Greece

[49] https://gh.bmj.com/content/4/1/e001157

[50] https://www.jstor.org/stable/43189553?Search=yes&resultItemClick=true&searchText=sovereign&searchText=default&searchText=the&searchText=price&searchText=of&searchText=haircuts&searchUri=%2Faction%2FdoBasicSearch%3FQuery%3Dsovereign%2Bdefault%2Bthe%2Bprice%2Bof%2Bhaircuts%26amp%3Bacc%3Don%26amp%3Bwc%3Don%26amp%3Bfc%3Doff%26amp%3Bgroup%3Dnone&ab_segments=0%2Fbasic_SYC-5055%2Ftest&refreqid=search%3Af34b6124cebd0216f0338f6506aff4fe&seq=11#metadata_info_tab_contents

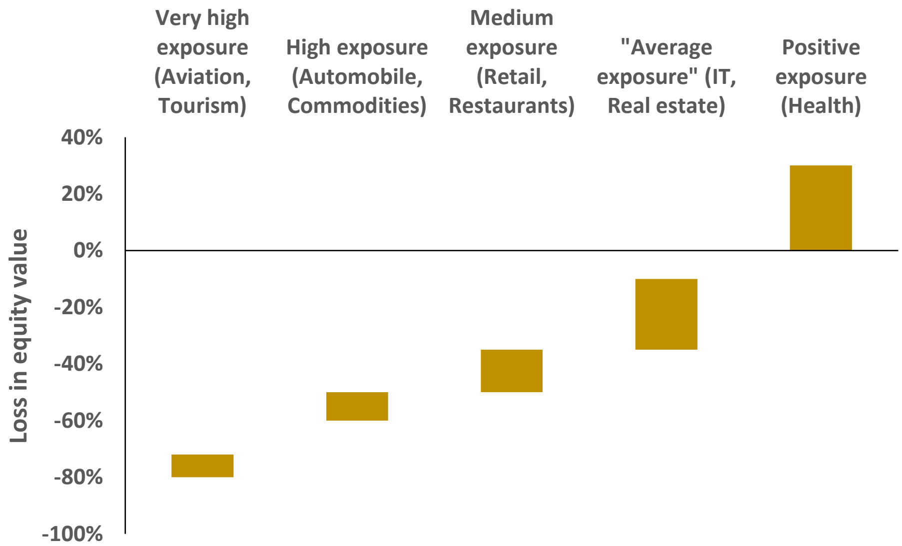
ix) Sector level analysis

As with climate change scenario analysis or stress-tests, pandemic stress-test scenarios are also likely to generate sector-specific shocks. A micro-prudential exercise should thus take into account not just market shocks, but the particular exposures and potential concentration risks of individual banks' and insurance companies. These concentration risks are unlikely to be captured by traditional concepts of sector classification or related ways to measure concentration. In this case for example, concentration risk is best understood as a combination of exposures to the flow of people, specifically tourism, restaurants, the aviation industry, and potentially related sectors and business activities. Similarly, it is also important to appreciate and understand potential off-setting effects, the health sector itself, or at least parts of it, being one intuitive example.

For this universe of assets, shocks are likely very different to the high-level shocks calculated above. For example, a 50% shock to air travel over the next 3 years will wipe out roughly 70-80% of the equity value of the industry depending on the scenario, and lead to default of over 10% of the industry, a figure likely understated by the simplistic formula used in this stress-test and potentially even larger.

A more granular breakdown would go beyond the scope of this report, but can be simulated using the same framework described above at sector level as part of a micro-prudential exercise.

The following illustrates what such a sector breakdown could look like in terms of risk modelling under a limited or isolationist policy response. The results are based on simulations but should be seen as illustrative, with further detailed modelling necessary to quantify stress-test scenario effects. Of course, an aggressive policy response might mitigate some of these effects.



V. COVID 19 scenarios vs. existing stress-tests

One of the critical questions is the extent to which past stress-test exercises can be used as an indicator for whether the banking or insurance sector is prepared for the crisis the modelling outlined in this paper suggests.

