Cambridge Centre for Risk Studies

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USING REAL WORLD SCENARIOS TO IMPROVE THE RESILIENCE OF PRIVATE INVESTMENT PORTFOLIOS

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"Historical performance is no guarantee of future results": Although analysis of experience data helps investment managers assess how their portfolios and assets would have performed against past crises, the next crisis will be different. Improving investment strategies against future risks requires tests against scenarios of likely – and unlikely – events across a wide range of potential causes. Real-world scenarios build hypotheses about plausible extreme events of the near-term future, based on scientific evidence, and uses them to assess how they could affect investments. Using real-world scenarios improves the resilience of investment strategies and provides better assessment of risk premiums in asset pricing.

1 Executive Summary

After the global financial crisis of 2008/9 (GFC), private markets have continued to expand at a tremendous pace as investors are increasingly attracted to the private asset class by a range of benefits such as better returns compared to traditional asset classes, a lower correlation with other assets and effective portfolio diversification. Spanning private equity, infrastructure, natural resources real estate and private credit, private markets have witnessed a period of phenomenal growth. Investors are committing to private markets in their search for stable income and/or superior returns.

The dynamic nature of private investments, however, employs multiple levers to drive value, leading to a significant level of idiosyncrasy, which is challenging to measure. Looking at the corporate space, this idiosyncrasy manifests itself in corporate strategy, M&A strategy, product developments, supply chain, technology utilisation and financial leverage which are all being optimised to maximise value in the medium to long term.

After the GFC there has been a reappraisal of investment modelling methods and analytical approaches, particularly in public markets. The crisis raised doubt that the framework for measuring risk in public markets was appropriate for portfolios comprising a combination of public plus a significant proportion of private market assets. The main criticism is that returns in private assets are more vulnerable to low probability, high impact tail risks and are therefore unlikely to be normally distributed. This has made it problematic to apply traditional systematic risk or non-diversifiable risk measures to private portfolios due to limited historical data. Furthermore, it is difficult to form robust conclusions about how assets perform under different macroeconomic scenarios.

To provide a solution, this project is an endeavour to incorporate scenario approaches with the latest developments in enterprise risk modelling techniques developed by the Cambridge Centre for Risk Studies (CCRS). They have researched market and macro risks to measure portfolio exposures to risk factors that can impact the individual constituents of an investment portfolio, often described as idiosyncratic risks.

An enterprise valuation model framework has been developed where constituents can be shocked when calibrated to a scenario to make the framework systematic across macro and market factors and, more significantly, the idiosyncratic contributions. Utilising a methodology combining Cambridge scenarios and digital twins representing portfolio companies, the portfolio-wide impact of a suite of scenarios can be assessed by measuring the extent of possible losses in firms' discounted cash flow, where the delta between the baseline and modelled cash flow, across all scenarios, is called Earnings Value at Risk. This enables investment managers to measure and prioritise the risk exposure and decide the optimal course of actions to mitigate and remediate the risk on their own portfolios.

This paper serves as an archetypal methodology that provides a basis for further research on integrating a multi-dimensional risk management paradigm into the investment decision-making process for private markets assets. A scenario stress testing approach can provide a complementary tool that helps assessing and confronting these uncertainties and therefore contributing towards the viability of a portfolio.

2 Introduction

The concepts presented in this report cover the ongoing research jointly conducted by the Cambridge Centre for Risk Studies (CCRS) and abrdn on improving the resilience of private investment portfolios. The body of literature addressing risk modelling of private market assets is relatively scarce compared to that of public market assets. As a result, assets traded in private markets have been treated interchangeably with those listed in public markets. In this process, there has been little fundamental difference between adjustments made to address the inherent characteristics of private market assets and risks the underlying investments carry and those made to public capital market assets. This report highlights the potential of using real world scenarios as a complementary approach to classical efficient market hypothesis and dynamic equilibrium models.

We define private market portfolios as those consisting of unlisted or privately held asset classes such as private equity, infrastructure, real estate, private credit and natural resources. Investments in private markets have historically been tainted with the perception that these assets have not always been easily accessible. As return-starved investors are looking for opportunities to improve their portfolio returns in the low yield environment, however, private market assets are increasingly viewed as an essential and core part of their asset allocation and overall investment strategies, adding significant value to their portfolios by offering better return potentials than conventional investment options, as well as diversification and volatility mitigation benefits.

Modelling and assessing the risks of private market investment portfolios is a challenging, especially regarding events in the tail of distributions. The Cambridge Taxonomy of Business Risks identifies broad categories of causal threats that could potentially cause a social or economic crisis. [1] This could, in turn, have the potential to impact the returns of investment portfolios and individual assets. Using real world scenarios to quantify the risk associated with an investment portfolio is an economic method of capturing some of the tail risk that a portfolio is exposed to. We take data from historical events to parametrise the model allowing for a robust method of risk analysis. This methodology can benefit an asset manager by highlighting the events that pose a serious threat to their portfolio, as well as outlining the key drivers behind the threat. This type of modelling is useful for high impact, low probability events that constitute tail risks, which are not easy to detect or measure within the traditional risk modelling framework as these models assume normality as a default.

This report presents the underlying concepts of using real world scenarios as a complement to standard risk management practices for stress testing private market investment portfolios. The key topics include:

- Review of traditional risk models
- Limitations of traditional risk models
- Taxonomy of portfolio risks
- Scenarios to support stress testing including their development and application methodology
- Scenario applications to private market portfolios.

