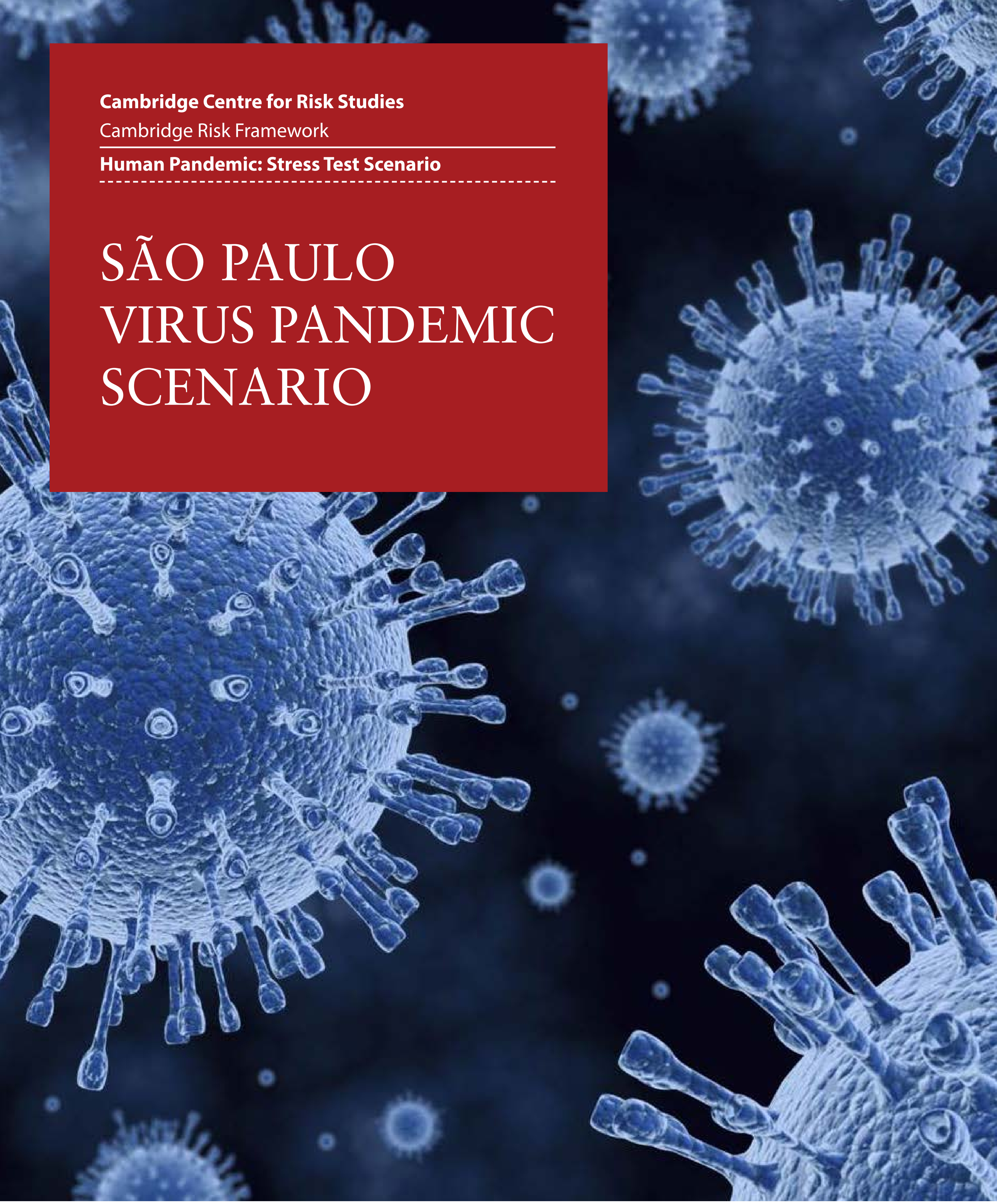

Cambridge Centre for Risk Studies

Cambridge Risk Framework

Human Pandemic: Stress Test Scenario

SÃO PAULO VIRUS PANDEMIC SCENARIO

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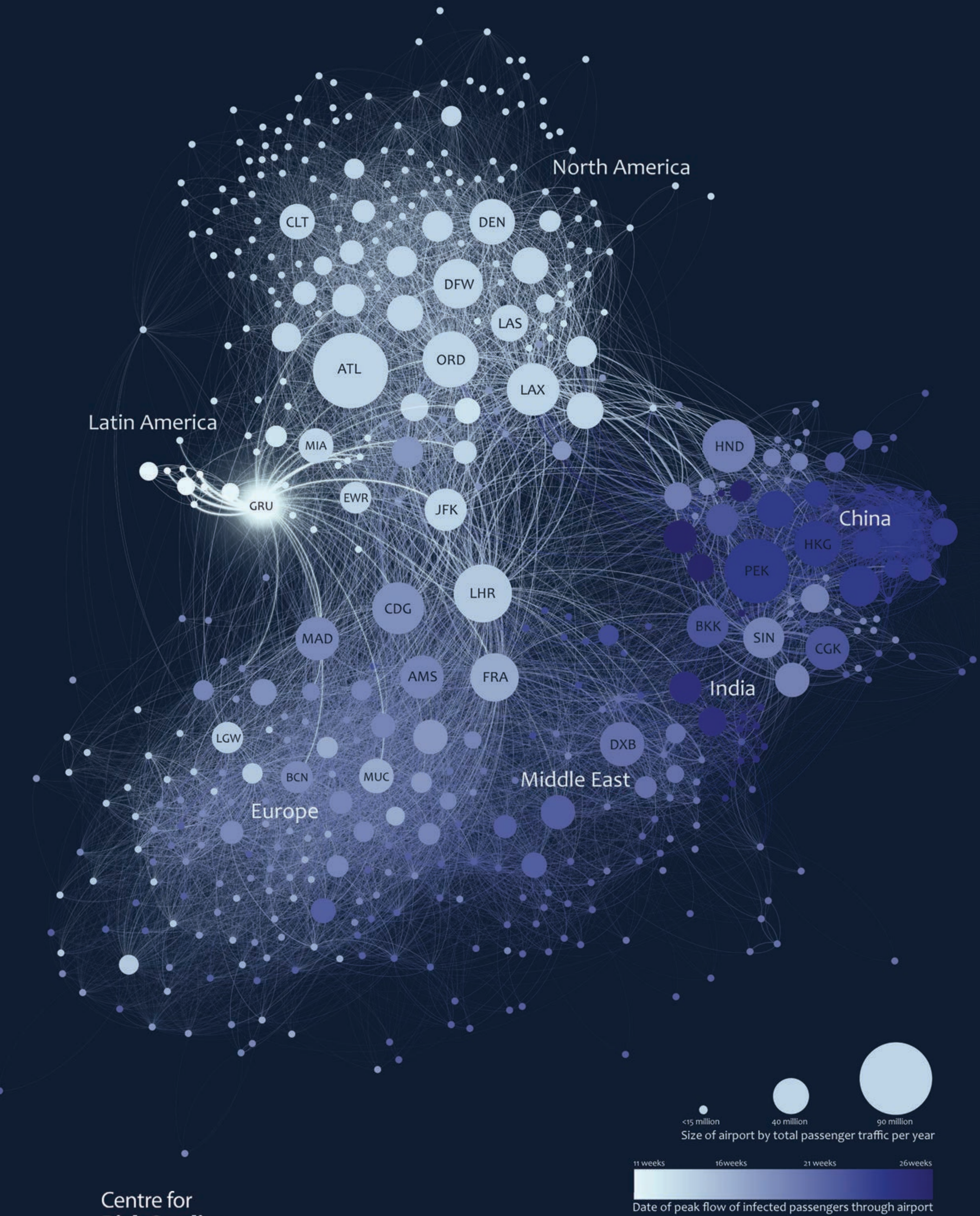

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CAMBRIDGE
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Air Traffic Network of the World
Conduit for Pandemic Spread

Infet: ed passengers spread the pandemic from o untry to o untry. Colour o ding shows the simulated spread of the Sao Paulo VIrus Pandemic oe r time.

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The views contained in this report are entirely those of the research team of the Cambridge Centre for Risk Studies, and do not imply any endorsement of these views by the organisations supporting the research.

This report describes a hypothetical scenario developed as a stress test for risk management purposes. It does not constitute a prediction. The Cambridge Centre for Risk Studies develops hypothetical scenarios for use in improving business resilience to shocks. These are contingency scenarios used for 'what-if' studies and do not constitute forecasts of what is likely to happen.

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Stress Test Scenario

São Paulo Virus Pandemic Scenario

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Pandemic peril

Nature and mankind are engaged in a continual battle in which new pathogens emerge and are combatted by antibodies and medical treatments that develop in response. An extreme pandemic could, in every nation, overwhelm the healthcare system and inflict massive social and economic damage.

We use a pandemic scenario to quantify the effects of such a catastrophe. Scenarios more generally can be used to cover the spectrum of extreme shocks. A suite of scenarios is a basis for a global enterprise to stress test itself and improve its resilience.

São Paulo Virus Pandemic Scenario

The São Paulo Virus Pandemic Scenario envisions a fictional strain 'H8N8' of an influenza virus, which is very infectious and moderately virulent. The illness debilitates its victims for weeks, inflicting massive damage on society, though it is only fatal in a third of a percent of infected cases. The pandemic is curtailed when a vaccine becomes available.

The virus kills 19-25 million people worldwide, in different variants of the scenario.

The world loses between $7 trillion and $17 trillion of GDP over five years, almost as severe as the Global Financial Crisis of 2007-2012. In financial markets, equities are badly hit. A typical investment portfolio suffers negative returns. Long term bond markets suffer, notably in the Eurozone and UK.

Behind the pandemic scenario

Scenario selection

The historical record dating back to the Plague of Athens in 430 BC gives a long perspective on disease epidemics. The influenza virus, which mutates rapidly, provides the seed for imagining a highly unlikely, highly impactful pandemic.

The São Paulo Virus Pandemic scenario was selected, in partnership with Risk Management Solutions, from the probabilistic event set of the RMS Infectious Disease Model.

Variants of the scenario

We give several variants: a 'standard' scenario (S1) of an influenza virus which is very infectious and moderately virulent; a similar scenario but assuming public health response measures are poor (S2); another alternative where the vaccine does not arrive in time (S3); and an extreme case combining poor response failure and vaccine failure (X1).

This is a stress test, not a prediction

This report is one of a series of stress test scenarios that have been developed by the Centre for Risk Studies to explore the management processes of dealing with an extreme shock. It does not predict a catastrophe.

A '1-in-100' Event

The São Paolo Virus Pandemic is extremely unlikely to occur. In fact we have chosen a severity of scenario that could only be expected to occur with a chance of 1-in-100 in any year. So there is a 99% probability that a scenario of this severity will not occur next year.

The unfolding scenario

We outline the timing and stages of the São Paolo Virus Pandemic. We subsequently estimate direct losses, then global macroeconomic losses and finally impacts on financial markets.

Picking on Brazil

We arbitrarily simulate the outbreak starting in Brazil. Apart from having a large poultry industry, Brazil is no more likely to trigger a pandemic than many other places. Where the pandemic starts is less important than how it spreads and its severity.

Quickly goes global

The virus rapidly spreads around the world by infected air travel passengers. Although in each country the infection wave is over in weeks, it takes around 7 months for it to spread around the globe, causing international disruption.

Racing to produce a vaccine

Until a vaccine is available, there is nothing to prevent the spread. Antiviral drugs help to reduce the impact of the infection but the global demand exceeds supply. Public healthcare capacity is quickly overwhelmed even in countries with advanced health systems. Shortfalls in healthcare capacity increase the death toll.

Government responses

Once the World Health Organization has declared a pandemic, governments respond by closing schools and suspending public gatherings to reduce contact rates in the population; and administering the vaccine when it becomes available. This is eventually successful in curtailing the pandemic.

Direct impacts of the pandemic scenario

Workforce absenteeism

In the course of the São Paolo Virus Pandemic, employers see absenteeism rates exceed 10% for a month, and 20% for a 15 day period. Absenteeism isn't evenly spread; suspension of operations in some organizations and regions increases overall damage.

19-25 million deaths

19 million people die from being infected by the virus worldwide. Without a vaccine, the death toll is 25% larger, at 24 million. Nearly half of the world's population is made sick for some period of time. Large numbers of people need medical treatment.

Insurance losses

The insurance industry pays out record sums due to the pandemic. Taken together, the insurance bill for life insurance payouts and medical treatment is between $190 billion and $265 billion. Many other non-life lines of insurance also suffer increased claims, for example liability cover, event cancellation and contingent business interruption.

Consequence analysis

Pandemic-triggered global economic crisis

The world's economy suffers from the major disruption of workforce absenteeism and a large drop in demand and consumption during the infection wave. We shock these variables in the Global Economic Model of Oxford Economics to estimate global macro-economic impact in terms of losses to global GDP output over 5 years. The output of the Global Economic Model is then applied to our standard investment portfolio consisting mainly of fixed assets.

There are many other side effects and systemic consequences of the pandemic – counterparty risk increases, and more extreme versions of the scenario trigger a financial crisis that causes a cascading failure of financial institutions and a liquidity crisis.

Lost global output of more than $7 trillion

The pandemic triggers a global recession, which bottoms out about a year after the pandemic starts. The consequences are felt for several years afterwards, with the overall effects being measured in lost GDP output over 5 years ('GPD@Risk') of $7 trillion, ranging to $23 trillion in the more extreme variant – greater than the $20 trillion output estimated lost as a result of the Great Financial Crisis of 2007-2012.

The pandemic-driven recession impacts different countries' interest rates, balance of payments, credit ratings, and exchange rates.

Financial market impact

Market consequences include significant changes in the valuation fundamentals of equities and fixed interest bonds, with short term shocks to prices and longer term changes in interest rates and yields. We measure financial impacts via a high-quality, low-risk standardized portfolio. This suffers negative returns and two years of volatility of loss and recovery, with many asset classes affected differently.

Longer term bond yields are impacted, with some markets significantly out-performing others. Eurozone and UK geographical markets are more susceptible than US or Japan markets.

Equities are badly hit, although winners include the healthcare, pharma, telecoms, and oil & gas sectors.

Risk management strategies

Global macroeconomic losses

The scenario is an illustration of the risks posed by new infectious disease outbreaks. The São Paulo Virus Pandemic is just one example of a wide range of scenarios that could occur.

This scenario aims to improve organizations' operational risk management plans around contingencies, and strategies for surviving financial and counterparty challenges. It presents a capital stress test for insurers to consider their ability to manage underwriting losses while also suffering market impacts on their investment portfolios.

Making the world safer

Pandemics pose a serious societal threat. Collective action is required to make the world safer, from individual actions, to global approaches by policy-makers. Building resilience is the key to a safer world.

Summary of Effects of the São Paulo Virus Pandemic Scenario and Variants				
Scenario Variant	**S1**	**S2**	**S3**	**X1**
Variant Description	Standard Scenario	Response Failure	Vaccine Failure	Response & Vaccine Failure
Infection Rate (% of population infected)	0.43	0.43	0.43	0.43
Global Death Toll	19 million	22 million	24 million	25 million
Duration of Infection Wave	7 months	8 months	9 months	12 months
<u>Insurance Losses</u>				
Life Insurance Payouts, worldwide	$99 Bn	$113 Bn	$119 Bn	$121 Bn
Excess Mortality loss ratio Life Insurance Payouts as % of annual premium income	4.0%	4.5%	4.8%	4.9%
Personal Accident & Health payouts	$93 Bn	$122 Bn	$128 Bn	$144 Bn
PA&H Loss Ratio PA&H payouts as % of annual premium income	9.2%	12.1%	12.7%	14.3%
Global recession severity (peak negative growth rate global GDP)	-2.5%	-2.7%	-2.9%	7.9%
Global recession duration	6 months	9 months	9 months	12 months
GDP@Risk $Tr (5 year loss of global output)	$7 Trillion	$10 Trillion	$14 Trillion	$23 Trillion
GDP@Risk % as % of Year 0's GDP	12%	18%	25%	40%
Standardized Investment Portfolio (with baseline expected return of 3.9% return without pandemic):	-1.40%	-1.80%	-3.00%	-4.10%
US Equities (S&P 500) Yr1Q2	-3.80 pts	-3.74 pts	-6.9 pts	-6.9 pts
UK Equities (FTSE 100) Yr1Q2	-17.7 pts	-18.2 pts	-36.1 pts	-36.1 pts
US Treasuries 2 yr Notes, % Change	+1.44%	+1.47%	+2.67%	+2.67%
Exchange rate US$ to £GBP, Yr1 Q2	+7.6%	+8.0%	+22.5%	+22.5%
Inflation increase in US, Year 3	+0.24%	+0.69%	+1.35%	+2.67%

Table 1: Summary impacts of the São Paulo Virus Pandemic Scenario

2 Stress Test Scenarios

This report describes a plausible extreme future scenario and explores the effects that it would have. It is not a prediction. It is a 'what-if?' exercise, designed to provide a stress test for risk management exercises by companies who want to assess how their business systems would hold up under extreme circumstances.

This report is one of a series of stress test scenarios that have been developed by the Centre for Risk Studies to explore the management processes of dealing with an extreme shock event. Each individual scenario may reveal some aspects of potential vulnerabilities for an organization, but they are intended to be explored as a suite, to identify ways of improving overall resilience to surprise shocks that are complex and have many faceted impacts.

The scenarios have been designed in a number of ways. Firstly they are selected as plausible, but not probable, extreme events that would disrupt normal life and business activity. They are illustrative of the type of disruption that would occur with a particular category of 'threat' or 'peril' – i.e. a cause of disruption. In this example we explore the consequences of a pandemic, as a representation of the threat of infectious disease outbreaks disrupting daily life. Other threats considered in our suite of stress test scenarios include geopolitical conflicts, extreme weather events, cyber catastrophes and financial crises.

Complex risks and macroeconomic impacts

These threats are of interest because they are complex risks – they impact the networks of activities that underpin the global economy, disrupting the interrelationships that drive business, and causing losses in unexpected ways and places. They have multiple consequences, in causing severe direct losses, but also operational challenges to business continuity, cascades of effects on counterparties and the macroeconomy in general, and on the capital markets and investment portfolios.

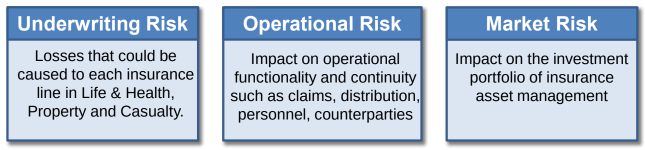
In these scenarios we explore how these effects might occur and try to trace the flow of consequences from initial losses to macroeconomic impact, and to market effects in the change of returns that would occur in a standardized investment portfolio.

The stress test is aimed at providing an illustration of the effects of an extreme event, to help a general audience understand the potential for events of this type to cause disruption and economic loss. It is aimed at informing the risk management decisions of a number of different communities.

Use of this scenario by insurance companies

The insurance industry uses scenarios as stress tests for their risk capital assessments, with explicit return periods of capital adequacy required by internal management, or for regulatory or reporting purposes such as AM Best, Solvency II, Lloyd's Realistic Disaster Scenarios, or other requirements. We offer this stress test scenario as a potential addition to the suite of scenarios that insurers may choose to use for their own internal purposes.

The particular contribution of this work is the assessment of the correlation of potential underwriting losses with an investment portfolio loss, while also considering the operational risks that could be challenging the business at the same time.



For insurers, the scenario provides an indication of potential losses across different silos of risk

The scenario attempts to assess indicatively where losses might occur across a range of different lines of insurance underwriting. Where we have access to data on total insurance industry exposure we have attempted some indicative quantification of the potential order of magnitude of losses. Insurers interested in assessing the impact to their own portfolios can apply these loss ratios to their own exposure in these lines of business.

We have also estimated how the event would impact investment asset values, using a standardized high quality, fixed income oriented portfolio to show the effect on indicative aggregate returns. Investment managers could apply these asset values changes to their own portfolio structures to see how the scenario would potentially affect their holdings.

Risk capital models make assumptions about correlations between underwriting loss and market risk. This report explores how this correlation occurs and provides a detailed example for one scenario.

It does not provide a probabilistic view of this correlation, but it does provide additional variants to the scenario that act as sensitivity tests and indicative additional data points around the primary narrative.

The scenario is deterministic and is not designed to provide exceedance probability data points.