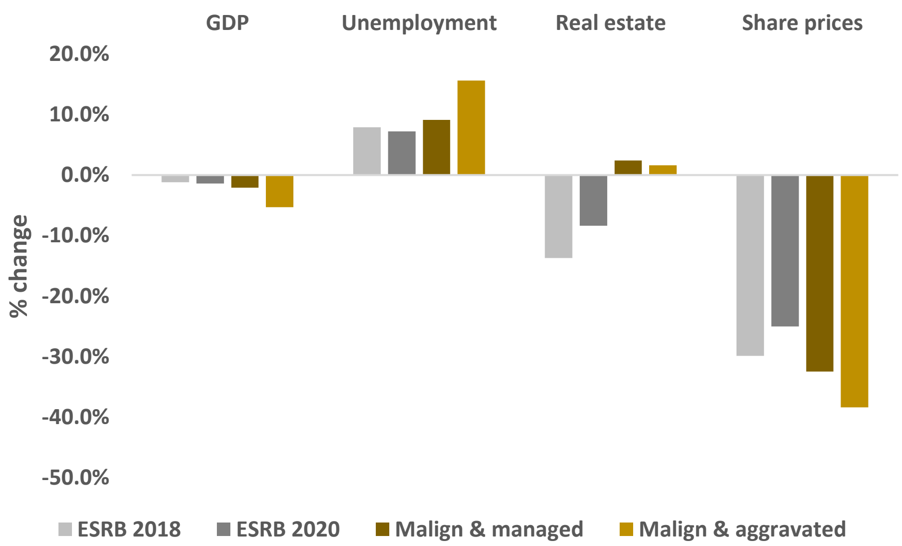
There are two points on that aspect. First, traditional stress-tests may reveal higher shocks than those identified in 'sustainability scenario analysis' or stress-test exercises like the scenario developed in this paper. However, unlike in traditional stress-tests, these shocks don't tend to be cyclical, but secular. As a result, we see a more permanent value destruction in many cases than in stress-tests. Mortality creates a permanent loss to labour supply – even if in this scenario that loss currently appears contained – unlike in a crisis where job losses do impact long-run productivity, but in principle the unemployed can eventually find new jobs.

Second, traditional stress-tests assume defaults and losses at asset class level. As a result, they cannot identify micro-prudential sector- or risk-specific issues. For example, in the case of climate change, asset class losses are contained under most transition scenarios, but lead to losses exceeding stress-tests in certain sectors.

Either way, in this particular case both the malign & managed and the malign & aggravated scenarios reveal higher shocks across comparable indicators in the first year of the stress-test relative to the ESRB Adverse Growth Scenario of the previous stress-test and the one that was planned for this year, but that has now been postponed.

Credit defaults – not an indicator explicitly defined in the ESRB scenarios – is likely to be higher than the ones implied by that stress-test as well then.

These findings suggest that its material to conduct snap stress-test using regulatory data where possible to minimize the burden on banks, but nevertheless test preparedness.



VI. The Armageddon scenario

The previous section highlighted a series of potential scenarios and outcomes in response to health effects, sentiment effects, and policy responses. Unlike with traditional stress-tests however, the pandemic stress-test scenario may generate a truly ‘Armageddon’ style outcome that dwarfs the outcomes described above. Such an outcome is unlikely to be productive from a supervisory practice, since the unchartered territory it would create would significantly impact the underlying fabric of society, and the ability for traditional institutions of government to function. While this may seem dramatic, it is simply a recognition of the reality that there are certain risks to society – and a specific articulation of pandemics is one of them – that are truly ‘existential’.

At this stage, it seems unlikely that COVID-19 will generate such an outcome without an incredible combination of ‘unlucky’ factors, notably a mutation to higher mortality, panic sentiment at unprecedented scale, and the total and complete breakdown of basic principles of good governance. At the same time, such a scenario does not seem unlikely for a future pandemic, given previous recorded mortality rates of other zoonotic diseases.

Of course, there is no meaningful ‘upper bound’ to the Armageddon scenario. However, it does not seem unreasonable to assume that a 6% mortality rate at 80% penetration is likely a lower bound at which a broader breakdown will become inevitable. Of course, this is speculative and may be higher and may also be lower.

Radical consumer response to such a dynamic in terms of reduction in demand and essentially an elimination of travel, tourism, parts of the retail sector, and recreational social activities from the consumer basket with only 50% of the associated savings transferred to other consumption goods, would imply a negative GDP shock of around 15-20%. Examples from SARS suggests that the sentiment shock may amplify by a factor closer to 4x the underlying economic effect, rather than the 1.5-2x simulated here.

Such GDP losses would likely transfer into +60% loss in equity value and +10% default rates across the economy, including the default of large sovereign issuers. This scenario is presented here not as a way to scare, but rather to recognize the looming shadow that pandemics – when they reach ‘existential risk’ level – represent to the economy and society more generally.