3 Portfolio Theory Since GFC

The GFC and the failure of many investment portfolio risk management tools to anticipate and manage the meltdown has led to a general reappraisal of investment models and analytical approaches.

The credit crunch and associated economic crisis that followed generated a large volume of commentary and interpretation, and considerable questioning of conventional economic theory. [2] Macroeconomic models relied on by several central banks, known as 'dynamic stochastic general equilibrium' (DSGE) models, failed to anticipate the downturn. Among other initiatives, it triggered a movement to 'Reinvent Economics'.

The critique of classical economic theory questions the basic assumptions, principally the 'Efficient Market Hypothesis (EMH)' and 'dynamic equilibrium'. Such models are felt to be valuable for many parts of economic decision-making but poor at understanding financial crises. Some commentators have suggested that traditional economics, developed during the early 19th Century, is based on a poor paradigm, thermodynamics, in which steady-states are eventually achieved. [3] A number of authors highlight the fallacy of the Efficient Market

[1] CCRS (2019).

[2] See, for example The Economist, July 18, 2009.

[3] See Beinhocker (2007), pp21-43 'Traditional Economics: A World in Equilibrium'.

Hypothesis in having no room for asset price bubbles or busts – the theory insists that markets are always correctly priced and that bubbles have to be nothing more than markets responding to changing fundamentals.[4]

3.1 Fat Catastrophe Tails

The issue for several analysts is that the tails of the distributions are fatter than might be expected from traditional analysis techniques. As early as the 1960s the mathematics of Mandelbrot demonstrated that distributions of market price fluctuations have much fatter tails than traditionally expected but traditional economists have tended to pursue mathematical characterizations based on 'random walks' (i.e. information-free randomness with trends).[5] These lead to underestimations of the likelihood of major market movements. The economist Gene Stanley of Boston University demonstrated that a market dip of the severity of the 1987 'Black Monday' has a likelihood of 10^{-148} in traditional 'random walk' mathematics.[6] Robert Merton, one of the Nobel-prize winning architects of the Black-Scholes model, is quoted in 1998 on the day after Long-Term Capital Management lost $4.4 Bn as saying "according to our models this just could not happen".[7] A similar quote is attributed to an unnamed chief financial officer in one of the world's largest hedge funds, after it had suffered huge losses in 2008 as saying it had suffered adverse "25-standard deviation events, several days in a row" according to their models.[8]

3.2 They weren't designed as Catastrophe Models

To be fair, the models that were so heavily criticised were not designed to estimate catastrophe risk. The DSGE models used by central banks were developed to inform economic and monetary policy and have performed well during periods of financial stability. Asset pricing models in general have been great aids to investment management and have themselves "created markets". Economic models based on theoretical principles were used from the 1970s onwards as 'engines' to drive market change rather than as objective 'cameras' to simply reproduce empirical facts,[9] and as such these models altered the markets they represented through, for example, enabling futures and derivatives trading, which today are major components of the financial market.

Financial asset pricing models have been under scrutiny since the Black-Scholes-Merton model was widely blamed for the failure of Long Term Capital Management in 1998.[10] These models have even been blamed for the behaviour of entire markets – when many traders are using similar models, they tend to make similar decisions. The claim is that this has increased the coordination of activity ('flock behaviour') and the correlation of asset prices across markets, asset classes, and geographies significantly over the past two decades.

Bank runs are cited as similar examples of shared beliefs fuelling 'mob psychology' in the general population. The increased speed of information flows through the market provided by the Internet, and the ubiquity of modelled views of pricing are significant factors in increased correlation and the speed with which market crashes can now occur. The concept of coordinated actions by individuals facilitated by extraneous factors which are not easy to explain is (rather charmingly) referred to by financial analysts as 'sunspots'.[11]

3.3 Alternative Economic Theories

Alternative economic theories have been being proposed, including Mandelbrot's 'Turbulent Markets with Memory',[12] Minsky's 'Financial Instability Hypothesis',[13] and the emerging field of 'Complexity Economics'.[14] Modern theorists suggest that 'punctuated equilibrium' or growth cycles of boom-and-bust, may be inherent properties of a healthy growing economy. In these views of economics, the characteristics of the financial system itself is what defines the frequency and severity of crises: i.e. financial catastrophes arise from 'endogenous' characteristics of the complex system, as well as, and perhaps even more than, 'exogenous' external shocks.

3.4 Complexity Economics

These alternative theories propose considering economic activity as a complex adaptive system. Some

4 Cooper (2008) is one key critic of the efficient market hypothesis, in his book *The Origin of Financial Crises: Central Banks, Credit Bubbles and Efficient Market Fallacy*.

5 See Mandelbrot (2008) and Beinhocker (2007) p179-181.

6 Presentation by H. Eugene Stanley at a conference on The Economy as an Evolving Complex System, Santa Fe Institute, Nov 16, 2001 in Beinhocker (2007) p180.

7 'How the Eggheads Cracked' by M. Lewis, *New York Times Magazine*, Jan 24, 1999 pp24-77.

8 Cooper (2008) p10.

9 MacKenzie (2006): *An Engine, Not a Camera: How Financial Models Shape Markets*.

10 See MacKenzie (2006) pp218-242 for an examination of the LTCM case study.

11 Allen & Gale (2008) 'The role of sunspots' p76 in *Understanding Financial Crises*.

12 Mandelbrot & Hudson (2008).

13 Minsky first refuted the efficient market hypothesis with his 'Financial Instability Hypothesis' in 1936, which is adapted by Cooper (2008) as a basis for improving central bank policy.