It is very approximately selected on the basis of expert elicitation, to be in the range of the 1-in-100 annual probability of occurrence worldwide, but not rigorously determined.

Use of this scenario by investment managers

The scenario provides a timeline and an estimation of the change of fundamental value in assets in an investment portfolio. These are segmented into broad asset classes and geographical markets to provide indicative directional movements.

The scenario enables investment managers to optimize portfolio strategies against shocks of this type

These provide insights for investment managers into likely market movements that would occur if an event of this type started to play out. In real events, market movements are chaotic and difficult to analyze. This analysis suggests how the underlying fundamentals are likely to change over time, due to the macroeconomic influences. Investment managers can expect this to be overlaid with a lot of noise and chaotic market activity.

The asset class differences and geographical distributions enable investors to consider how different portfolio structures would perform under these conditions and to develop strategies for portfolio management that will minimize the losses that might occur. Where there are obvious winners and losers by economic sector, these have been highlighted to provide inputs into optimal hedging strategies and portfolio diversification structures.

This report provides performance projections for a standardized high-quality, fixed income portfolio, under passive management. This is to enable comparisons over time and between scenarios. We also estimate returns for individual asset classes to help investment managers consider how this scenario might impact their particular portfolio and to consider the intervention strategies over time that would mitigate the impact.

Use of this scenario by organizations

Many companies and organizations in the public and private sectors use 'what-if' scenarios for understanding and managing risk.

This scenario is designed to help organizations improve their operational risk management, and to identify improvements in business practices that will increase their resilience to shocks of this type in the future.

Stress test scenarios to improve risk preparedness have been well studied in management science. Scenarios that are most useful for improving operational risk management are those that are disruptive and challenging, and that force participants to confront a changed reality. Such scenarios should challenge management assumptions about the status quo. For a scenario to be useful, it also has to be plausible (but not probable), and 'coherent' – i.e. everything in the scenario is consistent and interlinked.

Acceptance of a scenario can be a problem in implementing stress tests. It is natural for managers to challenge the assumptions of the scenario and to question how feasible it is. The actual details and severity metrics for the scenario are less important than the exercise of working through management actions, however this report includes a section explaining how the scenario was selected and the justification for the parameters of the scenario.

The scenario is selected to illustrate the severity of shock that can be expected from this particular threat type (cyber catastrophe) with around a 1-in-100 (1%) chance in any given year, so it is extreme but plausible.

Our other scenarios are also selected at the same level of (im)probability. It is worth noting that the Centre for Risk Studies taxonomy of shock threats identifies over 50 potential causes of future shocks.

Each threat type is capable of providing some level of challenging shock to parts of the world's economy at around a 1-in-100 chance each year, so a global organization could expect to experience, and have to manage through, one of these shocks on average every few years.

This scenario is presented as a narrative, with specific metrics of loss, impact, and disruption estimated as indicators of the levels of management challenge that would be faced. We try to make the narrative as realistic as possible, to help managers identify themselves and their organizations in the fiction for the purpose of exploring their decisions in this hypothetical situation.

Improving an organization's resilience to a crisis requires a number of management elements, for which scenarios can be useful components. A major challenge is improving awareness of the potential for shocks and the expectation of disruption. Many companies face the challenge of developing a risk management culture in their organization, where expectations of continuity of the status quo are properly challenged, and contingency planning is an evolving process.

The scenario is designed for use by organizations to improve operational risk management

Operational risk management involves a wide range of activities, including procedures and response planning under a wide range of potential conditions, and broader cultural issues such as measures to sustain institutional learning about risk, consideration of succession planning, shared value systems, incentives, reporting, governance, and management monitoring.

This scenario provides inputs into the contingency planning around a situation of eroding confidence in IT infrastructure, disruption to the economy, failures of business counterparties, and disruption to global supply chains. It is intended to help companies improve their resilience to future crises.

Use of this scenario by policy-makers

International agencies, national governments and local authorities consider scenarios for global and national security, public safety and welfare of the population. Studies of potential catastrophes are produced by agencies such as World Bank, World Health Organization, United Nations, World Economic Forum, OECD, and others to improve the awareness and decision-making ability of policy-makers. This scenario is proposed as an addition to that literature.

National governments create risk analysis frameworks and preparedness scenarios for civil emergencies. Examples include the United Kingdom National Risk Register for Civil Emergencies, and the Australian Government National Risk Assessment Framework.

These frameworks commonly include example scenarios as guidance for local authorities in preparedness planning for deployment of emergency services and extreme response needs. In some cases, performance reviews against classified versions of these scenarios are mandatory requirements for regional authorities.

This scenario is a contribution to the design of future versions of these policy-maker scenarios. It offers a view of the economic environment and broader business and social disruption that will be the context for the challenges of ensuring public safety and continuity of public services. It provides inputs into the decision making and resource planning of these authorities, and is offered as context for policy-makers concerned with disaster mitigation in general.

It is worth remembering in policy formulation in the public realm that there is considerable crossover between policy making and overall business and societal impact.

Some SITEs are in the organizations that are making policy and there is reliance in the public sector on outsourcing to the private sector. Organizations must ensure they do not become misaligned with policy in the cyber area.

Understanding threats

This scenario explores the consequences of a key emerging threat type – cyber risk – by examining the 1-in-100 severity of an IT catastrophe with a selected example of how that shock could come about.

For a process that truly assesses resilience, we would need to consider how other types of shocks might occur. It would include different severities and characteristics of other types of cyber threats. It would also include an appraisal of other types of threat that could cause shocks.

The Cambridge Risk Framework includes an attempt to categorize the potential threats of social and economic catastrophes, to provide a checklist of different potential causes of future shocks.

This has involved a process of reviewing chronological histories for over a thousand years to identify all the different causes of disruptive events, collating other disaster catalogues and categorization structures, and researching scientific conjecture and counter-factual hypotheses, combined with a peer-review process.

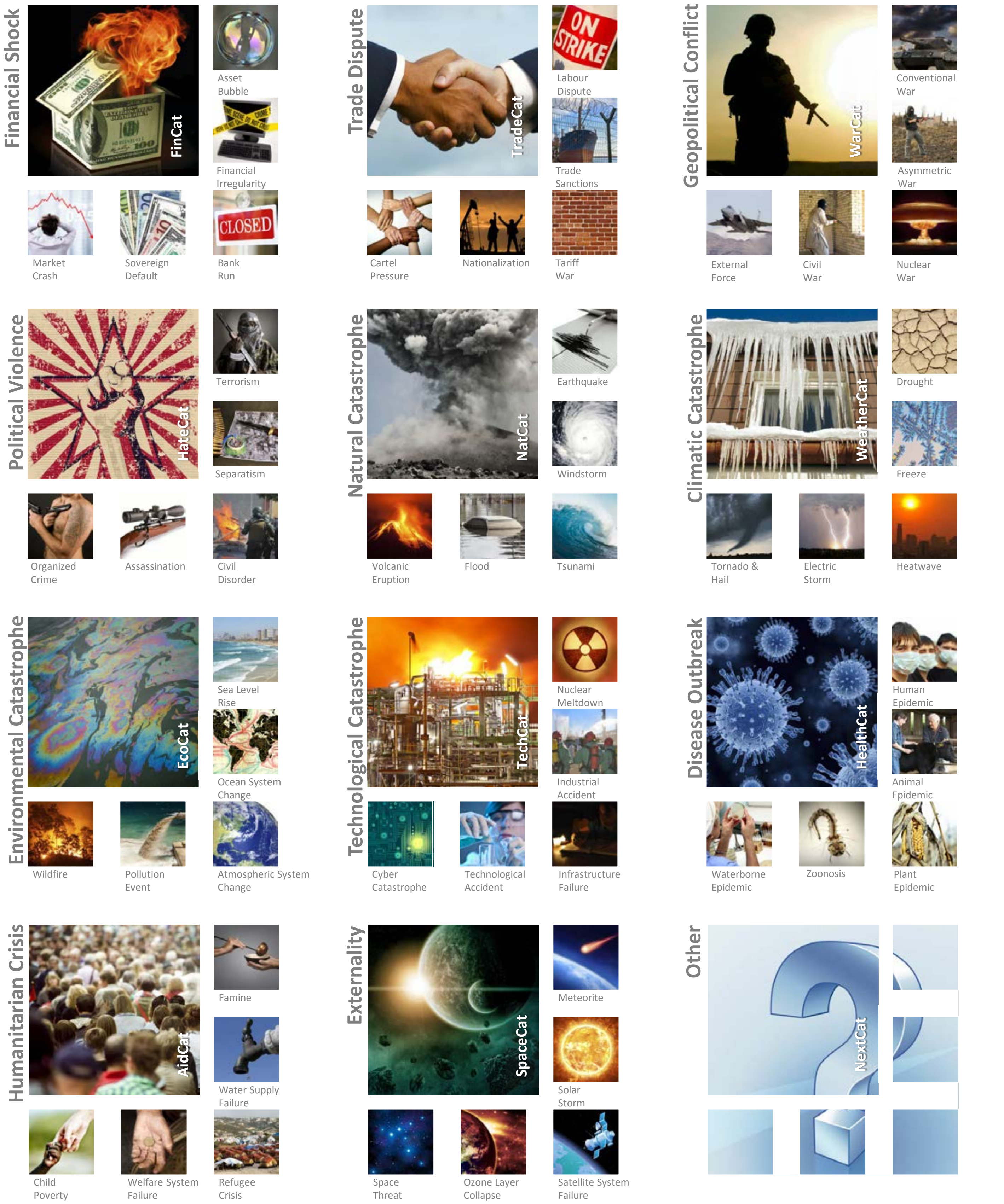


Figure 1: Cambridge Taxonomy of Threats provides a checklist for complex risks of concern to organizations

The figure on the previous page shows the resulting Cambridge taxonomy of macro-catastrophe threats that have the potential to cause damage and disruption to social and economic systems in the modern globalized world. The threat taxonomy is hierarchical and categorized by causal similarity. The report Cambridge System Shock Risk Framework: A taxonomy of threats for macro-catastrophe risk management provides a full description of the methodology and taxonomy content.

The taxonomy provides a company with a check-list of potential causes of future shocks. It also provides a framework for collating information about these threats and populating it with more detailed studies of each threat. Threat types of particular interest are profiled with a stress test scenario like the one described in this report.

The taxonomy is being used to map the global landscape of complex risks, and to provide a suite of potential stress test scenarios that inform an organization's ability to withstand the wide range of shocks that it could potentially encounter. It is an aid to improving the resilience of an organization.

Developing a coherent scenario

It is a challenge to develop a scenario that is useful for this wide range of risk management applications. Fully understanding the consequences of a scenario of this type is difficult because of the complexity of the interactions and systems that it will affect. The economic, financial and business systems that we are trying to understand in this process are likely to behave in non-intuitive ways, and to exhibit surprising characteristics. We are trying to obtain insights into this interlinkage through using an extreme scenario.

Systemic instabilities constantly challenge our intuition, with many examples such as crowd behavior, traffic congestion, financial crashes, power grid failures and others. These are examples of strongly coupled, complex systems that exhibit have unexpected behavior. In these systems we see patterns such as feedback loops; non-linear amplifications; control interactions; cascade effects; avalanche phenomena; threshold effects and regime shifts; emergent patterns of behavior; temporary stabilities; and equilibrium states. It is important to identify the potential for these scenarios to trigger these types of cascading consequences which are the main causes of catastrophic loss.

These effects are what we mean when we call them complex risks. For stress tests to be useful, they need to be 'coherent' i.e. the described effects are all consistent with each other, follow causal mechanisms and logical consequence, and the correlation patterns of multiple impacts are represented comprehensively. The development of a coherent scenario requires structural modeling – i.e. scientific consideration of the cause and consequence sequence along the chain of cause and effect.

A structural modelling methodology

To develop a coherent stress test we have developed a methodology for understanding the consequences of a scenario, as summarized in Figure 1.

This involves sequential processing of the scenario through several stages and sub-modeling exercises, with iteration processes to align and correct assumptions.

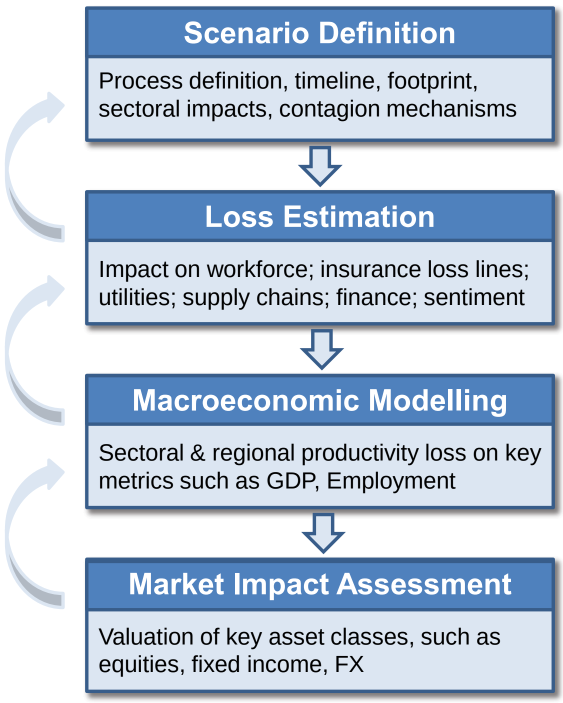


Figure 2: Structural modeling methodology to develop a coherent stress test scenario

The construction of a scenario using structural modeling techniques presents a number of challenges to fulfill the requirements for a coherent stress test.

- The first challenge is can we construct an extreme fictional scenario that has never occurred before and make it plausible? We have attempted to do this through using evidence-based precedents, and detailed analysis of how similar events of the past would play out today, under current conditions.
- Our second challenge is can these scenarios meet the criteria of being useable by businesses and ultimately adopted for use in risk management? To achieve this we have worked with key users to try to make these scenarios meet their

- management needs for stress test scenarios, and are actively seeking ways to get the scenario tested further and more broadly adopted.
- Other challenges include can we estimate the losses that would result from extreme events that have not occurred in today's world, such as the Sybil Logic Bomb? We have addressed this through using historical precedents and extrapolation from similar but less severe occurrences to provide an evidence-based approach to estimation.

We believe it is important to create a robust and transparent estimation process, and have tried to achieve this through detailed process of recorded assumptions made, and sensitivity tests about the relative importance of one input into another.

In the macroeconomic stages of the modeling, we are conscious that we are attempting to push macroeconomic models, calibrated from normal economic behavior, outside their comfort zone, and to use them in modeling extreme events. We have worked closely with the macroeconomic modelers to understand the useful limits of these models and to identify the boundaries of the models functionality.

A further test comes when we try to model the impact of hypothetical economic extreme conditions on investment asset classes and portfolios. We need to understand the limits of usefulness of assumptions such as asset value 'fundamentals' in investment performance estimation.

Uncertainty and precision

Overall the scenario consequence estimation process is steeped in uncertainty. The process entails making a number of assumptions, which feeds into a set of models to assess loss and direct impact. These are then used as inputs into a macroeconomic modeling exercise, with additional assumptions and the introduction of considerable uncertainties and variation. The outputs of this then feed the assessment of portfolio performance, with additional assumptions and uncertainties. Linking all the components into a coherent scenario is difficult to achieve and the process described in this report is one approach that has attempted to do this. It is flawed in that the process is imprecise and one of compounded uncertainty from one stage to the next and the credibility of multiple aspects of any particular scenario can be attacked.

The point, however, of producing the scenario is to understand the consequences in terms of their holistic effects, their relative severities and the patterns of outcome that occur.

The scenario production process, limited as it is, does provide interesting insights, and many of the applications of the scenario are achieved through this imperfect approach. The scenario is offered as a stress test, to challenge assumptions of continuing status quo and to enable companies to benchmark their risk management procedures.

3 Pandemic as an Emerging Risk

Disease epidemics have been the causes of some of the worst socio-economic shocks throughout human history. At its most extreme, large parts of 14th Century Europe lost a third of its population to the terrible plague of Black Death.

Date	Name	Cause
2012	Middle East Respiratory Syndrome Coronavirus	MERS-CoV
2002	Severe Acute Respiratory Syndrome	SARS
1981-today	Acquired Immunodeficiency Syndrome	HIV/AIDS
1918-1922	Russian Typhus Epidemic	Typhus
1855-1959	Third Pandemic	Bubonic plague
1962-1966	El Tor Cholera Pandemic	Cholera
1899-1923	Sixth Cholera Pandemic	Cholera
1881-1896	Fifth Cholera Pandemic	Cholera
1863-1875	Fourth Cholera Pandemic	Cholera
1846-1863	Third Cholera Pandemic	Cholera
1826-1837	Second Cholera Pandemic	Cholera
1816-1824	Asiatic Cholera Pandemic	Cholera
1793; 1690-1878	Yellow fever, U.S.	Yellow fever
1775-1782	North American smallpox	Smallpox
1679	Great plague of Vienna	
1665-1666	Great plague of London	
1629-1631	Italian plague/Great Plague of Milan	Bubonic plague
16th C	Spread of smallpox through colonization	Smallpox
1500-1800	Epidemics throughout Europe	Multiple
1577-1579	Following Black Assize	
1489	Spanish Siege of Moorish Granada	Typhus
1347-1350	Black Death	Bubonic plague
639	Plague of Emmaus/Amwas	Bubonic plague?
541-750	Plague of Justinian	Bubonic plague
251-266	Plague of Cyprian	Smallpox/measles?
165-180	Antonine Plague	Smallpox/measles?
430 BC	Plague of Athens	Typhoid/Plague/ measles?

Table 2: Historical Infectious Disease Pandemics[1]

But disease impacts are not just an ancient historical anomaly – this current generation has had to deal with the impact of HIV/AIDS – a previously unknown disease that medical science could not combat and that has killed 30 million people, many of them wealthy, educated people with access to the best healthcare available in the world.

[1] Murphy, 2005; Hays, JN, 2005; Little LK, 2006

Great plagues have devastated society periodically throughout history. Mankind and nature are engaged in a constant arms race.

Nature and mankind are engaged in a constant arms race – nature evolves new strains of pathogens to overcome natural defense mechanisms and infect human hosts, and mankind develops antibodies in response, and in modern times has augmented this with medical treatments.

Twenty known diseases have recently re-emerged or spread geographically. These new outbreaks are of more virulent and drug-resistant forms. At least 30 unknown disease agents for which no cures are available have been identified in human populations in the last few decades, including HIV, Ebola, and hepatitis C and E. Infectious disease outbreaks pose a major threat both nationally and internationally. They easily cross borders and can threaten economic and regional stability.

Rapid adaptation of pathogens

Viruses are exceptionally adaptable organisms. They are constantly undergoing genetic change and can undergo many generations of reproduction in a short period, evolving rapidly. Their adaptation through high mutation rates is partly because their reproductive processes have fewer genetic 'proof-reading' checks, particularly RNA viruses. High mutation rates enable random changes to explore vulnerabilities in their human or animal hosts.

Growing reservoirs of hosts

In addition, the populations of animals that they inhabit and replicate through are increasing rapidly. The global human population has doubled since 1970. Poultry stocks and farmed animal populations have seen massive increases as the developing world demand for protein in their diet has grown.

In China alone, the poultry population is estimated to have increased from fewer than one billion birds in 1980 to over 20 billion today. Pigs have increased from 50 million to over 700 million. These and other mammal populations are the reservoirs in which virus mutations take place, finally jumping from one species to another to infect humans. Many of the emergent infection diseases over the past few generations have their origins in the rapidly expanding but poorly regulated agricultural industries of the developing economies, where their close integration with human activity makes it easier for disease outbreaks to transfer from the animal hosts to people.

Man-made pandemic risk

Many countries now have sophisticated biological research laboratories handling dangerous pathogens, as biotechnology develops rapidly as a global industry. These laboratories – Biosafety Level 3 and above – are run with high safety standards, but they are complex systems and accidents do happen. There are now at least 42 known laboratories currently working with potential pandemic pathogens (PPPs) – i.e. H5N1 viruses, live versions of the 1918 influenza virus, or the SARS virus.

Statistics on the accident record of laboratories show that incidents are rare but significant. Over 5,000 researchers have suffered from some type of laboratory-acquired infections (LAIs) since 1930, and nearly 200 have died. Only a few recorded cases of laboratory accidents have resulted in any kind of epidemic, but one example is the 2007 outbreak of foot-and-mouth disease in cattle in England as a result of a virus escape from the Pirbright BSL-4 research laboratory. The 1977 Russian flu epidemic may have emerged from a laboratory virus escape.