Wuhan coronavirus compared to other major viruses

VIRUS	YEAR IDENTIFIED	CASES	DEATHS	FATALITY RATE	NUMBER OF COUNTRIES
Marberg	1967	**466**	373	80%	11
Ebola*	1976	**33,577**	13,562	40.40%	9
Hendra	1994	**7**	4	57%	1
H5N1 Bird Flu	1997	**861**	455	52.80%	18
Nipah	1998	**513**	398	77.60%	2
SARS	2002	**8,096**	774	9.60%	29
H1N1**	2009	**>762,630,000**	284,500	0.02%	214#
MERS***	2012	**2,494**	858	34.40%	28
H7N9 Bird Flu	2013	**1,568**	616	39.30%	3
2019-nCoV*	2020	**11,871**	259	2.2%	24

*As of January 31, 2020 **Between 2009 and 2010 ***As of November 2019

#Countries and overseas territories or communities

Sources: CDC; UN; WHO; New England Journal of Medicine; Malaysian Journal of Pathology; CGTN; Johns Hopkins University; The Lancet; Reuters, CIDRAP

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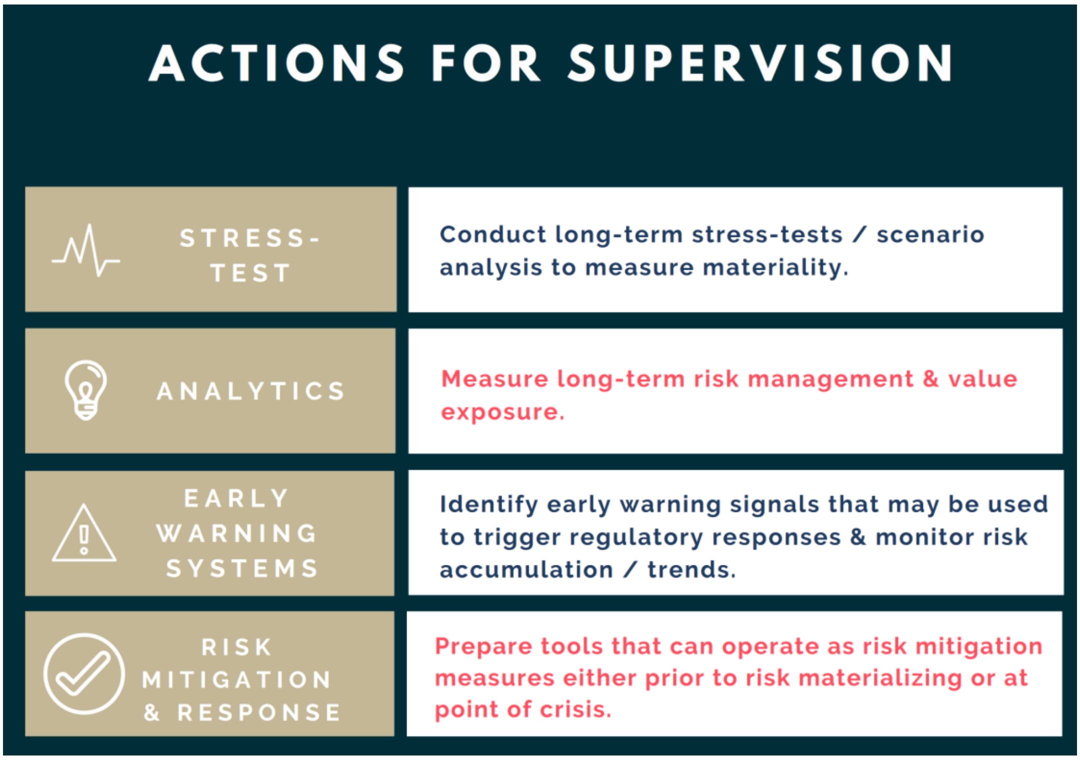
VII. Potential responses & application

This report represents a series of stress-test scenario variables that financial supervisors can use to run centralized, in-house pandemic stress-test scenarios for the COVID-19 virus over the next few months to plan and anticipate macro and micro-prudential disruption. While parameters require some calibration and an extension to sovereign bonds based on the specific profile of the supervisor and the markets they supervise, the indicators as a whole can largely be used as is – with the caveat that the uncertainty, imprecision, and 'back of the envelope' modelling approach used here of course cannot compete with the traditional infrastructure of stress-test design. Unfortunately, given that the post-crisis / pre-crisis world that we have enjoyed until February / March 2020 has now expired, the leisure to build such models is no longer at our disposable. Fast action is required.

Specifically, this report recommends the following actions:

- Application of centralized stress-tests using the scenario developed here or equivalent on existing regulatory data (e.g. Solvency II in Europe, Schedule D in the USA, Anacredit for banks in Europe) to identify maco and micro-prudential resilience;
- Targeted market interventions to support financial stability through monetary and supervisory policy operations;
- Broader investment in long-term supervision and stress-testing infrastructure.[51][52]

The figure below outlines the toolbox, published in an upcoming 1in1000 report on the appropriate regulatory intervention. Whatever the application of stress-test of the kind developed in this paper, it is imperative such work is complemented by a broader resetting of the supervisory toolbox towards measuring long-term value exposure and risk management, developing early warning systems, and preparing the appropriate toolbox for risk mitigation measures.