14 Outlined by Sornette (2003) in *Why Stock Markets Crash: Critical Events in Complex Financial Systems*.

even suggest that a better conceptual model for economic activity might be biological evolution.[15] These ideas are embraced under the term 'Complexity Economics' or as a new manifestation of a longstanding branch of theory termed 'Behavioural Economics'.[16] The economy is seen as a complex system, and a market crash is a catastrophic failure.

Even without an underlying theoretical basis, the plausibility and impact of extreme shocks can be assessed through scenarios that incorporate real-world characteristics of causal processes and interconnectivity.

4 The Past is No Guide to the Future

Statistical data of past yields and asset performance are used to calibrate many of the traditional models of investment risk premiums. Reliable trading data is available dating back to the 1970s - around 50 years. That period has seen many extreme events, crises, externalities, and blips. It could be assumed that the most extreme events observed in that period represent the '1-in-50' annual extreme. But what about the '1-in-100' – can we just extrapolate using an assumption about the distributions? Philosophically we do not believe that the past 50 years contains enough extreme examples to fully populate the tail risk from statistical experience. There is literature concerned with how to make allowance for 'strategic surprise' and new types of crises that have not been seen before, referencing 'Black Swans';[17] 'Dragon Kings',[18] 'Unknown Unknowns',[19] and 'Non-Modelled Risks'.[20] Many organizations expend significant resources to monitor 'emerging risks' and the threats they face, as a way of trying to anticipate potential new threats that could trigger devaluation events. Our approach is to consider a universe of potential threats, which allows for completely unforeseen surprise, but by exhaustive analysis and research to create a useable taxonomy of causal issues that have plausible capability of causing events in the next several years. Each of these are then tested with the development of a scenario that enables a portfolio stress test that illustrates those threats.

5 Limitations of Traditional Risk Models

When analysing portfolios, different modelling techniques can be employed to provide a view of risks associated with it. Commonly adopted risk management techniques are designed to evaluate a portion of the risk, but not all of it. For asset managers, a delicate balance must be struck between ensuring that an investment is profitable while accounting for enough risk to ensure that a sufficient buffer can be put in place to protect them. Typically, a statistical approach is taken to assess the risk associated with an investment, for example the likelihood of an investment failing. By setting a range of likelihoods in which asset managers are confident in investing, this builds a risk appetite. However statistical views may contain insufficient information about the potential for failure. When a major devaluation event occurs, it can have far reaching effects, as tail risks have potential to be beyond an asset manager's risk appetite.

As described above, the GFC is an example of such a highly-correlated catastrophic event outside of statistical bounds. At the time value-at-risk models captured 99% of the risk for a bundle of securities. It did not take into account the 1-in-100 (year) event which in this case was a mass default on mortgages in the US housing market. From a modelling perspective, the 1-in-100 event may have been overlooked when the securities were traded, with people under-pricing the tail risks. Investors and regulators have learnt some lessons and now apply better risk management principles. For example, there are now strict rules in place to limit speculative investments and dangerous corporate culture driving aggressive risk-taking. These rules provide a greater level of market oversight and tighter restrictions on disclosure policies.

Many modelling methods are not designed to model extreme tail risks. Macroeconomic generalized equilibrium models can be stressed with moderate variations, but can fail to resolve when the variations exceed the historical range of observed variation, particularly in the case of highly improbable but highly impactful accidents or natural phenomena, i.e. a catastrophe.

In a context of private markets, investors had invested in a variety of unconventional asset classes that they thought offered them diversification from equities, prior to the GFC. In this event, they were disappointed to discover during the 2008–09 equity bear market, this diversification was largely illusory. For that reason, we believe that the asset classes that provide the most robust diversification from equities are those whose underlying cashflows are insensitive

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[15] Beinhocker (2007) apes (as it were) Darwin's *The Origin of Species* in titling his book *The Origin of Wealth*.

[16] The Economist describes the state of the art of applying psychology studies to economics under the umbrella of Behavioral Economics, in Financial Economics: Efficiency and Beyond', p73-74, July 18, 2009.

[17] Taleb (2010).

[18] Sornette (2009).

[19] Rumsfeld (2002).

[20] ABI (2014).

to the business cycle. For example, in a private market universe, infrastructure is an asset class that can be economically insensitive thus less cyclical. Many underlying infrastructure assets such as energy generating farms, schools, hospitals and utilities like electricity grids have cash flows that are driven by long-term government-backed contracts or subsidies, further linked with inflation.

More recently during the COVID-19 market turmoil in 2020, looking at social infrastructure for example, we can see how well it fared when equities and real estate were experiencing large price declines. In terms of a returns perspective, most investors rely exclusively on assets that are listed on public markets, but higher returns are often available from unlisted or privately held assets like private equity, infrastructure, direct property, private credit and natural resources. Private assets typically offer higher returns than their listed versions because investors receive an 'illiquidity premium' in compensation for losing the ability to release their capital at a short notice. This premium typically adds 2–4% to returns, depending on the asset class. Strong demand for private markets in recent years indicates that this premium may be now at the low end of the range, however, given the low expected returns elsewhere over a long horizon.