In 2012 virologists created a transmissible version of deadly H5N1 in the laboratory – a discovery that caused a scientific controversy over the potential for researchers to accidentally trigger the pandemic they were trying to prevent. After a brief moratorium this 'HPAI H5N1 gain-of-function' research recommenced.

There is a small but non-zero chance that the next pandemic could be triggered by a laboratory accident.

Influenza

One of the most rapidly mutating viruses is influenza, a highly contagious RNA virus which has been responsible for some of the most widespread pandemics in recent history, Table 2. In an early epidemic in 15th Century Italy, the illness was attributed to "influence of the stars", hence "influenza". Influenza has proven very difficult to combat, because it changes so often. Vaccines need to be developed to match the particular strain in circulation – a process that takes several months each time. A new vaccine has to be developed each year for the seasonal flu strain that occurs during winter.

Influenza can debilitate healthy adults for long periods and can cause severe complications and death.

Influenza is constantly present in the human population and mutates to a new strain each year, causing a seasonal peak of infection each winter. It is a leading cause of infectious disease-related deaths in most countries around the world. In non-pandemic years influenza typically kills hundreds of thousands of people worldwide. The highest rates of mortality are in the elderly followed by children and those with pre-existing medical problems.

Every so often, the gradual mutations of the influenza virus (antigenic drift) give rise to a major genetic change (an antigenic shift or reassortment) that finds a new mechanism to infect humans and evade their immune systems, spreading rapidly through the population to cause widespread illness in a pandemic.

Avian flu

Since around 2003 a virulent new strain of influenza, H5N1, has caused public health concerns and commonly dubbed 'avian flu' or 'bird flu'. There have now been over 650 recorded human cases of which 59% have died, making it the most virulent strain of influenza ever observed.

So far H5N1 can only be caught from close contact with a bird, usually domestic poultry, and most cases have been in Southeast Asia.

Unlike other strains of influenza it has not adapted to spread between people through airborne transmission in coughs and sneezes. The big concern of public health authorities remains the possibility that H5N1 could mutate into a human transmissible form, and become a very deadly pandemic. The original fears and WHO warnings of 2005 have not materialized, but it remains a possibility.

The effects of influenza

Influenza's effects are much more severe than those of the common cold. It affects even healthy adults and causes fevers, nasal congestion, aches, and severe fatigue. It can be debilitating for many days and many people are so ill they are confined to bed. The performance of someone infected with influenza is reduced almost as soon as they are infected – they suffer symptoms ranging from disorientation and demotivation, through to more physical manifestations such as headaches and muscular pain, and then a period of high inflammation with high temperature, sweating, respiratory congestion, sore throat, and associated sneezing, runny nose and extreme fatigue. In extreme outcomes, the illness can be compounded by life threatening complications such as secondary infections, pneumonia, immune system breakdowns such as a 'cytokine storm' reaction, circulatory problems, heart attacks or extreme breathing difficulties. The severity of the body's response to the infection is different in every person.

Most people make a full recovery afterwards, but in some the effects are so severe they may need hospitalization and some die from the infection effects.

Date	Name	Cause
2009	Mek a n Swine Flu	H1N1
1977-1978	Russian Flu 'benign' pandemic, possibly caused by a lab release	H1N1
1968	Hong Kong Flu	H3N2
1957-1958	Asian Flu Pandemic	H2N2
1918-1919	Spanish Flu 'The Great Influenza'	H1N1
1889-1893	Russian Flu	H3N8 or H2N2
1830-1848	Four influenza epidemics occurring almost o ntinuously 1830 to 1848, possibly originating in China	
1788-1790	Initiated a pandemic era, of heightened global influenza activity for almost 20 ẏ ars	
1780-1782	Began in Southeast Asia and spread to Russia and eastward into Europe	
1761-1762	Began in Ameria s and spread to Europe and around the globe. First pandemic to be scientifically studied.	
1729-1730, 1732-1733	First detet ed in Russia	
1580	Swept oẹ r the entire globe, spreading east to west from Asia	
1557-1558	Asia origin. Highly fatal, and assoc ated with seẹ re o mplia tions	
1510	First reo gnia ble pandemic Ina ded Europe from Afria .	

Table 3: Historical Influenza Pandemics[2]

[2] Taubenberger, 2009

Historical Case Study
1918 Spanish Flu Pandemic

Emergency hospital set up for 1918 flu victims

The pandemic of "Spanish" influenza in 1918–1919 killed between 20 and 40 million people – more deaths than in World War I. In absolute terms it killed more people than the 14th Century Black Death Bubonic Plague, because of the larger world population in 1918.

The war was a key factor in enabling the spread of virus and depleting home nations of medical specialists. International troop mobilization and shipping movements spread the disease around the world. The public celebrations of Armistice Day, 11 November 1918, may have fuelled the spread to cause a catastrophic winter of influenza.

The pandemic preceded the onset of modern medicine, before the availability of antibiotics, and understanding of viral transmission and public health essentials was only basic. The flu was particularly deadly for people ages 20 to 40, causing severe and rapid bacterial pneumonia and triggering debilitating immune responses in healthy adults. 2% of people who were infected died, one of the highest case fatality rates recorded in transmissible cases of influenza.

According to estimates by the World Health Organization, between 5 and 15% of the world's population contracts flu each year resulting in between 250,000 and 500,000 deaths (WHO, 2006). Typically, recovery takes about 10 days. Influenza is most often deadly in the weak, old, or chronically ill. The most common cause of death is secondary complications such as bacterial pneumonia.

Healthy people can be affected, and serious complications from influenza can arise at any age. People age 65 years and older, people of any age with chronic medical conditions, and very young children are most likely to have complications from influenza. Pneumonia, bronchitis, sinus, and ear infections are four examples of such complications.

Vaccine

Vaccines are a major defense against influenza. Immunizing the population helps reduce the spread of an epidemic. The more people that are vaccinated, the better, but the development of an effective vaccine can only occur once the exact strain of the virus has been characterized. It then takes time – several months – to check that the vaccine is safe, by conducting clinical trials, and to put it into mass production. Producing enough vaccine to carry out mass vaccination to stop the spread of a pandemic is a race against time.

In past pandemics some corners have been cut, for example shortening the time to conduct drug trials to detect possible side-effects. In the 2009 pandemic, national governments indemnified the pharmaceutical companies against any liabilities that might arise from having to accelerate their clinical trials to make vaccine available to combat the swine flu spread. The vaccine that was produced is now being blamed for side effects in a small proportion of the recipients – particularly children – and has caused controversy about the indemnifications that were given.

Vaccine production methods are also time-consuming. Conventional techniques require the incubation of a vaccine dose in a live chicken egg, which is labour-intensive and requires large stocks of eggs. In-vitro cell culture vaccine technology holds out the promise of more rapid and industrial scales of production, but is not yet a feasible large-scale method of manufacture. The total worldwide capacity for manufacturing vaccine is estimated to be around a few million doses a month, so will take some time to produce enough to inoculate a large proportion of the world's population. Vaccination plans assume that batches of vaccine arrive over time, and are prioritized for front-line healthcare workers, high-risk individuals, children, and then the general population.

The speed of production of vaccines, and their efficacy when they are available, is a critical variable that affects the severity of the pandemic. In one variant of the scenario, S3, the vaccine is slow to become available, and has low efficacy. This makes the pandemic significantly more severe.

Pandemic response plans

The World Health Organization requires each country to publish a pandemic preparedness plan. These reveal the intended measures that each country will deploy when a pandemic is declared, to mitigate the impact of an infection on the population.

The plans generally assume that a vaccine will take several months to become available and consist of measures prior to the arrival of a vaccine that will slow the spread of the disease, reduce the number of people infected, and minimize suffering.

Pandemic response plans generally have three components:

1. Pharmaceutical Strategy – the stockpiling and distribution of anti-viral drugs, such as Zanamivir (Relenza®) and Oseltamivir (Tamiflu®), and antibiotics to reduce the effects of infection.
2. Primary Healthcare Strategy – how hospitals and general practitioners will deal with the greatly increased demand for their services.
3. Non-Pharmaceutical Strategy – the slowing of the spread of the disease by closing schools, preventing public gatherings, and other methods to reduce infection routes through the general population.

How successful these measures are in reducing the impact of the disease depends on a number of factors. Epidemiological studies help governments decide what the best approach should be, and these models show how effective a pandemic response plan might be in slowing the spread until a vaccine is available.

The efficiency of the execution of these published plans has proved to be very variable in past epidemics. If the primary healthcare workers experience a high level of infection themselves early on in the pandemic, then this has a cascade effect in increasing the severity of the impact of the disease on the rest of the population.

Some plans envisage the stockpiling and general distribution of antiviral drugs but these have not been tested. For many of these plans to be effective, they need to be implemented early in the pandemic timeline. Delays or slow implementation significantly decrease the effectiveness of these measures.

Many of these plans are intended to be implemented when there is an official declaration of a pandemic by the World Health Organization. Delays in declaring a pandemic could reduce the effectiveness of many preparedness plans worldwide.

Another variant of the scenario, S2, assumes the pandemic preparedness plans of national governments are less successful than hoped.

We also explore a final variant, X1, where vaccine strategy fails, combined with the failure of the national government pandemic preparedness plan.

4 Defining the Scenario

This scenario explores the consequences of a key emerging threat type – pandemic risk – by examining the 1% probability of severity that might be exceeded in a year, i.e. a '1-in-100' pandemic event – with a selected example of how that severity could come about. There are many ways that something this severe could occur and many variables that would change the characteristics of the event, but this scenario is one illustrative example of a way that this could occur.

We simulate the outbreak starting in Brazil. Brazil was selected to provide geographic balance relative to other stress test scenarios in the Centre for Risk Studies scenario suite. Apart from having a large poultry industry, there is no reason to suspect that Brazil is a more likely location than anywhere else for a new virus to mutate. The geographic location of the outbreak that triggers the next pandemic is relatively unimportant – the pandemic is global. Other than slightly more severe effects and earlier impact in the country of outbreak, only the sequencing and timing of spread is affected by the location of the outbreak.

Selected from RMS Infectious Disease Model

The pandemic scenario was selected from the probabilistic event set of the RMS Infectious Disease Model (IDM), and is used by kind permission of RMS, a supporter of the Centre for Risk Studies. Support for the study was provided by the infectious disease modellers of the RMS LifeRisks team.

A '1-in-100' event

The scenario we describe is unlikely to occur. In fact we have chosen a severity of scenario that could only be expected to occur with a chance of 1-in-100 in any year. So there is a 99% probability that a scenario of this severity will not occur next year. The scenario has been developed by reviewing the severity of infectious disease pandemics that might be expected once a century and then creating a narrative about how a pandemic that severe could come about, and what effect that kind of event would have.

The scenario is selected from the event set of the Infectious Disease Model (IDM) produced by Risk Management Solutions. The RMS IDM is a commercial model licensed by life insurance companies for use in risk management of life insurance portfolios. The model consists of several thousands of simulated synthetic scenarios of pandemics, with stochastic assessments of the variables that could occur, to deliver a probabilistic view of the risk spectrum of pandemics that could occur.

The RMS IDM is designed to provide a probabilistic view of numbers of deaths and illness severity levels that could result from infectious disease pandemics. It considers the likely combinations of parameters of potential pathogens and synthesizes around 5,000 different scenarios of disease pandemics, together with their relative likelihood of occurrence.

RMS models the spread of the infection through the population using Susceptible, Infected, Recovered (SIR) modeling, a well-established technique used by epidemiologists to accurately describe the spread of diseases.

The SIR model computes the number of people infected with an infectious disease in a closed population over time and is used to explore the effects of different circumstances and strategies to combat the disease, such as reducing the contact rates in the population through closing schools and public assemblies, and how vaccination programmes will reduce the infection spread.

Transmissibility and virulence

There are two key parameters of an infectious disease pathogen, like influenza. These are transmissibility and virulence.

Transmissibility

Infectiousness or 'transmissibility' is how fast the disease spreads through the population and what proportion of the population it ultimately infects. This is often measured in terms of the initial reproductive index (R_0), which is a measure of how many people are infected on average by the infected reference cases that can be traced early on in the outbreak. Transmissibility depends on contact rates, duration of infectiousness, and likelihood of contacts becoming infected.

Virulence

Virulence is how severely it makes people sick, and how many infected people die as a result. The virulence of a pathogen is measured in terms of its case-fatality rate (CFR), and determines how fatal the illness is. Pathogens can affect their hosts in different ways according to their genetic structure, and vary considerably in their virulence.

For example, seasonal flu has a low CFR (around one person per 1,000 cases), but even so, around 40,000 Americans die of seasonal flu each year. The 1918 virus had a CFR of over twenty times higher than seasonal flu.

Transmissibility and virulence trade-off

These two parameters are not independent: A disease that is very virulent kills off its host and scares people into reducing their contact rate, so the number of people that are infected is reduced. Viruses tend to sacrifice virulence for infectiousness as they mutate to maximize their evolutionary success.

Selecting a scenario

The 1-in-100 scenario could be caused by many combinations of infectiousness and virulence. The most extreme scenarios of very infectious pathogens that are also highly virulent are fortunately very rare. The likelihood of such a scenario is well beyond the threshold of improbability that the Centre for Risk Studies has standardized on for its stress test scenarios. The likelihood of very infectious-high virulence pathogens triggering a pandemic are much lower. Historically there are only a few examples of very infectious-high virulence plagues occurring over the recorded history of the past couple of millennia.

The options considered for a pandemic stress test scenario at the 1-in-100 level of likelihood included:

1. **Virulent Disease with Low Infection Rate**; a virus that kills a high percentage of those infected, but has a limited spread. An example precedent would be SARS. Fear of contracting the disease would be the main cause of economic disruption, but the actual number of infected people would be low.
2. **Highly Infectious Disease with Moderate Virulence**; A pandemic that infects a high percentage of the population. Absenteeism and scale of medical treatment required is the major societal issue. It would touch many areas of commercial activity and potentially multiple lines of insurance coverages.
3. **New Variant of Emerging Infectious Disease**; This could be a new variant of contagious pathogen for which medical science has no initial treatment, for example laboratory-developed, gain-of-function H5N1, AIDS, or a haemorrhagic virus. A new pathogen of serious societal consequence could be expected with an annual probability of 1%. However, the expected frequency and severity distribution of new pathogens suggests that a new emerging infectious disease with a 1% annual probability would not be as severe as an influenza virus. Emerging infectious diseases can be far more severe than influenza, but the probabilities of really extreme EID pandemics would be far lower than the target threshold here.

We have chosen to develop the stress test scenario for Highly Infectious Disease with Moderate Virulence. We have selected a specific scenario for use in the stress testing by looking at the return period of infectiousness, and picking an appropriate level of virulence that results. Figure 3 shows the exceedance probability distribution for proportion of the population infected in the RMS infectious disease model, and the 1% annual probability of exceedance level that this suggests.

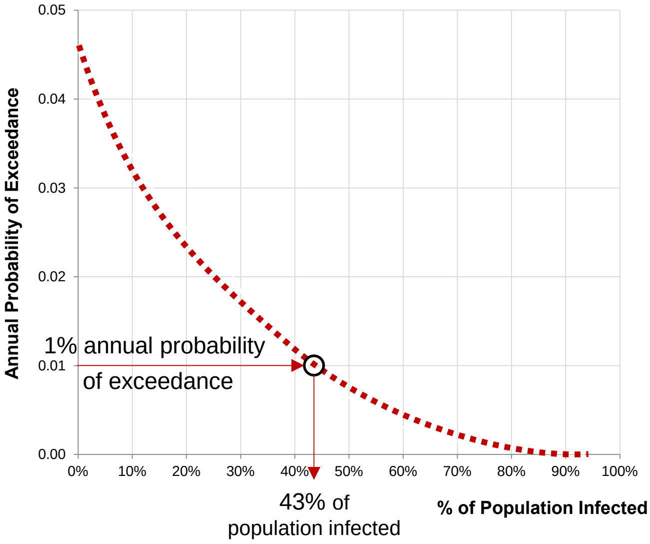


Figure 3: Probability of infection level in the population from RMS Infectious Diseases Model

The 1-in-100 level of infectiousness results in around 43% of the world's population being infected. This is different from country to country and in different regions. It is likely to be higher and more virulent in the initial outbreak region but to lose virulence as it spreads, so that the worldwide virulence is considerably lower than its initial phase.

We believe this will give the best stress test at the 1-in-100 level for multiple lines of insurance business. Future scenarios could be developed to explore the characteristics of the other candidate types considered.

Pandemic scenario stages

A. Outbreak

Evidence emerges that a new pathogen has emerged, but the implications are not yet apparent. Impact is regional – the location of the outbreak and industries associated with the region are directly impacted.

B. International Spread

Period of chaotic uncertainty as the disease starts to spread but little is known about the pathogen or what is occurring. The world is caught between the need for preparedness and concern for over-reaction.

C. Pandemic response

The characteristics of the pathogen become clearer. All countries are now experiencing the full impact of the infection spreading rapidly through their populations. There is no vaccine yet available but the world has to try to minimize the impacts of the pandemic and slow up the spread until a vaccine is developed.

D. Vaccination phase

The knowledge that a vaccine has been developed brings hope and optimism, but there are frustrations and public impatience in the time taken to obtain large quantities of vaccine and implement a vaccination programme. The disease continues to spread, and the worst of the impacts may be occurring at this time.

E. Post-peak tail-off

Once the wave of illness has peaked, the expectation may be that the pandemic is conquered, but the peak marks roughly the half-way stage in the pandemic. There may be an even longer period of continued illness spread, social disruption, and frustratingly slow progress in returning to pre-pandemic life.

F. Possible resurgent waves

After the pandemic has apparently passed, there will be resurgent waves of infection, possibly due to new strains of the virus as it mutates. The virus is likely to cause a heavy increase in the next seasonal flu. Each of these may cause alarm and public despondency.

Variants on the pandemic scenario

Pandemic Baseline S1

This is the best estimate of the consequences of the pandemic, given the parameters of the event. As the disease spreads, each national government carries out its response plans according to their official Pandemic Response Plan (PRP) as published with the World Health Organization, and these plans are as effective as they are hoped to be. Vaccine supplies become available within about five months of the start of the outbreak, as expected, and the vaccine has an efficacy similar to standard vaccines produced for seasonal flu and as achieved in previous pandemics.

Variant S2 – Response Failure

In this variant, the scenario is the baseline scenario S1 except that Pandemic Response Plans are poorly implemented by the authorities. Response is slow, actions are ineffective, and the public fails to cooperate. The resulting delays lead to significant increases in infection rates. Inability to increase emergency healthcare capacity leads to higher impacts on the population. Vaccine assumptions are as in S1.

Variant S3 – Vaccine Failure

This variant takes the baseline scenario S1, but assumes that the vaccine takes longer to produce, the resulting vaccine has a lower efficacy than expected, and takes longer for the vaccination to be administered to the general population. An example of how this might arise is if the strain of the virus is more complex and there are difficulties in using the standard processes to produce and manufacture the vaccine, and if the vaccine producers experience difficulties and adverse reactions during the clinical trial stage.

Influenza vaccine production still depends heavily on using chicken eggs to incubate the culture, so egg shortages, or the virus being so virulent that it kills the egg, would require alternative means of producing the vaccine such as using cell culture technology that has not been industrialised.

Vaccines sometimes need two separate courses – a second injection after a few days – for a recipient to achieve immunity. Some vaccines have low efficacy and may only confer immunity on less than half of the usual 70% of people who are vaccinated.

The final potential complication is the organization of the vaccination programme, with the population participating in an orderly process with an adequate number of clinical nurses to carry out subcutaneous injections. An orderly programme can vaccinate millions of people in a few weeks, but poor organization and shortage of medical staff could make the process much lengthier and less effective.

Variant S3 assumes that these complications lead to the vaccination programme making little contribution to the immunity levels in the population before the main wave of infection has passed through. Other response effectiveness assumptions are as in S1.

Variant X1 – Response and Vaccine Failure

In this variant, both the response failure (as assumed in variant S2) and the vaccine failure (as assumed in variant S3) occur together.

5 The Scenario

A. Outbreak

Clusters of unusual deaths and severe illness in otherwise healthy young men in suburbs of São Paulo are recorded by Anvisa, the National Health Surveillance Agency of Brazil. The casualties are mainly workers in poultry farms. Laboratory tests identify that they are infected with a new variant of influenza virus, H8N8.