[51] https://2degrees-investing.org/resource/into-the-fire-financial-supervision-in-a-post-crisis-pre-crisis-world/
[52] https://2degrees-investing.org/resource/a-primer-on-long-term-financial-supervision/

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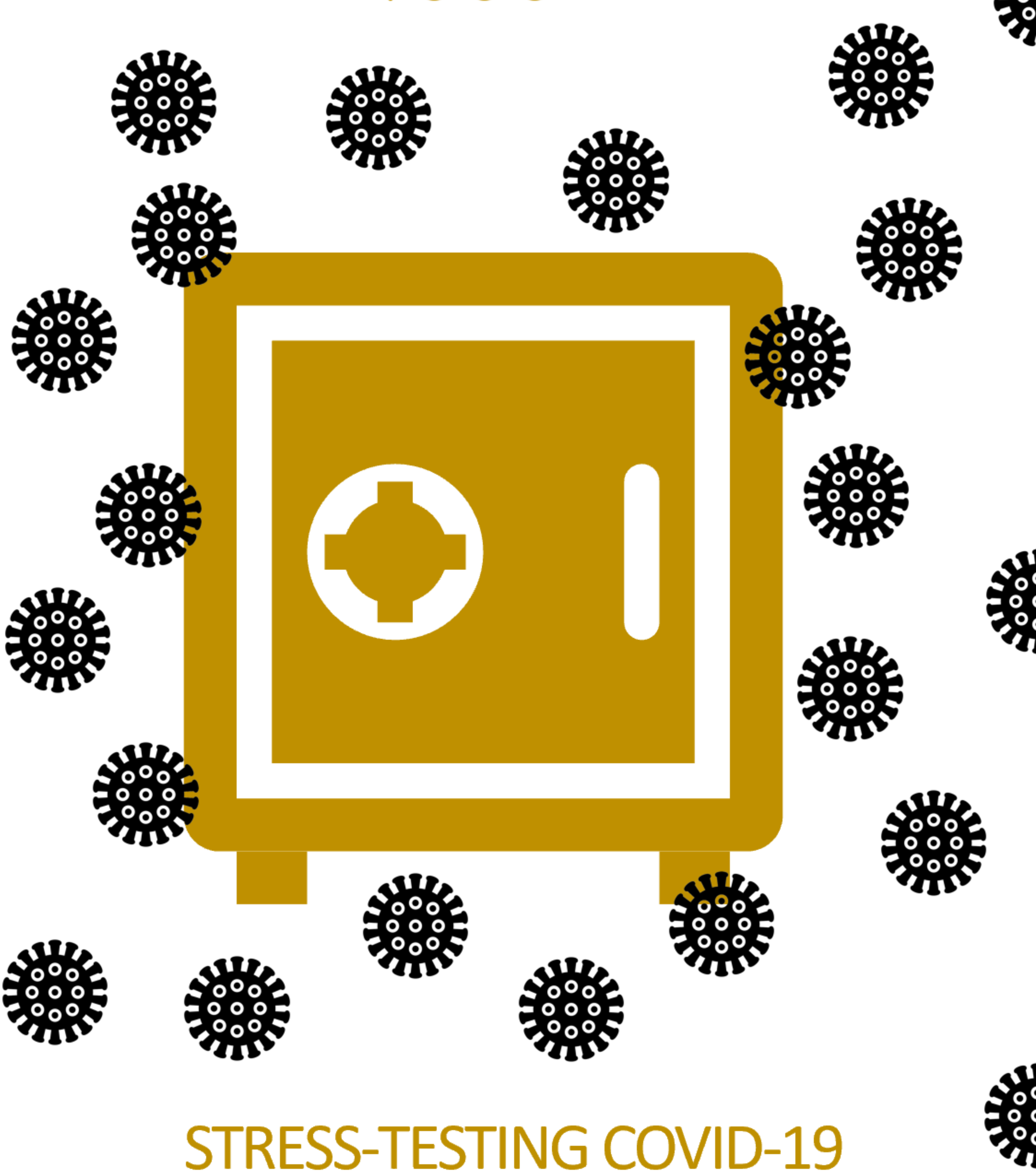

STRESS-TESTING COVID-19

AN EXPLORATORY STRESS-TEST SCENARIO FOR A GLOBAL PANDEMIC

DISCUSSION PAPER
MARCH 2020