Investors sometimes mistakenly believe that because private assets are illiquid this means that they get no cash return in the short term. In fact, many private assets offer a stable income return during the period they are held. One of the biggest challenges for investors in private assets is identifying and accessing the best investment opportunities given its return and risk appetite. The difference in performance between top and bottom-quartile managers is more significant for private asset classes than it is for listed markets. Hence, manager selection is critical as the funds with the best track records can often be hard to access.

In terms of market transparency of the private markets, there has been growing transparency in private assets, as suggested by Hudson and De Silva (2016), making them more viable due to diversification effects, yield, and risk tolerance. In general, the trend is that better information coming out of private markets is allowing markets to be more liquid. However, the problem remains that there are still gaps in the reporting periods as private assets take a discrete approach to publishing information. Unlike the usual methods of modelling risks for public assets, they acknowledge that these private assets are more vulnerable to low probability, high impact tail risks. This suggests that a different risk modelling approach is required for these types of portfolios.

6 Taxonomy of Portfolio Risks

Single variable stress tests (e.g. a sudden reduction in interest rate) can be applied to a portfolio to ensure that an investment is robust enough to weather a shock. However real-world shocks rarely affect a single variable. The underlying cause of the reduction in interest rate will also affect other economic variables, and depending on the cause, can have quite diverse effects. In order to prepare for the tail risks it is necessary to take combinations of extreme events, which can have multiple stress variables affecting an investment portfolio. The interrelationship between the impactful variables changes with the nature of the underlying real world cause of the shock.

Rebonato explores the difficulty of stress testing risks and argues for 'coherence' in stress test variables consistent with using real and hypothetical scenarios. [21] Event-tree approaches of randomly stressing multiple variables become rapidly unfeasible with more than a handful of variables, to branch out every event that can affect a portfolio, especially at the same time. Instead we focus on specific events modelled after real world scenarios.

A more grounded approach takes an understanding of the universe of potential exogenous and endogenous shocks and a broad evaluation of the causal drivers of these shocks. The underlying causes of systemic risks we have previously termed 'econotagions'.

CCRS has reviewed the landscape of risk to attempt to identify the broad categories of causal threats that could potentially cause a social or economic crisis with the potential to impact the returns of investment portfolios and individual assets.

This study, ongoing since 2014, has involved multiple research approaches and has resulted in two publications. Identifying threats involved an extensive historical review of causes of social and economic disruption over the past thousand years. This was augmented with a review of catastrophe catalogues and databases, a precedent review, a study of counter-factual theories, and a peer review process.

[21] Rebonato (2010)

Financial

Economic Outlook
- Recession
- Stagnation
- Contraction
- Credit Crisis
- Steady Growth
- Expansion
- Acceleration
- Peak

Economic Variables
- Commodity Price Fluctuation
- Inflation
- Interest Rates

Market Crisis
- Asset Bubble
- Bank Run
- Sovereign Debt Crisis
- Flash Crash
- Fraudulent Market Manipulation
- Cryptocurrency Failure
- Reserve Currency Shift

Trading Environment
- Tariff Dispute
- Cartel Manipulates Market
- Organised Crime

Company Outlook
- Hostile Takeover
- Credit Rating Downgrade
- Investor Negative Outlook

Competition
- Disruptive Competitor
- Aggressive Competitor
- Fraudulent Competitor
- Intellectual Property Theft

Counterparty
- Supplier Failure
- Customer Failure
- Government Failure
- Creditor Failure
- Counterparty Fraud

Geopolitical

Business Environment (Country Risk)
- Talent Availability
- Industrial Action
- Minimum Wage Hike
- Sanctions
- Territorial Disputes
- Logistics Restrictions

Corruption & Crime
- Corruption Deterioration
- Crime Wave/Piracy Increase
- Slavery Practices

Government Business Policy
- Emerging Regulation
- Corporation Tax Rate Hike
- Diverted Profits Tax
- Nationalisation
- Confiscation of Assets
- Privatisation
- License Revocation

Change in Government
- Nationalism/Protectionism
- Left-Wing Radicalism
- Right-Wing Radicalism
- Populism
- Environmentalism

Political Violence
- Social Unrest
- Terrorism
- Subnational Conflict & Civil War
- Coup d'État

Interstate Conflict
- Conventional Military War
- Asymmetric War
- Nuclear War
- Cold War

Technology

Disruptive Technology
- E-Commerce
- Gig Economy
- Artificial Intelligence
- 5G Technology
- Blockchain
- Robotics & Automation
- Augmented/Virtual Reality
- Cryptocurrency
- Autonomous Vehicles
- Drones
- Medical Advances

Cyber
- Data Exfiltration
- Contagious Malware
- Cloud Outage
- Financial Theft
- Distributed Denial of Service
- Internet of Things
- Industrial Control Systems
- Internet Failure

Critical Infrastructure
- Power
- Transport
- Telecommunications
- Satellite Systems
- Water & Waste
- Fuel
- Gas

Industrial Accident
- Fire
- Explosion
- Pollution
- Structural Failure
- Nuclear

Environmental

Extreme Weather
- Flood
- Tropical Windstorm
- Temperate Windstorm
- Drought
- Freeze
- Heatwave
- Wildfire

Geophysical
- Earthquake
- Volcanic Eruption
- Tsunami

Space
- Solar Storm
- Astronomical Impact Event

Climate Change
- Physical
- Liability
- Transition
- Increase in Extreme Weather
- Sea Level Rise
- Ocean Acidification
- Lower Carbon Economy

Environmental Degradation
- Waste & Pollution
- Biodiversity Loss
- Ecosystem Collapse
- Deforestation
- Soil Degradation