The new virus is circulating in the battery chicken population but has jumped species to infect the farm workers. The virus is similar to variants of H8N8 found in birds in China, and officials suspect that it may have come to Brazil through international imports of poultry.

Some of the deaths are occurring in friends and family of the poultry farm workers, demonstrating that that the virus has mutated and undergone an antigenic shift, and is now being transmitted from human to human. There is no vaccine available for H8N8 but the disease responds well to anti-viral treatment, if administered in the first 48 hours, before the infection is too far advanced.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Virus warning for Brazil

Mystery virus spreads as government warn citizens to avoid Brazil

Wednesday, March 12

Sao Paolo (1048 GMT – 0648 BRT) - **The UK Foreign & Commonwealth Office and US State Department have issued a travel advisory warning for Brazil following an outbreak of an as yet unidentified virus.**

Brazilian government officials have condemned the moves, calling them a "reckless, irresponsible and expensive overreaction", but UK officials point to the number of recent outbreaks and the lack of progress in identifying the

WHO specialists arrive in Brazil to investigate the mystery virus that has caused over 100 deaths.

it was reported that over 100 people have died in the last week.

Over a 10 day period there are over 100 deaths. Most of the deaths are in teenagers and young adults. The outbreak is quickly picked up by the international media who dub this the 'Killer São Paulo Virus'. Public health officials are trying to track all the known contacts of the people known to be infected – over 8,000 people are put into quarantine.

The death count suggests that the virulence of the virus could be disturbingly high. Case Fatality Rate estimates are wildly variable, as nobody knows quite how many people are actually infected.

A specialist team from the World Health Organization arrives in Brazil to investigate. A local doctor tells reporters that he estimates that "10% of people who catch the virus die".

The media reports are alarmist, with headlines such as 'Deadly pandemic on the way'. A WHO spokesman is quick to disparage these reports and warn against unnecessary reactions. However, international stock markets are affected by the news, with a particular impact on Latin American currencies and regional markets. Stock prices fall for international companies involved in exports to Brazil, particularly machinery and public transport suppliers, and chemical providers.

Measures taken to prevent any further spread of the virus include the large scale destruction of farmed chicken populations throughout Brazil and Latin America.

Exports of livestock from China and South East Asia are suspended. Poultry farms in many countries are subjected to testing programmes, and pockets of H8N8-infected chickens are found in many countries, leading to widespread preventative culls of poultry populations. Many farmers and meat producers are affected. There are shortages of chicken meat on the international market.

Foreign offices of many countries put out official advice to avoid unnecessary travel to Brazil. An executive of a US company on a business trip is hospitalized in Brazil with São Paulo Virus. He sues his company for not having prevented travel to the affected region. Many companies institute compulsory no-travel policies.

WHO declares 'Alert' level, the second tier on its four-phase pandemic risk scale and institutes an Emergency Committee to advise the Director General on preparation and response.

B. International spread

Cases of São Paulo Virus start to be recorded in several other countries, particularly those with strong air traffic connections to Brazil. United States and Southern Europe see clusters of new cases.

Standard procedure is for contact tracing and containment: in each case, with people that the infected person has come into contact with being traced, placed in quarantine and given anti-viral drugs. Laboratories become overloaded with requests to test suspected cases.


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Sao Paulo Virus sweeps across globe

All populated continents report cases of the mystery virus

Thursday, April 24

Atlanta, US (1454 GMT – 0954 EST) – **Fear is gripping the world as hospitals struggle to cope with increasing numbers of sick people. Researchers at the CDC are "making progress" in identifying the genetic characteristics of the Sao Paolo Flu Virus.**

Much is still unknown about Sao Paolo Virus, although health officials have stated it is one of the most infectious viruses they have encountered. People reporting symptoms are immediately quarantined but the virus is still

Business and tourism is trying to continue as usual but economists say productivity is down by a significant amount.

following earlier criticism of their reluctance to restrict air travel.

They quickly face a backlog of several weeks, meaning that officials cannot assess the extent of infection in the population. Eventually public health labs give up on conducting tests, and resort to only testing sample sub-sets.

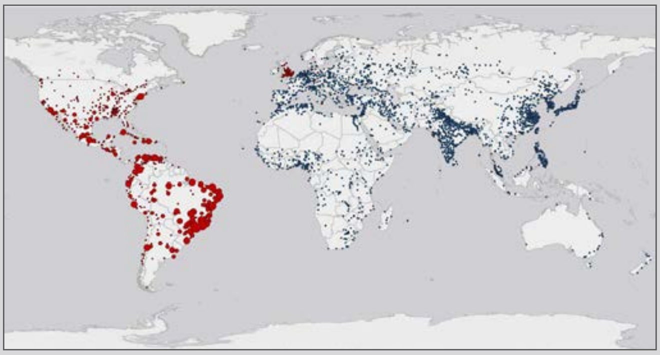
Deaths in countries across the world start occurring about two weeks after the index cases in each country. Traditional and social media focus on recording the incidence of people who are infected and highlight the deaths.

Personal knowledge of someone infected increases the perception of many in the general public, and social media help to personalise the pandemic. Fear is rapidly spreading that there is a deadly disease circulating for which there is no medical treatment.People advocate withdrawing children from school and staying away from workplaces or other social contact.

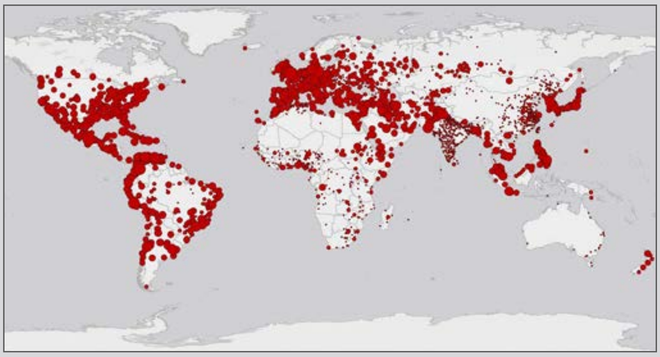
Public health officials and political leaders in each country try to respond to these fears with public pronouncements and reassurance. Politicians warn of the economic impact of a 'pandemic' false alarm. The WHO urges caution and resists declaring a global pandemic.

Many people from North American and Europe stop travelling, particularly to Latin America. The airline industry sees major drop-off in demand. Latin American tourism and international tourism generally is affected. Major sporting and entertainment events throughout the region are cancelled.

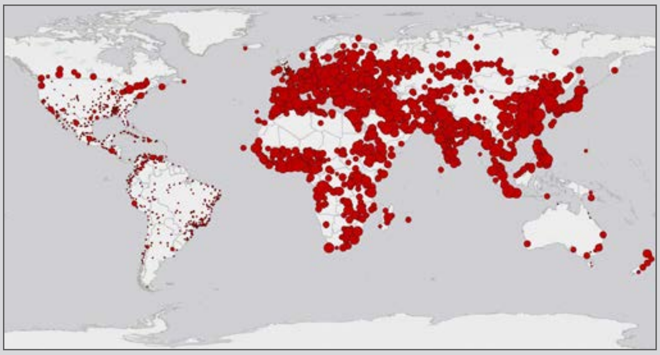
Public health officials are still grappling with understanding the characteristics of the virus, but identify that it has a high infectiousness index (Ro). If it is not possible to contain the spread of the disease, it will rapidly spread globally. This is a period of major uncertainty, with a lot of commentary, opinion, and news coverage, but few facts.



Week 8: Initial cases are appearing in cities worldwide, with major infection in the Americas.



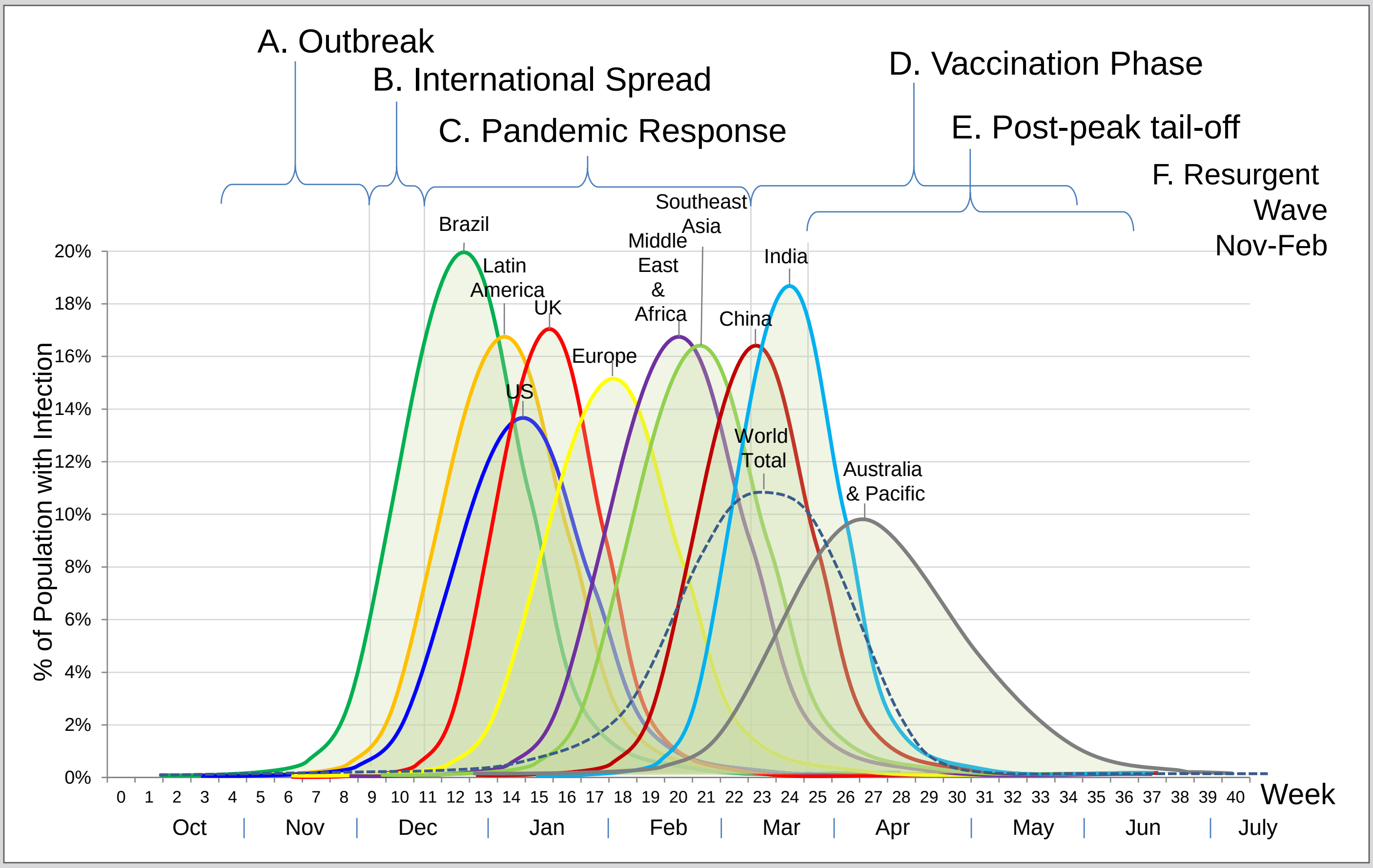
Week 16. Infection rates peak in Europe, are on the wane in the Americas and rising in Asia.



Week 20. Infection peaks in Africa and many parts of Asia, but is now dying out in the Americas.

Businesses grapple with the impacts on their operations of public concern and some levels of employee absenteeism.

A random sample surveillance test for H8N8 antibodies in the human population of São Paulo suggests that infection rates have been much higher than previously estimated. This means that there is likely to be significant numbers of people with mild infections that are spreading it to others. The spread is not likely to be containable by contact-tracing people with severe symptoms. However, this also means that the virus is less deadly than originally feared – the known death count is the tip of an iceberg of much broader spectrum of illness caused by the infection.



Many countries start ordering anti-viral drugs to top up their stockpiles, but demand exceeds supply; A major pharmaceutical company auctions its anti-viral production capacity.

C. Pandemic response

The spread of cases of São Paulo Virus is now evident within multiple continents, with caseloads increasing week by week. General practitioners and health clinics are swamped with people with suspected flu symptoms and people worried they may be infected.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BREAKING NEWS

WHO declares global pandemic

Some countries declare martial law to contain the outbreak

Saturday, May 17

Mexico City (1723 GMT – 1123 CDT) - **The WHO has declared a global pandemic, requiring governments around the world to shutdown public areas and prioritise medical attention.**

Critics argue that this announcement is coming weeks later than it should have done causing tens of thousands of unnecessary deaths and millions of extra infections.

Businesses have closed to minimise exposure, with experts suggesting that

Mexican army drafted in to contain virus outbreak in Mexico City

Thus far, casualties have been much lower in the west, where anti-viral medication has helped stem the severity of the virus.

After increasing political pressure and detailed review, WHO finally declares a global pandemic, and upgrades its pandemic alert to Phase 3 'Pandemic'. This requires governments worldwide to implement pandemic response plans. Every country has its own plan, each is a blend of increasing public healthcare resources and prioritising pandemic treatment, a pharmaceutical strategy of making stockpiles of drugs available to frontline healthcare services, and non-pharmaceutical strategies of reducing contact rates in the general public.

Typically, governments cancel non-emergency hospital admittance, and set up layered healthcare provision, including increased medical consultation capability, streamlined drug prescription processes, emergency hospital wards and improvised overflow bed facilities, prioritised critical care facilities, ventilators, and emergency equipment. Even so, the demand for medical treatment is typically exceeded, and care is triaged, with prioritization for life-threatened cases.

In many countries non-pharmaceutical strategies involve closing schools, suspending public gatherings, closing restaurants, theatres, stadiums and other activities. There is no official advice provided about suspending workplace activity. Public transport continues but trains and buses timetables are impacted by a reduced workforce.

Companies find that a growing number of their employees are off sick each week. They struggle to maintain business operations. Many companies institute rules for operation during a pandemic, including allowing work-at-home and remote access, daily sterilization of work surfaces, reducing the size of in-person meetings, and exposure of staff to contact with the general public. Even so, many are affected by absenteeism from staff who are sick, nursing sick family members, or unwilling to come to work. Management suspects that many reported cases of the virus are excuses for no-shows.

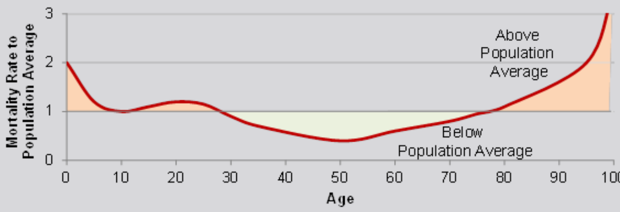
Many instigate reduced productivity working. Some companies close down their offices. Workers asked to continue work and who subsequently get sick bring claims against management for exposing them to unsafe workplaces.

Essential services, utility provision, power, water, trucking delivery, and other commercial activities are impacted by periods of service failures, caused by the absenteeism of operatives. Countries face power blackouts, delivery shortfalls, and shortages.

There is panic-buying of over-the-counter medical supplies, food, petrol, and general supplies. Restocking sold-out supermarkets, petrol stations, pharmacies, etc. becomes a problem with high absenteeism in delivery personnel. The army is drafted in to maintain essential supplies and services.

The increasing case loads now make it possible to measure the Case Fatality Rate with some confidence. CFR is averaging less than 0.5% – lower in countries applying rapid anti-viral treatment.

The age mortality profile of the disease is giving cause for concern. As with other strains of influenza, the highest impact is on the young and the old, but young adults are badly affected, with age ranges from mid-teens to 30s – economically productive youngsters – suffering mortality rates above the population average.



Age mortality profile of pandemic impact on population

Towards the end of this phase a leading virology lab isolates the São Paulo Virus and publishes the genetic characteristics, starting the race to develop a vaccine. The first potential vaccine culture is produced and tests begin on volunteers.

D. Vaccination phase

The timing of the vaccination phase is a major variable in the development of the scenario. If it can occur fast enough, then the death toll can be significantly reduced, the spread of the epidemic reduced and the overall impact mitigated. In this scenario, the expected case is for vaccine to start to become available in quantity three months after the pandemic outbreak. This is several weeks faster than occurred in 2009. It occurs around the peak of the infection wave. (In the second variant of the pandemic scenario, it occurs much later.)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Vaccinations begin for Sao Paulo Virus

Pharmaceutical companies struggle to meet demand for new drug

Wednesday, July 9

London, England (1029 GMT) - **The NHS has unveiled its vaccination programme, where health workers and the most vulnerable people will receive the first wave of vaccines. The UK death toll has already reached 40,000 however authorities believe the worst has passed.**

Despite long queues and some angry exchanges, western societies have managed the vaccination process in a smooth and efficient manager, claimed a WHO spokesperson. Less developed countries continue to struggle

Chicken eggs are used to create the vaccination for the Sao Paolo Virus, also known as H8N8.

In the UK, optimism is beginning to replace fear. Those vaccinated are given a certificate entitling them to return to work immediately. "It feels

There are continual announcements about the status of vaccine trials, the approval for use by the Federal Drug Administration and other drug regulators, the commencement of manufacturing processes, and the likely arrival dates of vaccine. These announcements boost public morale and give hope to the population. Tests show that the vaccine has limited side effects and an efficacy of 70% – (the percentage of those vaccinated who will not become infected if they are exposed to the virus).

Just as case loads are reaching very high levels, supplies of vaccine start to arrive in most countries. It is a race against time. As more of the population is vaccinated, the pandemic will slow up its progress.

Governments around the world have placed orders for the vaccine with the major pharmaceutical companies. One third of production is ear-marked for low-income countries. Vaccine production facilities have been expanded – there are now around 200 factories in 20 countries, most of which use a traditional chicken-egg incubation technique which takes several days to produce a dose, and collectively they produce around 100m doses a month.

Global production is maximised but demand is high across the world. Small amounts are given to each country and arrive at a slow rate, so vaccination is prioritised.

Front-line healthcare workers are first, followed by the most vulnerable (pre-existing medical conditions, elderly, pregnant women) and then children. Vaccination centres are set up, and members of the public are allocated an appointment date for their vaccination. Nurses administer a single injection. Vaccine has to be kept refrigerated, even in transit. There are long queues of people at each vaccination centre but the processing of large numbers of people quickly is very efficient.

As each person is vaccinated, they receive a certificate. Certified people are able to return to work.

The mood of the general public becomes more positive as it becomes apparent that the vaccination programme is beating the pandemic – they can see that this is the beginning of the end.

Clinical trials demonstrate that vaccine is safe, with limited side-effects, and the US Food and Drug Administration and the European Medicines Agency rushes through certification for general use.

Caseloads reach very high levels during the vaccination phase and may even have peaked in some countries before the vaccination programme starts.

E. Post-peak tail-off

The wave of illness has peaked, as the number of new cases is diminishing week by week.

The expectation is that the pandemic is conquered, but the peak marks roughly the half-way stage in the pandemic. The public starts to demand the relaxation of the restrictions that are in place.

Some local authorities accede to these demands and allow schools to re-open and other public activities to resume. In almost all localities where this occurs, infection rates suddenly increase again within a few days, forcing authorities to reinstitute their controls.

There is only frustratingly slow progress towards returning to pre-pandemic life.

It is evident that it will be a long slow process to kill off the pandemic. Companies re-orientate and prepare for resumption of normal business; however a continued incidence of new infections prevents normal activities. Absenteeism continues to inflict disruption across multiple economic sectors.

The public is losing tolerance during the long wait for resumption of daily life.

Companies that are well prepared compete vigorously to take market share from still-struggling competitors. Individuals who have been vaccinated, and those who have had a dose of the San Paulo Flu and recovered, are 'the immune' – they are unlikely to become infected and can return to work.

These individuals become valuable in the workplace as their risk of falling ill is less than colleagues who remain susceptible. Companies set up monitoring and registration schemes to identify those in their workforce who are immune. Some companies offer hiring bonuses and premium pay rates for immune staff. A number of companies seek advantage over their competitors through rapid recovery of their activities.

After the pandemic has subsided, there is a public clamour that such an event should never be allowed to occur again. Post-event reviews, government committees, and international investigations prompt a new regulatory framework for managing pandemic risk, both as a public healthcare issue, and as a business risk management problem to prevent recurrence of disruption.

New regulations are put into place requiring businesses to conform to new procedures, adding costs for businesses to operate.