Natural Resource Deficiency
- Fossil Fuels
- Biogeochemicals
- Raw Materials
- Water

Food Security
- Animal Epidemic
- Plant Epidemic
- Famine

Social

Socioeconomic Trends
- Ageing Population
- Gender Imbalance
- Wealth Inequality
- Poor Educational Standards
- Migration

Human Capital
- Failure To Attract Talent
- Gender & Diversity
- Labour Disputes & Strikes
- Loss of Key Personnel
- Employee Misconduct

Brand Perception
- Fake News
- Negative Media Coverage
- Key Influencer Disruption
- Negative Customer Experience

Sustainable Living
- Consumer Activism
- Sustainable Purchasing
- Supply Chain Provenance
- Diet

Health Trends
- Obesity
- Longevity
- Antimicrobial Resistance
- Medical Breakthroughs
- Healthcare
- Social Care

Infectious Disease
- Influenza Pandemics
- Coronavirus-like Epidemics
- Viral Hemorrhagic Fevers
- Preventable Disease Outbreaks
- Unknown Emergent Diseases

Governance

Non-Compliance
- Emerging Regulation
- Internal Corruption & Fraud
- Negligence
- Revised Accounting Standards
- Occupational Health & Safety

Litigation
- Private Lawsuit
- Mass Tort
- Class Action

Strategic Performance
- Divestitures
- Joint Ventures
- Mergers & Acquisitions
- Restructuring
- Poor Investment

Management Performance
- Executive Mismanagement
- Ineffective Board
- Management Execution Failure

Business Model Deficiencies
- Technology
- Customer Preference Change

Pension Management
- Contribution Management
- Fund Management

Products & Services
- Product Defect/Failure
- Innovation (R&D) Failure

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Figure 1: Cambridge taxonomy of business risks, v2.0.[22].

[22] CCRS (2019

Figure 1 shows the Cambridge Taxonomy of Business Risks. It is organised in a hierarchy of causal similarity, into 6 Primary Classes, 37 Families, and 170 Risk Types. The structure can be further subdivided into more granular types as required. This structure provides a universe from which to select scenarios of interest to stress a portfolio.

For example, the geopolitical class of scenarios considers the risk associated with not only the relations of a company to a governing body, but also the relations that the governing body has domestically and internationally. This can include specific scenarios such as emerging regulations, in which a governing body implements new laws that pose an impact to a company, or sanctions, in which a company could have exposure due to a supply chain shock created by a deterioration in relations between two countries.

Another primary class that can be expanded on is the environmental group of risks. This class covers not only the physical risks of extreme weather events, for example, heatwaves or tropical windstorms, but also the impacts associated with climate change. Beyond risk associated with physical change, there is also societal change, described as transition risk, driven by an increasing climate awareness. Transition risks can include areas such as developing carbon policy, where carbon taxes are implemented to push industries to reduce their climate footprint, or consumer demand shift, in which the market share is reduced as consumers become more climate conscious and reflect their purchasing decisions in that manner.

Using real world scenarios to quantify the risk associated with an investment portfolio is an economical method of capturing some of the tail risk for that portfolio. Taking historical data from events in order to parametrise the model allows for a robust method of risk analysis for the specific case. This can benefit an asset manager by highlighting the events that pose a serious threat to their portfolio, as well as outlining the key drivers behind the threat. This type of modelling is useful for high impact, low probability events that constitute tail risks.

While each individual scenario or stress test may reveal some aspects of potential vulnerabilities for an organization, 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. Importantly, a suite of scenarios can be compared to a taxonomy of risks that a company would normally protect against. This helps highlight scenarios that have not been previously considered or verifies the current strength or weaknesses in the taxonomy.

Over the past few years, new risks are beginning to emerge as well as new complexities being added to ongoing issues. The COVID-19 pandemic has shifted the world in substantial ways and that reflect in risk analytics as well as scenario modelling. Sustainability and climate change are driving the development of new scenarios to explore their unprecedented potential impacts. Scenarios provide additional information to improve preparedness for new threats and trends.

Integrating scenario modelling with traditional risk management methods allows portfolio managers to expand their current risk capture methods. It acts as a middle ground between the tail events and the rest of the risk capture to help them manage that area of risk.

7 Stress Test Scenarios

CCRS has been developing stress test scenarios since 2009 and has developed a standardized approach to scenario development that has been documented in best practice publications.[23] The approach has been used in the development of over 50 published scenarios by CCRS, and we have confidence that this provides a robust methodology capable of being applied to a wide variety of emerging or poorly understood risks that may need to be evaluated for portfolio risk assessment. Figure 2 shows the development methodology for scenario development.

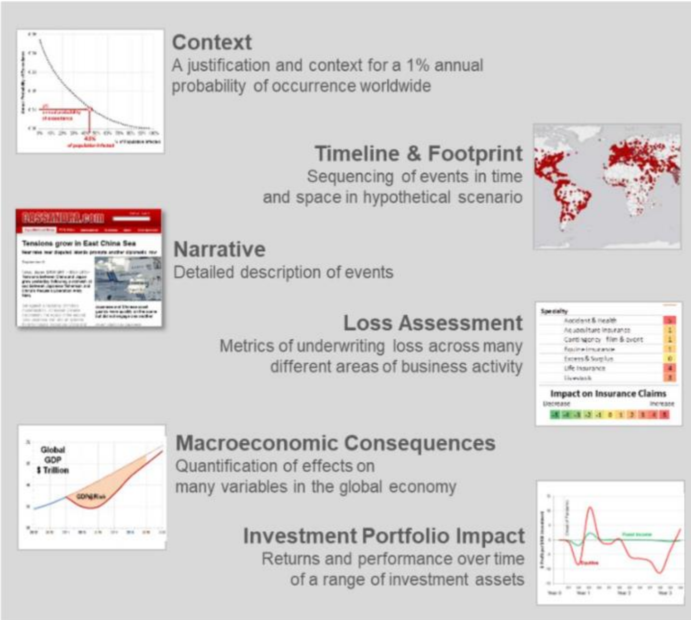

Figure 2: Scenario Development Methodology

Cambridge's risk modelling overlays exposure data with hazard and vulnerability models to generate

[23] CCRS (2018).

probabilistic and deterministic risk estimates for a chosen scenario.

Taking a critical look at a wide range of socio economic, technological, political, and environmental factors that influence the outcome of events, scenarios are commonly used in corporate strategy development and risk management practices. 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 must be plausible (but not probable), and 'coherent' – i.e., everything in the scenario is consistent and interlinked.

Scenario planning helps decision-makers identify and determine main forces driving future events in the planning processes. It also helps establish contingency plans that can be implemented to respond to environmental changes in a proper and timely manner, which is a critical element in maintaining organisations' long-term value and viability.

7.1 Was Pandemic Risk Underpriced in 2019?

Our stress test scenarios are derived from the threat taxonomy framework, Cambridge's ongoing effort to capture the fundamental causes of future catastrophes. Ranging from financial, geopolitical, technology and Social and Governance, majority of the primary threat categories are man-made, dealing with extreme cases of socio-economic, technological and financial system disruptions, whilst a range of natural phenomena will be separately considered as the environmental category to explore build-up and transmission mechanisms such as geological processes, conditions of meteorological cyclogenesis and threats arising from changing evolution pathogens. The primary purpose of developing such an extensive threat taxonomy is to establish a standardized approach for each type of threat, which is applied to ensure that results generated from different scenarios are comparable and a similar set of likelihood of occurrence can be used to allow benchmarking between threats.

Describing the range of variables that could influence the catastrophe events related to that catastrophe is a challenge, let alone predicting the specificity of how a catastrophe will play out. A scenario on human pandemic, which CCRS published in 2014[24], could serve as a prime example.

This scenario narrative had the disease outbreak beginning in São Paolo Brazil, instead of Wuhan China; coming from poultry instead of bats, and being a new strain of influenza virus rather than coronavirus. But the economic impact was similar – with a forecast 5-year loss of $7 trillion and $17 trillion of GDP, and the estimated winners and losers by sectors in the economy were broadly on track. The geographies of worst impact were not well forecast by our specific scenario, but the illustration showed that countries would have widely different impacts, and that timing of different waves would occur differently around the world. This was not prescience, it was evidence-based analysis turned into a scenario.

The last severe, world-economy busting pandemic was in 1918, before the advent of modern medicine and anti-viral drugs. Projecting forward the causal processes and estimating consequences of the human pandemic on today's population and economy required specialist application of epidemiology, economic theory, behavioural science, financial modelling, and government policy forecasts. The scenario was not a prediction, nor attempting to be a prediction. It was developed to explore whether, with only a 50-year statistical history, pandemic was under-represented in the risk pricing of assets.

Going through similar processes to explore the types of catastrophes in the taxonomy provides a good understanding of the 'landscape of risk', which allows a multi-dimensional assessment on risk exposures, risk relativities, concentrations, elements most at risk, and overall metrics of loss likelihood, all critical elements in risk management decisions.

7.2 Adding Scenarios to Inform Risk Premiums

In today's dynamically developing and substantially uncertain market environment, scenario analysis and stress testing are useful to understanding the risks and opportunities that organisations face. The integration of scenario planning into enterprise risk management frameworks increases organisational flexibility and reinforces long-term performance by helping managers to seek appropriate risk mitigation measures, and to develop and implement contingency plans and early warning systems more efficiently and coherently.

[24] CCRS (2014).

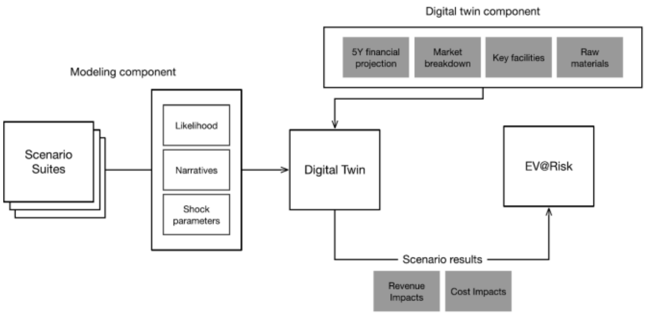

Figure 3: Scenario modelling framework.

For the success of these scenarios, we believe it is important to create a robust and transparent estimation process and have tried to achieve this through detailed processes that record assumptions made, and sensitivity tests about the relative importance of one input versus another. In the macroeconomic stages of the modelling, we are conscious that we are attempting to push macroeconomic models, calibrated from normal economic behaviour, outside their comfort zone, and to use them in modelling 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.