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'Open for business' as Sao Paulo fades

WHO: "Infection rates are slowing but there is still a threat"

Tuesday, August 19

New York (1438 GMT – 0938 EST) - **The head of the WHO rang the opening bell on the NYSE with gusto this morning. It was a signal that the city is open for business, but not without caution.**

The threat of Sao Paolo Virus still lingers on the streets of New York, as it does on most of the world's cosmopolitan hubs. Their multicultural blend of everything created a vulnerability not experienced across middle America.

Facemasks are required on the NYC and London transport systems

The return to normal has been inconsistent though, with several businesses failing as their cash flows dried up. "We're looking at the risk

Possible resurgent waves

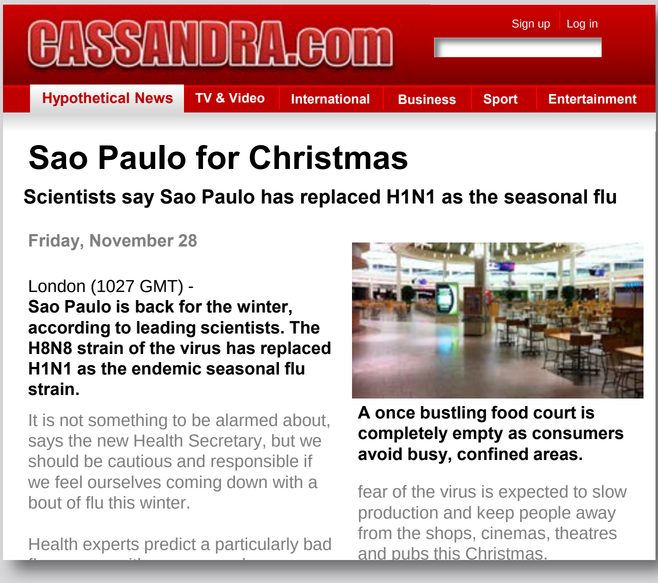
The São Paulo Flu virus displaces H1N1 as the endemic seasonal flu strain in common circulation. The following winter sees a very strong seasonal flu wave throughout the population as the new variant takes hold.

In this wave, many elderly and young children catch the flu and are made unusually sick as a result. Death rates are unusually high in the elderly.

This resurgent wave of the virus causes another period of disruption over the winter, with absenteeism resulting from employees having to look after old and young relatives affected by the new flu wave.

A particular strain of the new variant acquires Tamiflu resistance – people treated using Tamiflu no longer respond. This deprives medical science of a key weapon against the virus and increases the death toll of the winter wave.

The circulation of a strain that is resistant to antivirals is a real concern to public health officials. They begin a major programme of drug development to find a new treatment for the new strain.



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Sao Paulo for Christmas

Scientists say Sao Paulo has replaced H1N1 as the seasonal flu

Friday, November 28

London (1027 GMT) -
Sao Paulo is back for the winter, according to leading scientists. The H8N8 strain of the virus has replaced H1N1 as the endemic seasonal flu strain.

It is not something to be alarmed about, says the new Health Secretary, but we should be cautious and responsible if we feel ourselves coming down with a bout of flu this winter.

Health experts predict a particularly bad

A once bustling food court is completely empty as consumers avoid busy, confined areas.

fear of the virus is expected to slow production and keep people away from the shops, cinemas, theatres and pubs this Christmas.

The resurgence of the pandemic reduces public morale, with the realisation that the new influenza virus is going to be around for a long time, causing an elevated level of winter flu deaths in most countries each year.

6 Loss and Direct Impacts

The scenario described leads to a wave of infection in each community and country, at different times around the world. Everyone reacts differently to being infected and some people are made more sick than others. A fraction of people who catch the virus are made very ill, and without proper treatment and care, will die. The severity of the illness suffered can be alleviated with treatment, so the overall distribution of illness rates that finally occur in the population depends on the capacity to provide treatment and the drugs available to alleviate the severity of illness.

Table 3 shows a typical distribution of illness severity that might be expected in the population, expressed as a severity that would translate into demand for treatments. This is a world average. There could be significant differences between individual countries – for example we might see infection rates ranging from 30% in one country's population to 50% in another.

	Total Infected (out of 10,000)	**4,300**
1	Infected but minimal or no symptoms (asymptomatic)	700
2	Self-medicating	1,400
3	Needing Physician/GP Attention	2,000
4	Hospital Treatment Required	150
5	Critical Care Required for Recovery	28
6	Fatalities	14
	Fatalities as % of infected (Case Fatality Rate)	0.3%

Table 4: Typical illness severity distributions in average infected populations per 10,000 people

These illness severity rates imply levels of demand for treatments that well exceed the capacity that exists.

	US	UK
Hospitalization		
Total Hospital Beds	944,277	136,486
Average % Occupancy Normally	68%	86%
Pandemic demand (Needing hospital treatment)	1.8 million	312,000
Intensive/Critical Care		
Total Intensive/Critical Care Beds	67,357	3,770
Average % Occupancy Normally	80%	85%
Pandemic demand (Needing Intensive Care)	350,000	58,000

Table 5: Scenario pandemic demand for healthcare capacity, compared to actual capacity

Shortfall in treatment capacity

Table 4 demonstrates the level of capacity limitations and likely shortfall in treatment that will be available in a pandemic to treat some of the more severe reactions to the infection. These are mainly people who develop severe respiratory difficulties and need ventilator support, people who suffer bacteriological infections or develop pneumonia, and other medical complications, such as heart or circulatory emergencies. These require hospitalization and in severe cases, ventilator support and intensive care equipment.

In the US for example, the scenario projects that 1.8 million people would require hospital treatment, but the US medical system contains only 944,277 beds, of which 68% are normally occupied. In a pandemic, non-essential patients will be discharged to free up more beds, but the available beds will still only cope with a small proportion of the people who need it. The pandemic preparedness plan for many countries envisages the setting up of temporary hospitals in stadiums, deployment of military field hospitals, and other emergency provision. The main bottleneck for meeting the emergency surge demand is likely to be medical staff. This is less easily expanded, and at the very time of this increased demand, many of the medical staff will themselves be incapacitated from being infected. Front-line medical staff treating infected patients are expected to suffer higher infection rates than the general public.

The shortfall in capacity to meet pandemic demand is significantly worse for intensive care (known as critical care in US). For example in the UK, there are 3,770 intensive care beds, of which 85% are typically in use. In this pandemic scenario the estimated number of people who would need intensive care for recovery would be 58,000 – fifteen times larger than the total number of IC beds available. In the US, the pandemic demand for critical care is estimated at 350,000 relative to the 67,357 critical care beds that exist – five times larger than capacity. In the analysis, we have assumed that half of those who do not receive intensive/critical care die as a result.

Total Death Toll *(S1 Variant)*	
Worldwide:	19 million deaths
United States:	425,000 deaths
UK:	70,000 deaths

Table 6: Total death toll for world, US and UK (S1)

The death toll from the pandemic is likely to be a major focus of the public concern and authority response. It will dominate media attention.

However, the main impact of the pandemic is likely to result from the incapacitation – albeit temporarily – of a much larger segment of the population through the illness of infection.

Workforce absenteeism

People are debilitated for days, and in some cases weeks, during the period they are infected. In addition to those who are ill, people who have dependents who become ill also stay home to nurse them – the 'absent caring'. Some people stay home through fear of catching the disease, and fear-driven absenteeism increases with the perception of deadliness of the disease. Others cannot get in to work because the public transport system fails due to its own staffing difficulties. Figure 4 shows the cumulative absenteeism that might be expected in an average workforce during the peak wave of infection.

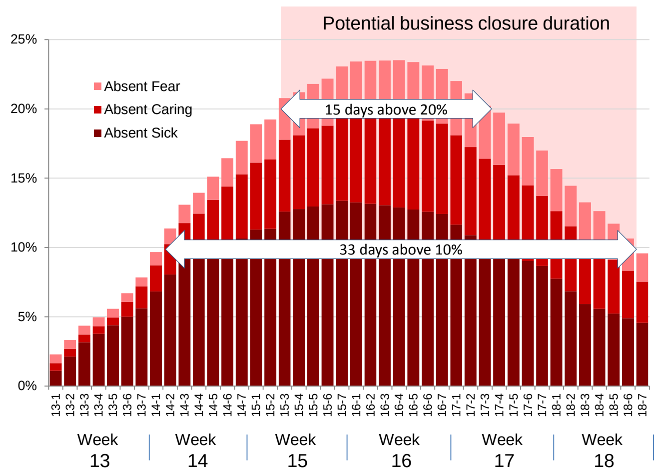

Figure 4: Absenteeism in the workforce during a pandemic (modelled for UK)

Although Figure 4 shows absenteeism from average illness rates in the population, illness rates vary considerably in different clusters of people, such as different towns or in the workforce of different companies.

Around 1 in 8 organizations will be hit by infection rates that are twice the national average in their workforce. Around 1 company in 50 will have three times the national average. Although some companies are more likely to suffer higher infection levels because of their activities (higher interaction with the general population or providing healthcare services may increase illness levels in the workforce), there is also a significant random element to the clustering of disease.

A company preparing for operational continuity would be advised to consider the possibility of randomly experiencing absenteeism levels significantly higher than the average in the population.

Absenteeism has a non-linear effect on productivity and may reach a tipping-point where businesses have to close. Studies show that many businesses can operate reasonably well with absenteeism levels below 10%, but beyond 10% productivity drops off disproportionately and with absenteeism of 20%, many vital operations become difficult and some businesses are likely to suspend operations.

Figure 4 shows that a company with levels of infection in its workforce similar to the population average should expect to experience absenteeism of 10% or more for over a month. Absenteeism of 20% or more would occur for around two weeks. A company that did decide to suspend operations when absenteeism reached 20% may not resume operations until absenteeism has dropped to well below 10%.

Organizations that experience above-average infection will close earlier. Some will close pre-emptively. Companies that trade with businesses that have suspended operations may themselves be unable to continue their activities. Managers may consider it a responsible action to suspend business operations for the duration of the pandemic peak, particularly when many other businesses are closing.

The cascade of organization closures will ripple through the social and economic fabric of one country after another, and may lead to lengthy periods where a large proportion of economic productivity is suspended.

Disruption to the global economy

The globalized economy means that major corporations will have to manage over the six months or more that the pandemic illness wave is progressing round the world, with offices in different countries closing for weeks at a time. Companies managing global supply chains and international trading operations could experience disruption at different times from suspension of activities in many territories at different times during the many months that it takes for the pandemic to spread around the globe.

This wave of business suspension and disruption to operations will cause some companies more difficulties than others. Some may fail. Businesses may find that their counterparties are unable to honour their obligations, and this could lead to a spiral of business difficulties and economic failures.

Failures could also impact the financial system, with credit and liquidity becoming scarcer. The pandemic could trigger an international financial crisis.

Life and Health insurance payouts

The international insurance industry will face significant claims as a result of the pandemic scenario. These will be most evident in the life and health insurance sector, where the illness treatment payouts will be significant, and deaths will trigger payouts on life insurance policies.

Life insurance penetration varies significantly from country to country, with the largest concentrations of life insurance in United States, Japan, and Europe, where group life cover is a standard employment benefit and house mortgage lending is commonly linked to individual life insurance guarantees.

For this scenario study, a global life insurance exposure database was developed in collaboration with Axco Insurance Information Services Ltd.

Each year $2.4 trillion of life insurance premium income is collected worldwide, which relates to an estimated 1.2 billion life insurance policies. These have a total aggregate value of life cover of $78 trillion. Figure 5 shows a mapping of insured lives around the world from the global life insurance exposure analysis.

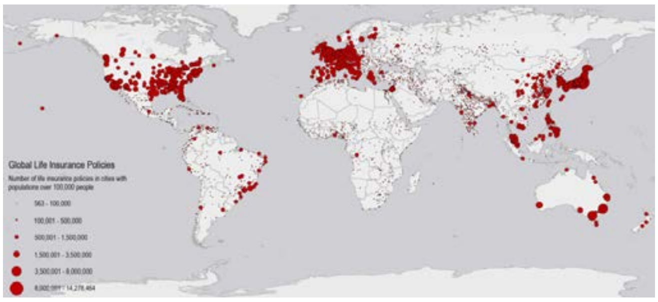

Figure 5: Life insurance policies around the world

	Total Payout	Loss Ratio (% of annual Premium income)
Life Insurance Payouts	$99.2 Bn	4.0%
Personal Accident & Health	$92.7 Bn	9.2%
Total	$191.9 Bn	5.5%

Table 7: Life and health insurance payouts from São Paolo Virus pandemic scenario (S1)

An estimation of the life insurance payouts was made from applying the mortality ratios in each country to the life insurance exposure in that country. Normal mortality rates in insurance portfolios tend to be lower than mortality in the general population, but this underwriting effect is likely to be reduced where infection rates are high, and the age mortality distribution is high in young economically-active adults, as assumed in this scenario.

Healthcare insurance claims were estimated from unit costs of insurance treatment tariffs for physician consultations, hospital admissions and critical care, scaled for each country, and factored by the estimated claims on those treatments by insureds suffering different severities of illness in each country.

The worldwide total estimated payouts for death benefits and healthcare cover is shown in Table 7. In S1, this gives a loss ratio of 4% for life insurance and a significantly higher 9% loss ratio for healthcare. The average annual life insurance payouts on deaths that occur naturally for insured lives is around $940 Bn, so the payouts represent an excess loss of about 11%.

Losses to other lines of insurance

In addition to the payouts for life and health, the insurance industry can expect to experience claims across a large number of other underwriting lines.

Accident & Health coverages
Reimbursement for illness treatment costs

Government (Local Authority) liability
Compensation for deaths that might be blamed on local authority decision-making

Healthcare liability
Deaths that may be blamed on medical malpractice

Event cancellation insurance
Public gatherings cancelled by health officials

Biotech product liability
Vaccine deficiencies (possible waiver from government authorities)

Management liability
Major business losses attributable to poor pandemic response decision-making by senior management

Property loss
Increased incidence of fire, water escape damage in buildings left unoccupied during office closures

Agriculture
Losses from untended crops and unfed animals as a result of sick farm workers

Contingent Business Interruption
Named suppliers unable to meet obligations

Civil Authority Business Interruption
Possible prevention of business operations (e.g. restaurants) by public health act

Auto Insurance
Decrease in claims from lower vehicle usage during pandemic progress

Annuity & Pensions
Decrease in liabilities from premature deaths of annuitants

Class	Line of Business	
Property		
	Personal Lines/Homeowner	-1
	Personal Contents	0
	Commerc al Combined	1
	Construt ion & Engineering	2
	Commerc al Fac ltative	1
	Binding Authorities	0
Casualty		
	Workers Compensation	4
	Directors & Officers	3
	Financ al Lines	4
	General Liability	3
	Healthca re Liability	5
	Professional Lines	1
	Professional Liability	2
Auto		
	Personal Lines	-1
	Commerc al & Fleet	-2
Marine & Specie		
	Cargo	0
	Marine Hull	0
	Marine Liability	1
	Spec e	2
Aerospace		
	Airline	3
	Airport	4
	Av ation Produt s	3
	General Av ation	2
	Spae	0
Energy		
	Downstream	1
	Energy Liability	2
	Onshore Energy & Power	2
	Upstream	0
Specialty		
	Ac dent & Health	4
	Aquac lture Insurane	1
	Contingeny - Film & Eve nt	5
	Equine insurane	1
	Exe ss & Surplus	3
	Life Insurane	3
	Live stok	1

Class	Line of Business	
Life & Health		
	Life Insurane	3
	Health Insurane	5
	Ino me Protet ion	4
	Death & Disability	5
	Hospital Cove r	5
Pension and Annuities		
	Standard Annuities	-2
	Variable Annuities	-2
	Enhane d Annuities	-3
	Life Settlements	-3
War & Political Risk		
	Kidnap & Ransom	0
	Politia l Risk	3
	Politia l Violene & Terrorism	0
	Produt Rea ll	3
	Trade Credit	5
Agriculture		
	Multi-peril c op	1
	Crop hail	0
	Live stok	1
	Forestry	2
	Agric lture	1

Key to change in insurance claims

Major dec ease in c aims	-5
	-4
	-3
	-2
	-1
No c ange in c aims	0
	1
	2
	3
	4
Major inc ease in c aims	5

Table 8: Exposures & Claim Impacts

Pomegranate Inc.

Corporate operational risk example

Pomegranate Inc. is a fictional company used to illustrate the possible effects of scenarios on a corporation. Pomegranate is assumed to be a U.S. consumer electronics company, the 9th largest international player in the highly competitive computer hardware market. It has 100,000 employees worldwide, with headquarters in California, U.S.A., and operates in 75 countries, deriving three quarters of its sales from the main markets of US, Japan, China, and Europe. It sells computers and associated products which it assembles in China, from components and manufacturing suppliers in 20 different countries. It produces over 10 million laptops & tablet units a year. Its new flagship product range is the Pomegranate Persephone 5G tablet computer, currently being launched into a highly competitive consumer market and fighting for market share.

In the pandemic scenario Pomegranate is hit hard:

- Pomegranate suffers above-average absenteeism in United States throughout December and January. Its retail staff, in daily contact with the general public, suffers high levels of infection early on in the pandemic.
- Staffing shortages force it to suspend operations and close stores, missing the key Christmas period of high retail volume, losing revenue.
- A senior manager is infected on a business trip and dies. His family brings a legal action against the company, citing poor travel guidance from the company. The company belatedly issues guidance restricting non-essential international travel.
- Pandemic-related absenteeism hits its Southeast Asia operations in Feb-March, crippling manufacturing in the region. Pomegranate's main assembly plant in Shanghai is badly affected, reducing the number of product units it can provide. Shortages all along the supply chain result in a major shortfall of Pomegranate products available.
- The Pomegranate launch of its new flagship product, the Persephone tablet computer, suffers from lack of available units to sell. Pomegranate loses market share to competitors in its vital opening season.
- Pomegranate sees a 25% stock price fall.
- Stockholders bring a class action against the company executives for failing to have adequate contingency plans for a crisis of this type. The company notifies its insurer of an action under its Directors and Officers liability insurance policy.
- Pomegranate corporate bonds are downgraded by rating agency, making them no longer investment grade.

7 Macroeconomic Consequences

Infectious diseases have major economic impacts. They cause supply side shocks to output in causing labour shortages from the absenteeism of the workforce, and they cause demand shocks by depressing consumption through fear and uncertainty. There are many studies in the literature estimating the economic impact of a pandemic. These are difficult to compare, because the scenarios vary considerably in severity and characteristic between each study, and the methodologies differ in terms of the types of costs and economic loss being considered. The overall macroeconomic effects of a pandemic are:

- Labour supply for economy productivity varies over time and space, and can suffer severe localized shortages that diminish output. The labour participation rate is a major variable.
- Demand drops for a wide range of goods, as a result of fear of the disease and public misapprehension. Discretionary consumption is most strongly affected, but final consumption is reduced across the whole economy.
- Some demand is deferred and boosts the recovery after the pandemic cycle is believed to be over.
- There are general increases in the cost of doing business, which add inflationary pressure on the supply side, but this is counterbalanced by lower consumption on the demand side.
- There are sectoral differences in economic impact, with tourism, travel, and hospitality being affected early on in the spread of a pandemic.
- Impact is highly variable geographically and in population clusters, with random occurrences of extreme infection. This variability leads to failures in businesses and localized operational problems that might not be expected from average statistical projections of impacts.
- Shocks are transmitted and amplified through the interconnectivity of business networks. Weak counterparties fail and trigger a cascade of increased business pressure throughout the trading network.
- Government expenditure increases on emergency response and health care provision.
- There is a global economic re-evaluation of country level risk, with risk levels rising for the more vulnerable countries. Currencies, sovereign debts, and interest rates are affected.

Economic Case Study

The Economic Impact of SARS

The first recorded cases of Severe Acute Respiratory Syndrome (SARS) occurred in China's Guangdong province in November 2002. The disease spread to 32 countries over eight months, with a total of 8,273 confirmed cases and 775 deaths. The high case fatality rate (almost 10% of people who caught SARS died from it) made it highly feared. People avoided travelling and it suppressed demand for tourism and in the services sector for retail, hotels, restaurants and transport.

The most significant economic impacts occurred in China, Hong Kong, Taiwan, and Singapore. Some estimates suggest that Hong Kong GDP (Seasonally adjusted) fell more than 10% in Q2 2003 as a result of the SARS outbreak.[1] Other surveys show that in April 2003 Beijing tourism revenues were down 80%, and travel and transportation were down as much as 50%.[2] Taiwan is estimated to have experienced a 43% drop in services exports (principally tourism) and a 7.9% drop in personal consumption by residents.[3] China is estimated to have suffered a GDP loss of around 0.5% in 2003.[4]

A tourist in Hong Kong carried the disease back to Canada and caused another outbreak there in March 2003. Toronto was the only city outside Asia to be affected: 400 cases were reported and 44 died. 25,000 residents of Toronto were quarantined. The economic consequences for Canada were quite severe: 35% of Americans felt it was unsafe to travel to Canada[5]; Canadian hotels lost $64 million in revenue and a third of the Toronto tourism workforce was laid off[6]. The Bank of Canada estimates that SARS cut Canadian GDP by 0.6% in Q2 of 2003.

The currencies of Indonesia, Thailand, the Philippines and Singapore all sustained big losses as traders fled towards the perceived "safe haven" status of the U.S. dollar, and there were increases in economies' risk premiums in international capital markets.[7]

[1] Siu and Wong (2004)

[2] Hai et al (2004)

[3] Chou et al (2004)

[4] Hanna and Huang (2004)

[5] Harvard School of Public Health

[6] Canadian Tourism Association; Canadian Lodging Outlook

[7] Lee and Mckibbin (2003)

Economic Case Study

Economic impact of 1918 Pandemic in the US

The 1918 Spanish Flu pandemic is profiled as a case study in section 3, above. Around a quarter of the US population was made sick in the pandemic and 675,000 Americans died, at a time that the national population was 103 million – less than a third of its current size. Studies of the economic impacts of the 1918 pandemic are mainly reconstructed from newspaper reports.[8]

The pandemic caused a severe disruption to the national economy. One insurance company reported a 7-fold rise in the number of life insurance claims. The pandemic stopped a lot of small businesses from operating, many of which went bankrupt. In some cities, businesses reported declines of up to 70%, examples being retail grocery businesses reporting business reduced by a third. Not all businesses declined however – Little Rock, Arkansas, reported drug store sales up, and as a result of bed rest being prescribed for flu victims, increased demand for beds, mattresses, and springs. Industrial plants were running at reduced capacity due to labour shortages – the factories were already short of help because of the war draft. Mines closed and halved their outputs for several months. Railways reported more than a quarter of their workforce being on sick leave. Telephone systems had to suspend services due to a shortage of human operators.

The economic consequences were extremely variable from place to place. Many businesses, especially those in the service and entertainment industries, suffered double-digit losses in revenue. The shortage of labour after the pandemic resulted in higher wages for workers for some time, and triggered a temporary hike in costs of services. The effects in some towns and sectors lasted for several years. Some analysts suggest that the human capital impacts of the pandemic affected economic activity for decades afterwards.

Here we attempt to take a holistic view of the impact of this pandemic scenario and its variants across the global economy.

Macroeconomic model types

Macroeconomists take an eclectic approach to modelling that can be separated broadly into six major categories, as described below. The most widely used macroeconomic models are commonly described as computable general equilibrium models (CGE).

a) Visual Models are simple graphical representations of how an economy should behave under a strict set of pre-determined assumptions (e.g. supply and demand curves). They are simple to interpret and understand but are limited in ability to capture the interaction of complex economic phenomenon.

b) Mathematical Models are formal and abstract, and solve simultaneous equations derived using basic theoretical assumptions about how an economy should behave (but necessarily not how it actually does behave). For example a simple mathematical model may include a supply function explaining the behaviour of producers, a demand function for the behaviour of purchasers, and specify how the model equilibrium conditions will be satisfied.

c) Econometric Models use observed data to measure economic phenomena. Historical data are collected and relationships between different macroeconomic variables determined statistically. Equations are derived that explain and forecast how different variables in the economy might behave. Econometric models allow estimations of future performance and relative uncertainty, however as they are defined by historical data, future estimates are projections of the past.

d) Computerised Simulation Models are the most advanced and widely used of all macroeconomic models, combining features of both mathematical and empirical models with Monte-Carlo simulation to perform sensitivity and uncertainty analysis. Models are usually used either for optimisation or projection, and can be static or dynamic. Dynamic models incorporate business cycles and other changes to the economy over time.

e) Computable General Equilibrium models (CGE) make use of the observation that the supply and demand for goods and services, and other factors of production in the economy, tend to be balanced – to be in 'equilibrium'. These models combine economic theory and empirical evidence to trace changes in economic indicators throughout time. They are typically used for comparing a policy intervention against the baseline. An advancement of CGE models is the Dynamic Stochastic General Equilibrium Model (DSGE), which introduces a probabilistic framework into forecasts and considers a distribution of future random shocks.

[8] Garrett (2007)

Variable	Applied	S1	S2	S3	X1
Scenario Variant		Standard scenario	Response failure	Vaccine failure	Response + Vaccine Failure
Duration (Primary Economic Effects)		12 months	15 months	12 months	18 months
Labour Participation Rate	Peak Shock	Pandemic model output (by country)	As S1	+25%	+50%
Final Consumption	Peak Shock	-2%	-3%	-3%	-4%
Tourism Exports	Peak Shock	-5%	-15%	-15%	-25%
Share Price	Peak Shock	-2%	-3%	-3%	-4%
Government Consumption	Peak Shock	+3%	+3%	+3%	+3%

Table 9: Macroeconomic variable inputs into the modelling of the São Paolo Virus Pandemic Scenario

Macroeconomic models are useful in bringing order and structure to complex phenomena, and to explore the 'what-ifs' of economic consequences. However, while they provide guidance and insight, their outputs must be used appropriately and treated with caution and scepticism. Each type of economic model was developed for a specific purpose and is only as good as its assumption sets, parameters, and calibration. Real economic behaviour is complex and the simplifications that result from a modelled view can only provide indications of comparative directionality.

Oxford Economics Global Economic Model

The model used in this analysis, the Oxford Economics Global Economic Model (GEM), is the most widely used international macroeconomic model with clients including the IMF and World Bank. The model provides multivariate forecasts for the most important 47 economies of the world with headline information on a further 34 economies. Forecasts are updated each month for 5-year, 10-year and 25-year projections.

The GEM is best described as an eclectic model, adopting Keynesian principles in the short run and a monetarist viewpoint in the long run. In the short run output is determined by the demand side of the economy, and in the long term, output and employment are determined by supply side factors. The Cobb-Douglas production function links the economy's capacity (potential output) to the labour supply, capital stock and total factor productivity. Monetary policy is endogenised through the Taylor rule, where central banks change nominal interest rates in response to changes in inflation. Relative productivity and net foreign assets determine exchange rates, and trade is the weighted average of the growth in total imports of goods (excluding oil) of all remaining countries. Country competitiveness is determined from unit labour cost.

Modelling the São Paulo pandemic

The macroeconomic modeling of the pandemic requires the estimation and simulation of a series of variables. A number of key indicators were selected to simulate the effects of the pandemic scenario as defined in Table 9.

Estimation of the Labour Participation Rate requires a detailed modeling of the infection rate in each country over time, and the absenteeism that it creates in the workforce. The RMS pandemic spread model uses epidemiological techniques of Susceptible-Infected-Recovered (SIR) to estimate the infection of the population. This was adapted to model the absenteeism that would result. The absent unwell, the absent caring, the absent from fear, and the unable to get to work were included in this analysis, and calculated for 19 regions of the world, that comprise all the major nations. The resulting absenteeism was estimated for each country, by week for the duration of the pandemic. This provided the key labour participation rate shocks that were applied to the Oxford Economics Global Economic Model.

In addition Final Consumption shocks were applied, calibrated to the types of demand downturns and revenue losses recorded historically in disease outbreaks, most notably in specific discretionary consumption sectors. For the model input this was averaged for all economic sectors in a country's economy. Tourism Exports – revenues received from tourists visiting from another country – were shocked to a similar magnitude of tourism revenue loss from historical disease outbreak precedents. An initial Share Price shock is applied to reflect the market reactions observed in each of the precedents. Government Consumption increases are estimated from emergency response costs, healthcare provision cost to meet pandemic demand, and increased costs of services.

The increase in government consumption is sustained for an additional three months after the infection wave has passed, to account for the continued demand for services that could continue for quite some time after the initial emergency.

Shocks are applied for the duration of the infection wave and then are allowed to recover endogenously.

Macroeconomic impact on employment

One of the most significant economic impacts caused by a global pandemic is absenteeism from work. This is modeled through a direct decrease in labour supply and therefore a decrease in the overall labour participation rate of the economy. The unemployment rate is not just a function of absenteeism but the combined effects of all other macroeconomic impacts caused by the pandemic. An increase in the unemployment rate caused by the pandemic is a function of the initial unemployment rate, consumption, investment, market confidence and the labour-to-capital ratio. Figure 6 shows how the unemployment rate is impacted across several selected countries by the pandemic scenario S1.

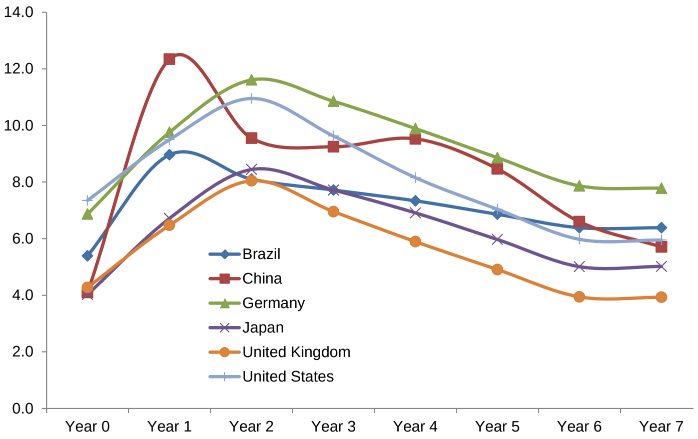

Figure 6: Unemployment rate in different countries triggered by the pandemic (S1 scenario)

Note that for the six countries shown, the peak unemployment rate does not coincide with the peak incidence of infection. For most countries, the unemployment rate peaks around one year after the peak level of infection. This is because other economic factors, such as a decrease in final consumption, a decrease in tourism trade and a decrease in the share price index, suppress economic activity in the short to medium term resulting in higher unemployment beyond the infectious period of the pandemic. China is one exception to this general rule.

In China, unemployment increases from 4% to 12.3% and the peak in unemployment coincides with the peak incidence of infection.

This is because China has a high labour-to-capital ratio and so has an economy that is highly dependent on its labour force, making it especially sensitive to worker absenteeism.

Impact on exports and imports

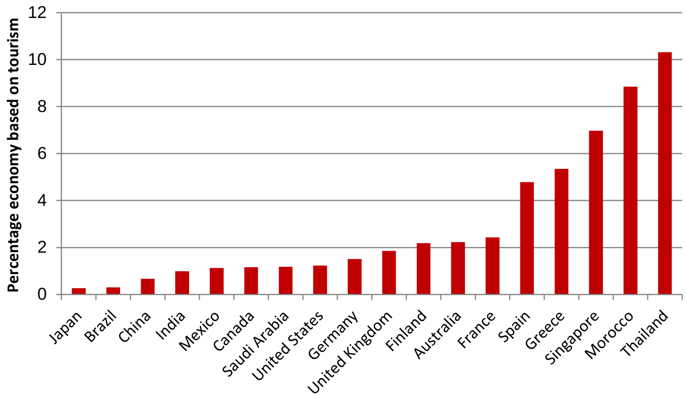

Figure 7: Percentage of income from tourism trade for different countries[9]

The main impact on exports is through decreases in income from tourism. Previous pandemics have shown that people avoid travelling when there is a high risk of infection. Economies that rely on tourism as a source of income will therefore be more heavily affected than countries who have little or no tourism trade. Figure 7 shows the value of receipts from tourism in 2012 as fraction of overall GDP for a selection of different countries in the world.

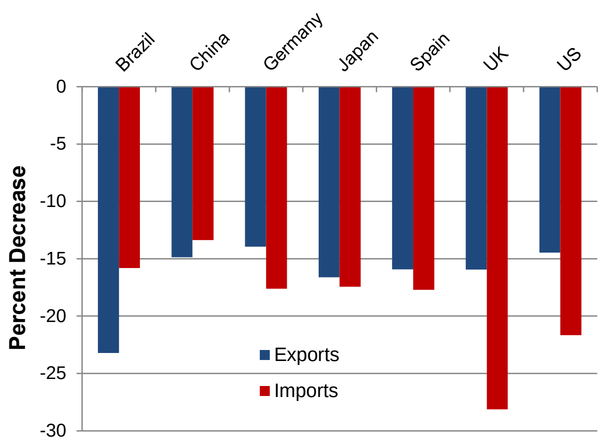

Figure 8: Decrease in the value of trade during the pandemic compared to baseline (S1).

Countries that rely on income from tourism will be more affected by the outbreak of a pandemic. During the pandemic, global trade is suppressed due to the economic downturn. The expected impact on exports and imports depends largely on a country's historical balance of trade, the importance of labour as a factor of production, and the value of exported goods as a ratio to the value of exported services, including tourism.

[9] Source: World Bank Database (http:www.worldbank.org)

If a country is typically an importer of goods and services then imports will be most affected, if a country is typically an exporter of goods and services then exports are most affected. Figure 8 shows the decrease in imports and exports for several selected countries due to the pandemic.

Impact on inflation

The initial impact of the pandemic has the effect of depressing short term demand as aggregate income is decreased due to lower wages caused by absenteeism, and consumer spending is waylaid until the future. This has the effect of putting downward pressure on consumer prices and therefore lowering the rate of inflation for the duration of the outbreak.

As the economy begins to recover, employees return to work and pent up demand causes inflation to increase above baseline projections. This can clearly be seen in Figure 9 where there is an initial drop in the rate of inflation, most strongly felt in China, before prices increase in the medium term and then stabilize at baseline levels towards the end of the period.

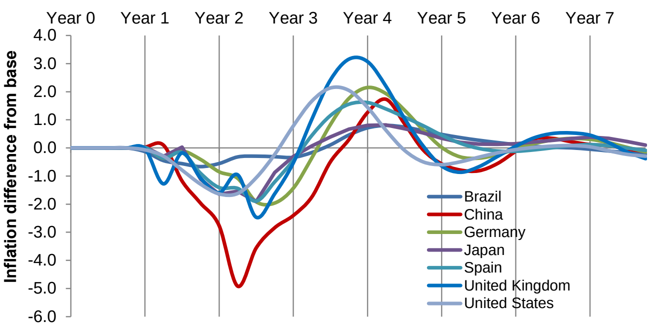

Figure 9: Impact of the pandemic scenario on inflation for different countries, relative to base (S1)

Impact on interest rates

Interest rates affect investment. As the financial and economic risks of the pandemic propagate around the globe, risk premiums are re-evaluated and interest rates are adjusted. When investments carry a high risk premium interest rates accordingly increase to match the risk that a loan will not be repaid. As seen in Figure 10 the long term interest rates vary markedly from country to country.

Interest rates are obviously a significant dimension of the macroeconomic projections as it has a big impact on bond pricing and therefore on the yield of the investment portfolio for major institutional investors like the big insurers.

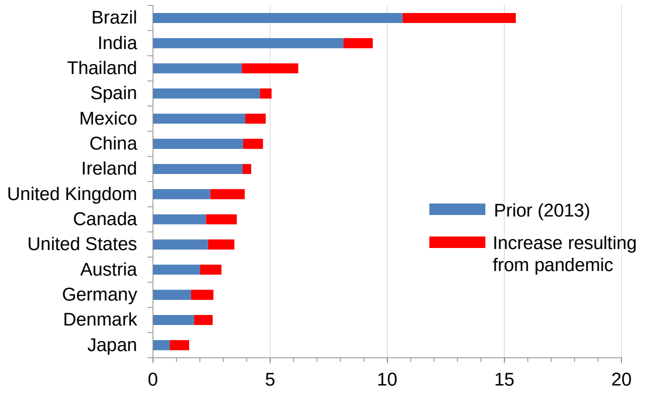

Figure 10: Long term interest rate changes for selected countries as a result of the pandemic (S1) by Year 2

Country credit ratings

A country's credit rating is an evaluation of the credit worthiness of a government and its ability to pay back debt and the likelihood of default. Estimates for a countries credit rating compared to baseline projections are given for a selection of different countries in Figure 11 for the scenario. As indicated, credit ratings affect each country differently. The credit worthiness of Ireland, Spain, Mexico, and the United States all decrease by over 20% compared to baseline projections. Ireland suffers the largest drop in its credit rating score dropping by over 40% in the X1 scenario.

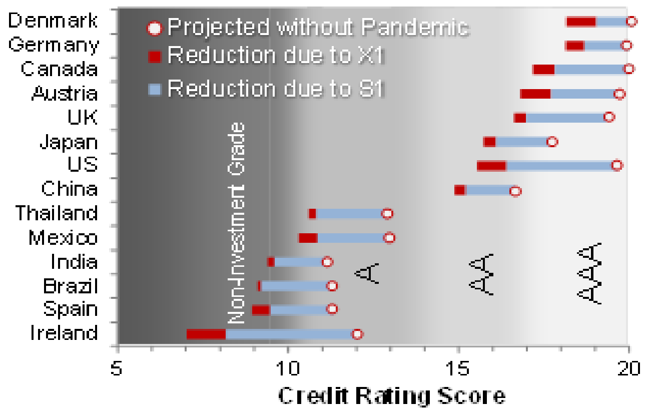

Figure 11: Projected impact of pandemic on selected country credit ratings by Year 2 (S1 and X1)

Impact on balance of payments

The Balance of Payments (BoP) for a country is an accounting record of all the transactions between a country and the rest of the world. The full impact of the pandemic on the global economy takes several years to manifest as shown by the balance of payments records for European countries given in Figure 12. In Europe the BoP is expected to be around $200 Bn in year 3, but the pandemic reduces this to $37 Bn in scenario S1 and in the most severe scenario, X1, creates a $160 Bn deficit in year 3.

Productivity and growth

A global pandemic will have an significant impact on productivity and growth. The São Paulo pandemic infects citizens in every country of the world, leaving no economy unaffected.

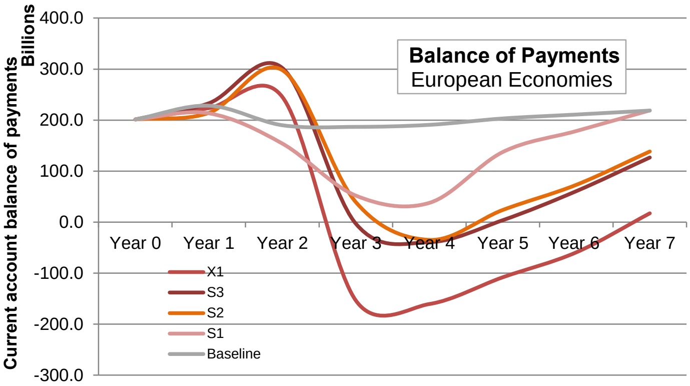

Figure 12: Balance of payments of European economies as a result of pandemic scenario variants

Differences in a country's ability to slow the infection spread, and protect citizens through vaccinations and treatments for the sick, will play a large part in determining the overall level of economic impact. Wealthy countries, for example, are able to afford medical care infrastructure, expensive drug stockpiles, and trained healthcare workers to provide treatment. This increase in government spending will boost output in the short term and lessen the severity of economic impacts. Less-developed economies have fewer resources for healthcare treatment and emergency response. These countries face higher infection rates and effects generally, which increases the overall economic impacts for these countries.

Compounding these primary effects are secondary effects on the movement of capital. Economies perceived to be at higher risk, such as developing economies, will experience capital flight where assets will be sold in favour of more secure assets in more developed economies. Demand for government bonds are expected to increase over this period in more advanced economies.

The overall economic impact of the disaster varies from country to country and depends on a complex array of different factors. Interestingly and for the majority of countries, the peak of the economic downturn appears to occur 6-12 months after the peak rate of infection as shown in Figure 13. Each country then has a unique recovery path, roughly returning to baseline projections around the year 6.

As shown in Figure 13 the pandemic causes a global recession in all four scenarios. The magnitude and duration of the recession increases as the severity of the pandemic plays out in each scenario.

Across all scenarios the global recession peaks in the in fourth quarter after the first outbreak. In scenario S1, the recession peaks at -2.5% growth, in S2 it is -2.7%, S3 is -2.9% and in X1 it peaks at -7.9%. In scenario S3 and X1 the recession begins one quarter earlier than S1 and S2. The recession lasts for one year in X1, 3 quarters in S2 and S3 and half a year in S1. In all four scenarios the global economy bounces back to positive growth rates in year 2 and peaks in year 3, before equilibrating with baseline projections by the fourth quarter of year 5.