The guiding principle for Cambridge's scenario development is to create probabilistic scenarios that are plausible but extreme, i.e. tail events, and use them to stress an investment portfolio. The baseline variant of the scenario is typically specified with assumptions based on the expected outcome conditional on the scenario definition (L1), while more pessimistic assumptions for the key variables that drive the loss (L2) and even more severe but plausible losses and combinations of extreme conditions are assumed for more extreme variants (L3 or L4).

Scenarios of course, are developed as stress tests and are not intended to be predictions. By analysing granular information on key locations and critical supply chain dependencies like facilities crucial to managing raw materials, which can be rolled up to hundreds of companies in investment portfolios, the scenario approach can help those managing the macro risk management framework and processes better understand the essential drivers of fundamental and systemic risks and linkages that can adversely impact the viability of private market assets.

Scenarios can also serve as a helpful tool measuring the risks to which investment portfolios are exposed and managing uncertainties emerging from the dynamically changing environment. They can help investment managers examine the scale of loss which could be potentially suffered from their portfolio by stress testing the portfolio assets. The stress test results help investment managers identify accumulated or concentrated exposure that can occur in several ways, which can therefore lead to higher than originally expected losses.

8 Application to Private Market Assets

Spanning private equity, infrastructure, natural resources real estate and private credit, private market assets have come a long way: private markets are investments that are not traded on a public exchange or market and for a long time, investing in private markets was just a niche area for highly specialised investment professionals. Since the GFC, private markets have continued to expand at a tremendous pace as (institutional) investors have been increasingly engaged in funding business activities in the economy. This led to a rapid growth in the private investments sector, as investors heavily exposed themselves to private markets in their search for yield. Meanwhile, banks came under a heavier regulatory burden and consequently pulled back from certain areas of the economy, which weakened their traditional role in extending credit to business activities.

In line with these structural changes in capital markets, the attraction of private markets has increased. Private markets investment portfolios attract investors as an allocation to private market assets offers a range of benefits such as better returns compared to traditional asset classes, a lower correlation with other (public market) assets and effective portfolio diversification. According to a PWC estimate, alternative assets (e.g. real assets, private equity and private debt) will reach $21.1 trillion by 2025 accounting 15% of global assets under management (AUM).[25]

The use of scenarios is valuable when looking at private market investments. By its nature, the dynamic nature of private investments employs multiple levers to drive value. For Real Estate or Infrastructure, it could be the development of a project, including design, consent, development

[25] PWC (2017).

capitalisation and stabilisation of the investment. In Private Equity, looking at the corporate it manifests itself in corporate strategy, M&A strategy, product developments, supply chain, technology utilisation and financial leverage; these are all optimised to maximise value in the medium to long term. This dynamic transformation leads to a significant level of idiosyncrasy, which is challenging to measure and is not always positive.

Public market data is often used to derive or proxy the likely performance of a particular sector or market but falls short when dealing with the idiosyncrasies of Private Investments and trying to determine its sensitivity to tail risk events. Therefore, we need to create a bridge between the scenario framework and assessing the aggregate economic impact. To achieve this, we need to disaggregate the valuation components of the corporate or project. Therefore, a combination of credit and default style analysis and forward scenario analysis is utilised.

We utilise an enterprise valuation model framework where specific constituents can be shocked when calibrated to a scenario. To make the framework systematic, these linkages are broken down into three main segments.

1. Idiosyncratic - these include information around management and governance, the capital structure, the operating platform, understanding a firm's competitive advantage or corporate strategy.

2. Market factors - consider sector growth, discount rates and valuation multiples, market liquidity, transparency, secular changes, and industry trends, including country-level factors such as political and tax risks.

3. Macro factors - include business cycle indicators, financial cycle indicators, monetary policy, interest rate expectations, inflation expectations.

Each of these segments allows us to flex the enterprise valuation model.

However, geolocation linkages must be considered for more detailed risk appraisal to incorporate the broad range of systemic risks that affect the real world. Information such as the location of critical facilities such as headquarters and critical supply chain locations to allow several scenarios to be able to cover financial, geopolitical, technology, environmental, social and governance risk (as detailed in section 7).

Once calibrated on an asset-by-asset basis, the risk can be rolled up to the portfolio to the aggregate risk and show the impact of specific tail events to the portfolio. Applying this dynamically is a real advantage when investing in private markets because risks are constantly changing. Therefore, understanding the potential impact of such events is valuable when constructing portfolios of scale.

Historical Correlation[1]: January 2011–December 2020 Click Asset Class to Highlight RESET

	Positive	Negative
High	0.7-1.0	(0.7)-(1.0)
Moderate	0.4-0.7	(0.4)-(0.7)
Low	0.0-0.4	(0.0)-(0.4)

	Investment Grade Bonds	Cash	Commodities	Currencies	Equity Market Neutral	Event Driven	Global	Hedge Funds	International Equity	Long/Short Equity	Managed Futures	REITs	S&P 500®
Investment Grade Bonds	1.00												
Cash	0.12	1.00											
Commodities	(0.17)	(0.12)	1.00										
Currencies	(0.04)	(0.03)	(0.47)	1.00									
Equity Market Neutral	0.05	(0.15)	0.35	(0.58)	1.00								
Event Driven	(0.05)	(0.25)	0.65	(0.33)	0.39	1.00							
Global	(0.03)	(0.16)	0.60	(0.49)	0.42	0.83	1.00						
Hedge Funds	0.10	(0.22)	0.60	(0.36)	0.50	0.91	0.84	1.00					
International Equity	(0.02)	(0.15)	0.60	(0.57)	0.45	0.80	0.96	0.81	1.00				
Long/Short Equity	(0.05)	(0.20)	0.56	(0.43)	0.52	0.85	0.90	0.92	0.87	1.00			
Managed Futures	0.47	0.04	(0.12)	0.09	0.08	0.04	0.08	0.35	0.05	0.17	1.00		
REITs	0.38	(0.14)	0.34	(0.26)	0.31	0.61	0.70	0.63	0.64	0.62	0.22	1.00	
S&P 500®	(0.06)	(0.17)	0.55	(0.38)	0.37	0.80	0.97	0.81	0.87	0.87	0.10	0.70	1.00