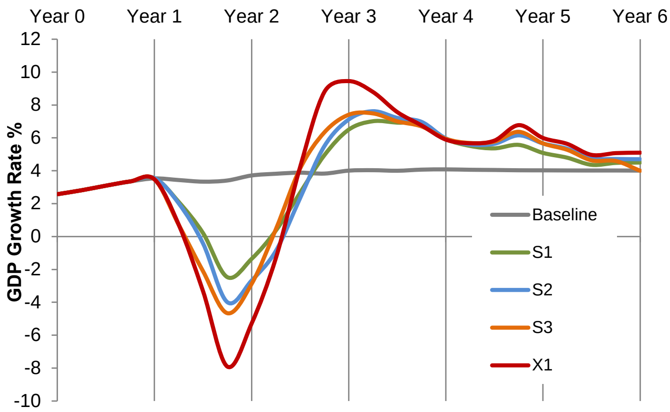

Figure 13: World GDP Growth rate ($US Real, PPP)

GDP@Risk

The macroeconomic consequence of the scenario is modelled as described, using the Oxford Economics Global Economic Model. The impact of the scenario is then compared with the macroeconomic projection of the global economy that is forecast without a crisis occurring, to assess the GDP at risk from this scenario.

The Oxford Economics macroeconomic forecast for the world economy (as of 2014) is for average annual growth of 3.2% sustained for the next decade. This is higher than the average annual growth of 3.0% that the world economy achieved during the boom years of 1980 to 2006, preceding the Great Financial Crisis of 2008-2012. This is a positive outlook, with the size of the global economy reaching $80 trillion by 2025: around 145% of its current size.

The Oxford Economics model is not explicitly probabilistic, but the expected baseline is estimated at the median, or 50th percentile, view of a wide fan of uncertainty of all of the potential future trends that might occur. The reality of economic progress resembles a random walk along the trend, with variation and fluctuations occurring from time to time.

Modelled views necessarily present a smoothed view of the trend, and this is the view we take as the baseline that is likely to occur without a crisis.

When a crisis occurs, such as the pandemic scenario considered here, there is a significant deviation from the expected trend in GDP growth. Figure 14 illustrates the dip in global GDP that is modelled to occur as a result of the scenario, in all its variants. These are compared with the expected trend without the scenario (the dotted line).

The total GDP loss over five years, relative to the expected forecast without the pandemic occurring, defines the 'GDP@Risk' for the scenario. This is expressed as a % of the total GDP for the year ('Year 0') before the occurrence of the event. Table 9 provides the GDP loss of each of the variants of the scenario, as total lost economic output over five years, and as GDP@Risk – the % of Year 0 GDP.

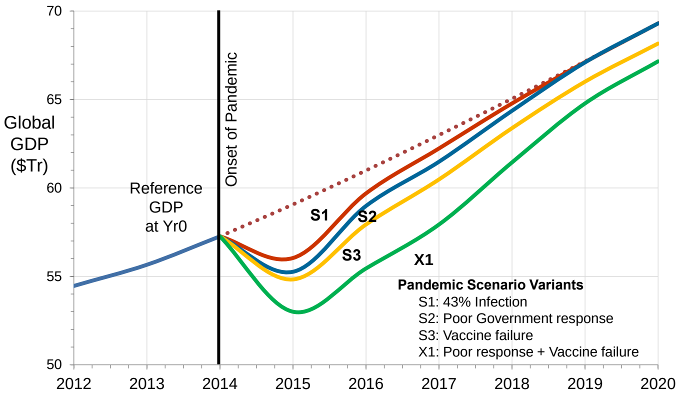

Figure 14: Global GDP Impact of Pandemic Scenario

Se nario Variant	Infet ion Rate	Global Death Toll (Million)	Duration of main wae (months)	GDP Loss over 5 years (GDP@ Risk)	GDP@ Risk as % of Yr0 GDP
S1: Standard Scenario	0.43	19 m	7	$7 Tr	12%
S2: Response Failure	0.43	22 m	8	$10 Tr	18%
S3: Vac ne Failure	0.43	24 m	9	$14 Tr	25%
X1: Response & Vac ne Failure	0.43	25 m	12	$23 Tr	40%

Table 10: GDP Impact of Pandemic Scenario Variants

Pandemic scenario impact on global GDP

The pandemic S1 scenario is estimated to cause the loss of $7 trillion of global output over a five year period, equivalent to 12% of the total GDP of the year prior to its assumed start point. The most extreme variant, X1, is estimated to cause a loss of $23 trillion, or 40% of the Yr0 global GDP.

For reference, the Great Financial Crisis of 2007-2012 caused loss of output relative to the trend of global growth prior to the crisis, of $18 trillion, which is 38% of the Yr0 GDP (i.e. 2007 where global GDP reached $48.1 trillion just prior to the crisis). Scaled to current (2014) GDP values, this would be a GDP loss of $20 trillion. The X1 variant of the pandemic scenario is estimated to cause a greater loss of economic output to the world than the Great Financial Crisis of 2007-2012.

As shown in Figure 14, the pandemic has a significant impact on the global economy and its effects are felt for a number of years after the pandemic infection wave is over. The world experiences an initial severe downturn in loss of output during the year that the infection wave occurs, and then goes through a recovery cycle.

In the standard variant, S1, there is a significant recovery during year 2, with global output recovering close to the baseline estimate of where the global economy would have been without the event occurrence. It takes another three years to return to the level of the baseline trajectory.

Variant S2 has a bigger impact on the economy, and the recovery takes longer, but returns to the baseline trajectory in a similar timescale to variant S1.

Variant S3 provides only a slightly larger shock than S2, but its recovery is far longer, and does not return to the baseline trajectory even after six years, and may reestablish a new future trajectory that is permanently below the baseline by around a trillion dollars.

Variant X1 causes a major shock with poor and slow recovery that does not return to the baseline trajectory even after six years, but it remains permanently below the baseline by at least two trillion dollars.

Economic conclusions

A pandemic of this severity clearly has very significant implications for the global economy. In this analysis we have demonstrated how the interlinkages in the economy mean that pandemic-driven absenteeism and the reductions in demand that can be expected during a pandemic have major repercussions throughout the global economy. It causes a shock to the economy that persists for many years afterwards. In the more severe scenarios of S3 and X1, the loss is so severe that the world economy never fully recovers to where it would have been without the pandemic occurring, but is reset to a new, lower point from which growth resumes at similar rates, so the world economy is permanently diminished by the catastrophe.

The factors that make the scenarios worse themselves combine in non-linear and escalating ways. Using GDP Loss over 5 years as a metric, S2, with response failure, is $3 trillion worse than S1, and S3, with vaccine failure is $7 trillion worse than S1, so their arithmetic combined increase is $10 trillion however X1, combining both response failure and vaccine failure, is $16 trillion worse than S1, showing how these factors compound each other to cause a super-catastrophe for the world economy, that hits a very sharp recession peak of -7.8% negative growth, more than twice as severe as the other scenario variants.

8 Impact on Investment Portfolios

The macroeconomic effects of the pandemic – causing major reductions in global outputs and periods of recession – will hit the capital markets. This section considers the market impact of the pandemic, and the consequences for investors in the capital markets.

The performance of equities and bonds in different markets are estimated from the macroeconomic consequences, and compared with a baseline projection of their expected average performance that would result from the economic projections without the pandemic occurring.

Valuation fundamentals

Note that these are estimates of how the fundamentals of asset values are likely to change as a result of these market conditions, as directional indication of valuation. This analysis is not a prediction of daily market behaviour and does not take into account the wide variations and volatility that can occur to asset values due to trading fluctuations, sentiment, and the mechanisms of the market.

A standardized investment portfolio

We explore the impact of the market change by considering the performance of a standardized, hypothetical investment portfolio. Every investment portfolio has a different structure and balance. The impact on each asset class is presented below, to assist with assessing how these projected market changes apply to an individual unique portfolio.

The standardized investment portfolio is based on a structure that is focused on high quality and fixed income assets, of the type that major insurance companies hold.

We consider a high-quality fixed-income portfolio with about 70% of investments in sovereigns and corporate bonds most of which are investment grade, rated A or higher.

Details of the standardized investment portfolio are shown in Table 11 and Figure 15 to 16.

Long-term bonds are assumed to have an average maturity of 10 years, while short to medium bonds have a maturity of 2 years for US, UK and Japan, and 3 months for investments in the Eurozone.

Investments are spread across countries like the US, UK, Eurozone, Japan and emerging markets.

	USD	GBP	Euro	Yen	Other	Total
Government med/long	8%	7%	5%	2%	2%	**24%**
Government short	6%	5%	4%	2%	3%	**20%**
Cash	2%	1%	1%		1%	**5%**
AAA short	2%	2%	2%	1%	1%	**8%**
AAA med/long	4%	3%	1%	1%	1%	**10%**
AA short	1%	1%	1%			**3%**
AA med/long	2%	1%	1%		2%	**6%**
A short						**0%**
A med/long	**2%**	**2%**	**2%**	**2%**		**8%**
BBB and lower	**2%**	**2%**	**1%**		**1%**	**6%**
Equities etc	**2%**	**2%**	**2%**		**4%**	**10%**
Total	**31%**	**26%**	**20%**	**8%**	**15%**	**100%**

Table 11: Composition of the High Fixed Income Portfolio Structure

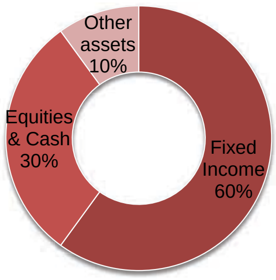

Figure 15: Asset classes in standardized portfolio: high proportion of fixed income

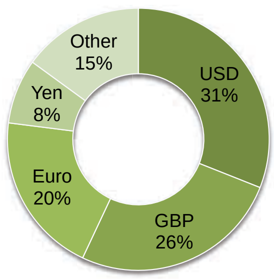

Figure 16: Asset classes in standardized portfolio: high proportion of fixed income

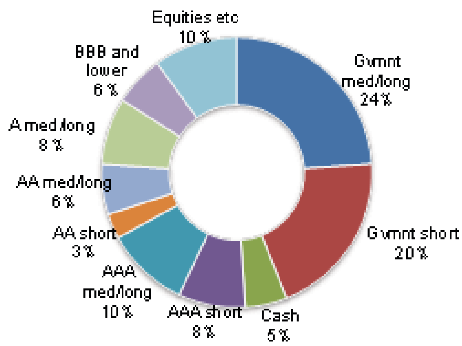

Figure 17: Asset classes in standardized portfolio: high proportion of fixed income

Typically the geographical market structure of an investment portfolio for an insurance company is carefully matched to the geographical locations of their underwriting exposures, to minimize exchange rate risk. Different insurer geographical exposure will result in different market distributions.

Equities compose about 10% of the investment portfolio. We assume for simplicity that equity investments correspond to stock indexes.

Computation of returns

The return for the portfolio is estimated using standard methods as outlined in the following.

For each bond *b*, the return $r_b(t)$ at time *t* is computed as:

$$r_b(t) = y_b(t) + g_b(t)$$

where $y_b(t)$ is the bond yield and $g_b(t)$ the capital gain.

The yield on government bonds is taken from the output of the macroeconomic analysis presented in the previous section. For corporate bonds the yield is computed adding a credit spread to the yield of government bonds with corresponding maturity. The values used for credit spreads are reported in Table 11, and are similar to those reported for US corporate bonds in 2006 (tests show that the qualitative pattern of results discussed below is robust with respect to changes in credit spreads up to a factor of 2).

The capital gain is computed from bond yields as

$$g_b(t) = -D_b\,[y_b(t) - y_b(t-1)]$$

where $-D_b$ is the bond duration, for which we assumed the following values: D_b=7 for ten year bonds, D_b=1.8 for two year bonds and D_b=0.4 for bonds with maturity of three months. In our analysis we assume no default on sovereign bonds, while defaults on corporate bonds are accounted for through the introduction of a discount factor that calibrated to obtain in the baseline scenario the default probabilities shown in Table 12.

For the stressed scenarios we assumed that default probabilities increase by a factor of 3. The qualitative pattern of the results derived are robust with respect to changes in this assumption.

Stock returns are computed as

$$r_s(t) = y_s(t) + g_s(t)$$

where $y_s(t)$ is the dividend yield of stock s and $g_s(t)$ its capital gain.

The latter is computed from the stock price $p_s(t)$ as

$$g_s(t) = \frac{p_s(t)-p_s(t-1)}{p_s(t-1)}$$

The macro-economic model produces a forecast for dividend yields of UK stocks, that we assume to be similar to those of US and Eurozone stocks.

The return on the whole portfolio is then computed taking a weighted sum over the returns of all assets.

	Credit spread (bp)	Default probability
AAA medium/short	16	0.52%
AAA long	68	0.52%
AA medium/short	37	0.52%
AA long	80	0.52%
A long	51	0.29%
BBB and lower	95	2%

Table 12: Credit spreads and default probabilities for corporate bonds

Passive investor assumption

The analysis results are presented assuming a passive investment strategy. This means that the portfolio retains its structure and remains constant throughout the scenario, without any response to the performance of the assets within it, or portfolio rebalancing. This assumption is unrealistic, as we would expect an asset manager to react to changing market conditions in order to reduce losses and large fluctuations in returns. However this assumption enables us to benchmark the performance for a fixed portfolio to use as a metric to observe the market changes.

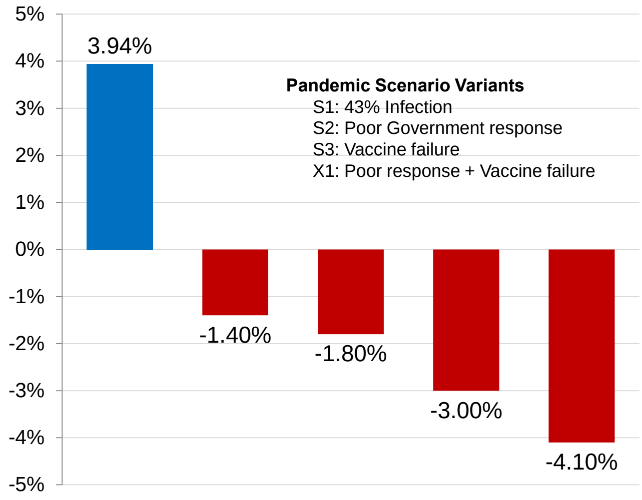

Figure 18: Returns for the Standardized Portfolio for the pandemic scenario variants, relative to baseline.

Understanding what drives the behavior of the fixed portfolio over the timeline of the scenario can, for instance, give useful insight towards the design of optimal investment strategies.

Portfolio returns

The returns for the standardized portfolio in the first year of occurrence of the pandemic are presented in Table 12, for the different variants of the scenario relative to the baseline performance of the portfolio that would be expected without a pandemic.

In all cases we observe significant departures from the baseline, with short-term losses between -1.40% for the mildest variant of the scenario and below -4% for the most extreme.

In Figure 19 we show profits and losses of the representative portfolio over a longer period of time. From the plot we can see significant negative as well as positive deviations with respect to the baseline, signaling the fact that an active portfolio management strategy can be used to reduce losses.

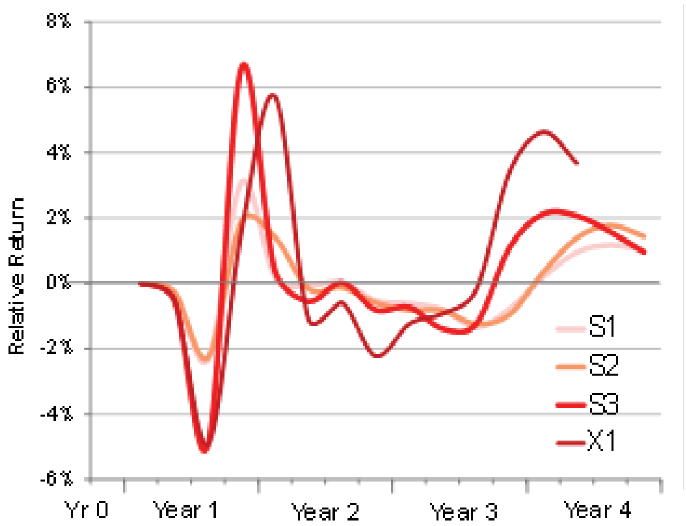

Figure 19: Portfolio returns under different variants of pandemic scenario, change with respect to baseline.

For instance, in the specific case represented in Figure 19, reducing the size of the portfolio in the First quarter of the scenario, buying into it in the third quarter and selling again in the fourth quarter would produce much higher returns with respect to the benchmark of a passive investor.

In all cases there are significant deviations from the baseline, and losses are registered in the first year of the scenario. Increasing the severity of the shock increases the amplitude of the deviation from the baseline.

It may be useful to look at a breakdown across different asset categories of the portfolio performance for the S1 variant of the scenario.

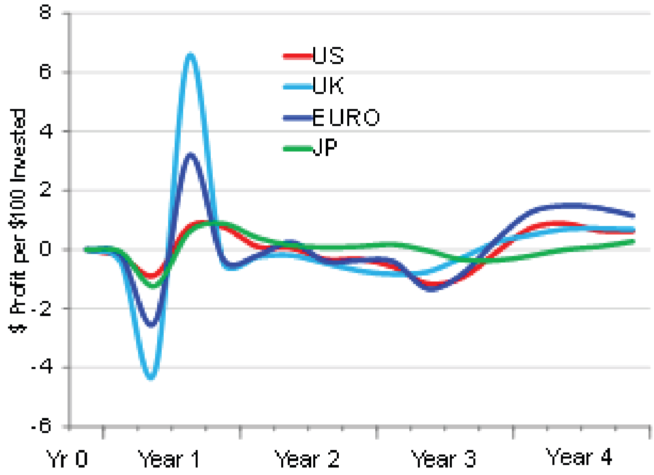

Figure 20: Relative return of a $100 investment in different geographical markets

Figure 20 presents relative profits per $100 investment in assets of specific countries. For each country, we assume the investment to be spread across different asset categories is as in Table 13. Investments in the UK and Eurozone are the most susceptible to the scenario, with deviations from the baseline between -4.5% and +6.5% for UK assets and between -2.5% and 3% for aggregate investments in the Eurozone.

A breakdown of the portfolio performance between equities and fixed-income is presented in Figure 21.

	US	UK	Euro	Japan
Equities	-3.0	-17	-10.0	-7.0
Government 10-year Bonds	-1.0	-5.0	-3.5	-1.7
A-AAA Grade Bonds	-1.0	-5.0	-3.5	-1.7
B Grade Bonds	-6.2	-9.5	-8.0	-7.5
Standard Portfolio (Mix of assets in that market)	-1.2	-4.1	-2.5	-1.3

Table 13: Loss per $100 of investment at Q2 Year 1 (Peak of Pandemic) in Pandemic Scenario S1

As is well known, equities are much more sensitive to the shock of a scenario like this than government and high grade bonds, particularly in the short term. Bond values are sensitive to inflation and interest rate changes, which flow from the scenario, but take time for their effects to become apparent.

A more fine-grained breakdown that also accounts for different assets categories can be found in Table 13, where we report for each category the maximal loss registered within the first year under the S1 variant.

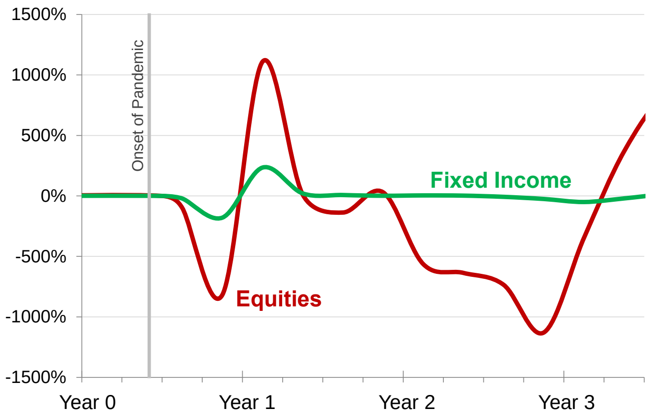

Figure 21: Timeline of Fixed Income and Equities change relative to baseline, Pandemic scenario S1

From the table we see that, as for the aggregated results presented in Figure 20, the largest deviations from baseline are associated for each asset class with investments in the UK and Euro zone.

In Table 14, a full range of representative asset types and key analysis metrics are presented, including credit spreads, inflation estimates, interest rates, and foreign exchange values, to enable managers of investment portfolios to apply these stress test scenarios to their individual portfolios. Each individual portfolio is different, and will be composed of many different asset types.

We have made the simplifying and unrealistic assumption in presenting the portfolio returns, that the investor is passive and does not change the portfolio to try to mitigate the losses. In Table 14 we try to address this by showing short term impacts separately from long-term impacts.

Short term impacts are those that occur in the first few months of the crisis onset, and represent the shocks that could potentially catch investment managers with insufficient time to respond. Longer term impacts are those that play out over a longer time period, in this case three years, and have structural implications for the fundamental underlying values of these asset types, but if recognized in time would enable the portfolio manager to respond to in a timely manner.

Interestingly, Japanese and to a lesser extent German bonds show growth in the short term but decline in the longer term.

Correlation

A general approach to apply these representative asset shocks to a portfolio of many other assets types is to assume a correlation structure across the full asset range – i.e. how each class of asset is likely to behave relative to these representative asset classes.

Note however, that during a major financial crisis, such as this pandemic would undoubtedly trigger, the correlations between assets tighten and converge. Applying an assumption that the correlations would be similar to those observed in non-crisis routine trading could lead to underestimation of the impact.

Market impact conclusions

In this section of the analysis we have considered how the macroeconomic consequences of the pandemic would influence the performance of a standardized investment portfolio, such as that maintained by an international insurance company. We estimate the performance of the portfolio under the different variants of the São Paulo pandemic scenario and compare it with the baseline performance that might be expected in the absence of a pandemic occurring.

The standardized portfolio would be fairly robust against this scenario, but the returns would be significantly reduced. In the sensitivity indications provided by the different variants of the scenarios, there is a very significant non-linear jump in the severity of the degraded returns between scenarios S2 and S3, with the negative returns being nearly twice as severe in S3 as S2.

Sectoral investment differences

It has not been possible in this analysis to examine how different sectors of the economy would behave during the pandemic scenario, or how different investment asset types will perform by industrial classes.

We have identified from historical precedent how tourism and discretionary expenditure sectors can expect to be badly impacted during the pandemic, and have used tourism export metrics explicitly in the analysis. We can expect hospitality, travel, airlines, and service sectors to be worse affected economically than average. Sectors with personnel that have high interaction with the general public can expect to see high levels of infection, and so be worse hit than other sectors.

Some sectors will see increased business as a result of the pandemic, particularly suppliers of healthcare or services needed during the emergency. Within sectors, companies may gain competitive advantage if they are able to manage their business practices to keep their workforce healthy and have good plans in place for a faster recovery than their competitors. Companies will find that their own threats are not just their customers and workforce, but also their commercial counterparties and trading partners.

Those who have well managed credit risk management strategies and fully understand their counterparty risk will be better positioned to withstand the threats posed by the systemic risk that this pandemic poses.

Investment strategies for pandemics

This section presents a simplified view of how investment asset class value fundamentals are likely to change as a result of the pandemic scenario. It offers these as a guide to the likely market movements that could occur with these asset classes.

We take a passive investment management assumption to provide a benchmark for considering more complicated asset management strategies.

Although the analysis presents different variants of the pandemic scenario to give an idea of sensitivity, it has not been possible to systematically test the stability of results with respect to the parameter settings used to develop the scenario development. A systematic evaluation of all the uncertainties in the analysis approach would be useful in the future.

REAL USD PERCENTAGE VALUES				Baseline	Short-Term Impact (Δ Max)				Long-Term Impact (Δ Max)			
				Yr0Q4	Yr1Q4				Yr3Q3			
				B0	S1	S2	S3	X1	S1	S2	S3	X1
US												
Bonds Short	TSY 2Y	Interest rate, 2-year T-notes (levels)	Δ	0.3	1.47	1.44	2.67	2.67	-0.76	-0.76	-0.78	-0.81
Bonds Long	TSY 10Y	Interest rate, 10 year government bonds (levels)	Δ	2.7	1.13	1.11	1.77	1.77	-0.76	-0.76	-0.77	-0.80
Equities	S&P	Share price index (% change)	%	100	-3.80	-3.74	-6.90	-6.90	-27.67	-41.31	-44.72	-62.31
Credit	YSA CSPA	Credit spreads, period average (levels)	Δ	0.3	0.08	0.07	0.14	0.14	0.44	0.70	0.59	0.95
Inflation	USA CPI	Consumer price index	%	100	-0.29	-0.29	-0.15	-0.15	0.24	0.69	1.35	2.67
UK												
Bonds Short	GBP 2Y	Interest rate, 2-year T-notes	Δ	0.5	4.36	4.23	10.14	10.14	1.03	1.13	1.11	1.43
Bonds Long	GBP 10Y	Interest rate, 10 year government bonds	Δ	2.8	3.76	3.65	8.62	8.62	0.81	0.90	0.90	1.19
Equities	FTSE	Share price index	%	100	-18.2	-17.69	-36.15	-36.15	-22.63	-26.88	-24.00	-31.81
Credit	GBP CSPA	Credit spreads, period average	Δ	0	0.33	0.32	0.68	0.68	0.15	0.21	0.11	0.24
Inflation	GBP CPI	Consumer price index	%	100	-1.26	-1.22	-2.28	-2.28	-0.28	-0.31	0.34	1.34
Foreign Exchange	USD/GBP	Exchange Rate (US$ £GBP)	%	1.6	8.05	7.66	22.53	22.53	5.86	5.51	5.58	5.59
EU (Germany)												
Bonds Short	DEM 2Y	Interest rate, 2-year German gov bond yields	Δ	0.2	2.40	2.32	5.02	5.02	0.17	0.04	0.12	0.21
Bonds Long	DEM 10Y	Interest rate, 10 year German gov bond yields	Δ	1.8	2.17	2.10	4.12	4.12	0.01	-0.10	-0.03	0.04
Equities	DAX	Share price index Deutscher Aktien Index	%	100	-10.94	-10.66	-20.06	-20.06	-14.31	-22.0	-20.26	-33.14
Credit	DEM CSPA	Credit spreads, Period Average	Δ	1.8	0.22	0.21	0.41	0.41	0.21	0.33	0.20	0.35
Inflation	DEM CPI	Consumer Price Index Germany	%	100	-0.36	-0.35	-0.43	-0.43	-1.19	-1.23	-0.92	-0.70
Foreign Exchange	USD/EUR	Exchange Rate (US$ per Euro)	%	1.3	1.53	1.40	4.45	4.45	2.02	1.56	1.85	1.76
Japan												
Bonds Short	JPY 2Y	Interest rate, 2-year Japan, gov bond yields	Δ	0.1	2.21	2.20	4.83	4.83	-0.48	-0.43	-0.44	-0.41
Bonds Long	JPY 10Y	Interest rate, 10 year Japan gov bond yields	Δ	0.6	1.26	1.25	2.42	2.42	-0.48	-0.43	-0.44	-0.41
Equities	NIKKEI	Share price index Nikkei 225	%	100	-7.48	-7.40	-13.13	-13.13	-8.43	-13.93	-9.70	-13.45
Credit	JPY CSPA	Credit spreads, Period Average	Δ	0.2	0	0	0	0	0	0	0	0
Inflation	JPY CPI	Consumer Price Index Japan	%	100	-0.29	-0.29	-0.56	-0.56	-1.50	-1.43	-1.17	-0.72
Foreign Exchange	USD/JPY	Exchange Rate (US$ per JPY)	%	0.013	2.64	2.58	7.09	6.78	0.06	-0.03	-0.07	-0.47

Table 14: Short and long term impact on representative investment portfolio assets from all pandemic scenarios

9 Managing the Risk

Infectious diseases pose a serious threat to our society and this scenario illustrates an example of the type of impact that they can have. The example starts by considering the type and severity of scenario that could be expected with a 1% probability of exceedance per year – a '1-in-100' type of event.

The analysis of diseases shows that a novel genetic shift in influenza triggers a human pandemic on average about every 20 to 30 years, and that there is a very wide range of characteristics of pandemics, ranging from the mild and slow-spreading to the virulent and highly infectious. Our choice of scenario to illustrate the 1% annual probability is a new mutation of virus that is highly infectious, but only moderately virulent. It infects 43% of the population but with good healthcare resources available, it only kills a third of a percent of the people it infects.

Although influenza is one of the fastest mutating viruses that is constantly finding new weaknesses in human immune systems, research also shows that there are other types of emerging infectious diseases that evolve from time to time, with even more deadly potential. Examples include HIV/AIDS, SARS, and MERS. These illustrate the potential for rare, but very deadly infectious diseases that would be far more severe than the influenza pandemic we illustrate here. The context for this scenario is that there is an entire distribution of potential severities of pandemics that can occur. The more severe, the less likely they are.

Management of the risk of pandemics recognizes the wide range of types and severities of pandemics that can occur. A global organization should expect to have to manage a crisis from a localized disruptive infectious disease epidemic somewhere in one of the territories where it does business, on average every few years. An enterprise's ten year business plan should expect there to be just less than an even chance of needing to manage the business through a global pandemic of some severity during the decade, and about a 10% chance that the pandemic would be as severe as the one depicted in this scenario. There is also a small but feasible chance that the business may have to face an extreme infectious disease outbreak that would be much worse than the one described here, and would be deadly and widespread.

The spectrum of potential infectious disease events is varied, and can trigger events of severity ranging from mild and localized, to catastrophic and global. Managing the risk of infectious diseases means being prepared for a range of potential manifestations, not just the scenario described in this report. The objective of considering a stress test scenario of this type is to be resilient across a range of potential crises that could occur, rather than being focused on the scenario itself.

Organizations

Organizations should be aware of the potential for pandemic events to occur that would trigger high levels of absenteeism in the workforce, and disrupt business activities in different parts of the world for many months. Companies with contingency plans prepared in advance will be better equipped to manage the operational risk posed by a pandemic.

Contingency plans should prioritize the protection of the workforce, in ensuring that work practices are safe for employees and providing best-practice advice and health care information. Measures would include restricting business travel into outbreak areas, limiting exposure to infection from contact with the general public, and reducing the potential for transmission of disease within the workplace through limiting face-to-face meetings, and ensuring high standards of hygiene and a sanitized work environment. Some companies have gone further and issued their employees with access to anti-viral drugs if a pandemic were to occur. Organizations should institute a practice of monitoring the health of its employees and their dependents, checking who is sick, keeping in contact, and tracking those who have recovered. It is also a business advantage to know who has recovered or been vaccinated, as they acquire immunity and can potentially work without fear of further infection.

During the outbreak, the focus is likely to be on business continuity, ensuring sufficient personnel is available for essential activities. This implies training staff to equip them with the overlapping skills to provide backup to other departments that might be depleted by absenteeism. This report has highlighted that the levels of absenteeism expected may be tolerable for many businesses if it is evenly spread and at average levels, but that illness and absenteeism will be unevenly spread and clustered, because of the nature of infection spread. Some departments or work functions will see much higher absenteeism than others, and with very little warning.

The same will apply to suppliers and counterparties. Their organizations will similarly be struggling with infection waves. Business continuity may involve finding substitute suppliers or counterparties at short notice, and having contingency plans in advance for supplier multi-sourcing may help with sudden supply chain disruption from pandemic absenteeism. International counterparties could suffer their disruptions at different timescales as the pandemic progresses around the world. Some counterparties may be so badly affected that they are unable to continue trading. Credit risk tolerance and cash flow planning should apply stress test scenarios like this one to develop good financial risk management practice for this contingency.

Information is vital in dealing with the emergency period – knowing how and where the pandemic is spreading and how it is affecting the operational functions of the organization, but ultimately a severe crisis may make even the information infrastructure fail. The 'fog of war' is equally applicable to crisis response, and managers often have to make decisions without reliable information about everything that is happening.

Ultimately the management may need to suspend business operations in certain parts of the organization for a period of time. Making this decision based on clear guidelines drawn up beforehand is better than improvised or localized decisions. Critically, the contingency plans should identify the criteria for when to resume operations once the main effects have subsided. Studies of business crises have demonstrated that organizations that have good recovery plans to restore business operations quickly can gain major competitive advantage over rivals when several are affected by the same event.

Developing a risk management culture in an organization requires constant awareness raising that these kinds of crises are possible, and having plans and rehearsals for response to an event of this type.

This report is intended to contribute to the awareness raising and disaster planning process for the risk management of an organization.

Insurance companies

Insurers face all of the operational risk management issues of a sizeable organization, and addition have to deal with the reporting and settlement of claims during a crisis of this type, as well as investment portfolio management, which is considered in the next sub-section below.

This report has highlighted that claims from life insurance portfolios would be significant in a scenario like this one, but if averaged across the industry, would be manageable within excess mortality risk limits set by capital regulation or most management loss tolerance thresholds.

Variation between portfolios might make some companies see higher idiosyncratic losses than average as national and regional differences in mortality levels can be very significant.

Insurers can assess their own risk capital requirements for loss likelihoods at key reference return periods using probabilistic scientific models of pandemic risk. Leading insurers make use of these models to estimate the likely losses to their portfolios for the full distribution of return periods. Traditionally excess mortality risk has been estimated from the statistical variance of past claims experience, but with no significant pandemics captured in recent history, insurers relying on extrapolation of claims experience to estimate the magnitude of tail-risk pandemic losses are liable to underestimation. Insurers using a reference event, such as the 1918 pandemic, to set their risk appetite, have to extrapolate 1918 observations to the present day and make complex adjustments that carry high levels of uncertainty.

This deterministic scenario is not a substitute for a probabilistic risk assessment and should not be used to indicate an insurance risk capital requirement. The characteristics of the selected event were identified from a mid-range scenario from the RMS Infectious Disease Model that provides an approximate 1-in-100 event for infection rate (not mortality) and the event has been modified to explore parameters for severe stress testing, so the losses cannot be assumed as representative of any particular return period for mortality losses. The variants have no probabilities attached to them, and should be treated as illustrative deterministic sensitivity tests.

Healthcare insurance lines see much higher loss levels, relative to normal fluctuations around average annual payouts and demand. The major volatility of a pandemic scenario for insurers is compensation for healthcare treatments in population-level epidemics of this magnitude.

The portfolio management implications for a pandemic are significant. The classic diversification strategy for insurers has been across multiple international markets. In a global pandemic, the losses from these markets all correlate. Diversification strategies for pandemic losses are to offset against alternative business lines, such as annuity and pensions portfolios, which are negatively correlated.

Despite the obvious losses in life and health lines, non-life and general insurers will also suffer significant losses. In this report we identify a large number of lines of non-life business that will plausibly see an increase in the number of claims generated, ranging from event cancellation insurance, to directors &

officers' liability covers where there are potential routes to significant claims that could occur from the fallout and consequences of the pandemic. These may be surprising and not fully accounted for in the capital models of multi-line insurers, where silos of insurance business lines are generally assumed to be independent.

This scenario challenges that assumption by providing an example where losses correlate across multi-line exposures. Insurers develop contingency plans for managing large numbers of claims in natural catastrophes, but in this example those contingency plans are tested even further by proposing that these claims will be occurring during high illness-driven absenteeism among insurance claims management personnel.

Investment managers

The scenario demonstrates that there will be a significant impact on the markets and that the managers of investment portfolios will see significant losses across major asset classes. Investors will need to follow their classic 'flight to quality' strategies during these major market movements.

The pandemic will play out over several months, but initial signals and intimation of a developing pandemic could cause extreme market volatility at the start of the process. The severity of the pandemic is likely to be determined by the infectiousness of the virus ('R0') – which is likely to be estimated relatively early from the first few index cases – and the case fatality rate (CFR) – which will take some time to determine after a large number of cases have been through their infection lifecycle. Investors should watch for these reference metrics as early warning indicators of the likely forthcoming market consequences.

The likely patterns of investment asset impact are described in this report for the assumptions made here for this specific scenario. Different markets, investment instruments, rating grades, currencies, and credit spreads are affected. Investors can create portfolios that are able to offset and hedge some of these expected movements. Many investors structure their portfolio to pursue an investment return strategy but also to be resilient to major market shocks of this type, including the ability to rapidly move positions and to create liquidity in crisis situations.

The first two variants of the scenario, S1 and S2, show a significant market impact from the event, but do not cause a sufficiently large market movement to trigger a cascading failure of the financial market system. Scenarios S3 and X1 however do suggest that they could trigger defaults of major corporations and that these could potentially cause liquidity shortages among their counterparties and a general credit crisis that could escalate across the international financial system. In these kinds of financial crises, price plunges of investment assets are highly correlated.

In the industrial sectors of the equity markets, there are many losers and only a handful of winners. Losers include travel, airlines, tourism, discretionary consumer products, and education sectors. Winners include medical suppliers and pharmaceuticals, healthcare providers, telecoms, oil and gas, online retail businesses, and pension funds.

The market is expected to bounce back fairly strongly from the initial shocks sometime after the major wave of infection has passed. Monitoring the week-by-week indicators of numbers of cases and detecting the inflection point when cases stop increasing and start to decline could prefigure the market recovery and enable an investor to position themselves to benefit.

The longer term effects on interest rates and inflation consequences will play through over time. An investor who understands the way that these macroeconomic consequences will unfold can manage their investment portfolio to avoid being caught out by these changes when they occur.

Policy-makers

Infectious disease outbreaks of this type pose very significant challenges for the health and well-being of the population. The most significant preparedness issue for national security is the resourcing of healthcare treatment capacity. In normal times there is constant focus on cost management and efficiency in our healthcare systems. The main effect of this is to cut excess capacity, but this also means reducing safety margins for any sudden demand increases such as those that will be needed in a pandemic. National security contingency planning should focus on being able to provide surge increases in capacity to deliver basic healthcare provision. Most important of these is a greatly increased provision of critical care facilities. The nature of healthcare provision cannot be increased by an order of magnitude without changing the structure and nature of the provision, so planning for a pandemic of this type will need to envisage very different methods of delivering healthcare to scale it up sufficiently.

Essential services of power, utilities, fuel and food supplies will face major challenges of absenteeism in their workforce. Front line emergency personnel who will be allocated to assist, such as police, army, and fire services, will also suffer personnel losses through illness. Essential services will need careful protection and a high redundancy in their staffing provision to ensure continuity during the peak of the crisis.

The effectiveness of local and national authorities in combatting the spread of the disease is a major variable in the impact of the scenario – their ability to reduce contact rates in the general population through closing schools and suspending public activity. Variants S2 and X1 explore the consequences of poor quality government action. These are mainly actions that are taken too late to be effective, so decisive and proactive management is needed. There is a constant tension between the economic damage that will ensue from intervention and suspending business activity with the need for public safety and subsequent damage to the economy. Authorities are often caught with poor information and a fear of false alarm.

Investment in disease surveillance globally seems woefully poor compared with the threat that we face, namely the danger to the global economy of a major disease outbreak. The vital information that is required to act early, decisively, and in a well-informed manner can only be obtained through front-line collection of public health data and medical sampling.

If acted upon immediately, an early detection of an outbreak could enable containment and potentially complete prevention of a global pandemic. These measures are not possible today, because many of the areas where animal reservoirs give rise to new emerging diseases are some of the world's poorest regions with minimal public health surveillance. Investment by the richer nations in surveillance in these regions and proactive disease prevention and eradication would be cost-effective even on a self-protection basis.

In fact the current measures in place to combat a pandemic are structurally inappropriate to manage a threat of a global nature. The world's preparedness plans are primarily national. Each country has its own measures to combat a spread in its own population and yet in an era of globalization, will find it impossible to prevent new infections coming in across its own borders. Rich countries stockpile drugs and invest in vaccines, while poorer countries are faced with lower cost measures and will harbor pools of infection for longer periods of time, potentially re-infecting the richer countries.

Managing the risk of pandemics by having individual countries protect themselves piecemeal is inefficient and ineffectual. Combating the threat of pandemics requires truly international cooperation and global investment in developing the infrastructure, surveillance, intervention capacity, and economic incentives to combat the threat at source in each of the areas where outbreaks may occur.

This report demonstrates the scale of the threat of a pandemic to the global economy and to the social wellbeing of the population of the world.

We argue that the threat of pandemic is of sufficient magnitude to be taken very seriously by everyone. This risk has implications for individual organizations, insurance companies, investment managers, and most critically of all, to the national and international policy-makers who need to address this threat.

We offer this report as a way to highlight the risk, and to encourage actions by all of the major stakeholders in managing this risk and making the world a safer place from the impact of future pandemics.

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