Figure 4. Correlation matrix of asset classes[26]

Since the GFC, efforts have been made to overcome the inherent limitations in calculating exposures to hazard risk. The traditional modelling methods used to price exposures, treat market and macro factors work in a fragmented and siloed manner. Separate models based on these two types of factors provide analytically strong estimates of exposure, but do not take into consideration the interplay between these factors. These models have evolved into a more integrated and holistic approach, which is increasingly coordinated with enterprise-wide strategies as a key part of a multi-dimensional risk management paradigm. This project is an endeavour to incorporate scenario approaches with the latest developments in enterprise risk modelling techniques developed for market and macro risks to measure portfolio exposures to risk factors that can negatively impact the individual constituents of an investment portfolio, often described as idiosyncratic risks.

9 Scenarios to Manage Portfolio Risk

The continued blurring of the lines between public and private assets presents a unique set of challenges to decision-makers. In accommodating markets, the convergence with a certain degree of diversification benefits will play nicely and perform well as the investments stably outperform public-market benchmarks. However, things might not go as expected in more volatile markets where the

[26] Guggenheim Investments (2021).

differences in risk profiles, namely liquidity, data availability and connectivity to the economy, which have been distinguishing characteristics of private assets, may reduce the diversification benefits that investors expect.

In a more volatile market, correlations among asset classes will increase due to stressed macroeconomic and market conditions, which can lead to unusual correlations within the private markets investment portfolio itself. Meanwhile, normally liquid markets may suddenly become illiquid and the systemwide liquidity and credit problems in the market would lead to a situation in which it becomes impossible for all companies in the portfolio to find sources of working capital or (re)finance their operations. Under this circumstance, private market assets that were originally assumed to be an uncorrelated source of excess return could reveal a stronger connection to certain risk drivers in the industry, which could be a channel such that the impact of risk events in the public markets or adjacent asset classes can be amplified by leverage or systemic issues. Strong management teams (often referred as GP Skills) are critical in delivering results in good times, but their ability to manage crisis situations will be even more critical when uncertainties are prevalent.

The diversification benefit by adding balanced private market portfolios can provide returns that have low correlation with equities and also low correlation with each other, e.g., private equity and infrastructure. Therefore, the addition of each diversifier to the portfolio lowers the overall portfolio risk. Given that their individual returns are reasonably attractive it is plausible to construct a lower-risk portfolio with a higher expected return than equities or a traditional 60/40 portfolio. We believe that in an environment of very low government-bond yields and modest global growth, private markets can offer better return prospects than traditional balanced strategies, while preserving the defensive characteristics. This approach has the benefit of a natural bias towards assets with reliable cash flows.

However, with growing uncertainties and risks being more and more interconnected, there has been an increased difficulty in designing a sustainable investment portfolio, i.e., determining the right combination of viable and profitable industries. Efficiency of the present financial methods of building and maintaining portfolios could be significantly undermined when the level of uncertainties in the market is rising and the business environment is under distress. Scenario stress testing approach can provide a complementary tool that helps investigating and confronting these uncertainties and therefore verifying the viability of portfolio.

Taking advantage of a methodology combining Cambridge scenarios and digital twins representing portfolio companies, the portfolio-wide impact of a suite of scenarios can be compared on an equal footing as the impact of the scenarios will be measured as the extent of possible losses in firms' cash flow generation, where the delta between the baseline cash flow of portfolio companies and modelled cash flow, over all scenarios, called Earnings Value at Risk. The calculated results of stress tests would enable investment managers to measure and prioritise the risk exposure and decide the optimal course of actions to mitigate and remediate the risk on their own portfolios.

10 Conclusions

This study aims to be a proof of concept to establish a basis for further research on integrating a multi-dimensional risk management paradigm into the investment decision-making process for private markets assets. Most organisations recognize that effectively managing risk in investments is a complex undertaking that blends judgement with quantitative approaches. There are gaps in the standard risk modelling approaches based on standard deviation, which may obfuscate the true scale and nature of one's underlying risk by compressing diverse aspects of risks into a single dimension. It is therefore essential for investors and risk managers to consider a more complete risk management framework. We believe real world scenarios can complement the standard risk management practices and help managers ascertain the risks more comprehensively.

Our research suggests that the application of stress scenarios examining the universe of potential exogenous and endogenous shocks adds values in evaluating the risk adjusted performance of private markets investments. The dynamic nature of private investments employing multiple levers to drive value require a more integrated and holistic approach to capture idiosyncrasies in the underlying assets and measure the sensitivity to tail risk events of those investments.

As a next step, the focus of our future research will be on scaling the proof-of-concept work by testing the models and framework with multiple iterations (e.g., different types and combination of investments, industry sectors, and geolocations), calibrating the results and assessing the impact of assimilated portfolio-level results on the scenario specification and modelling framework.

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