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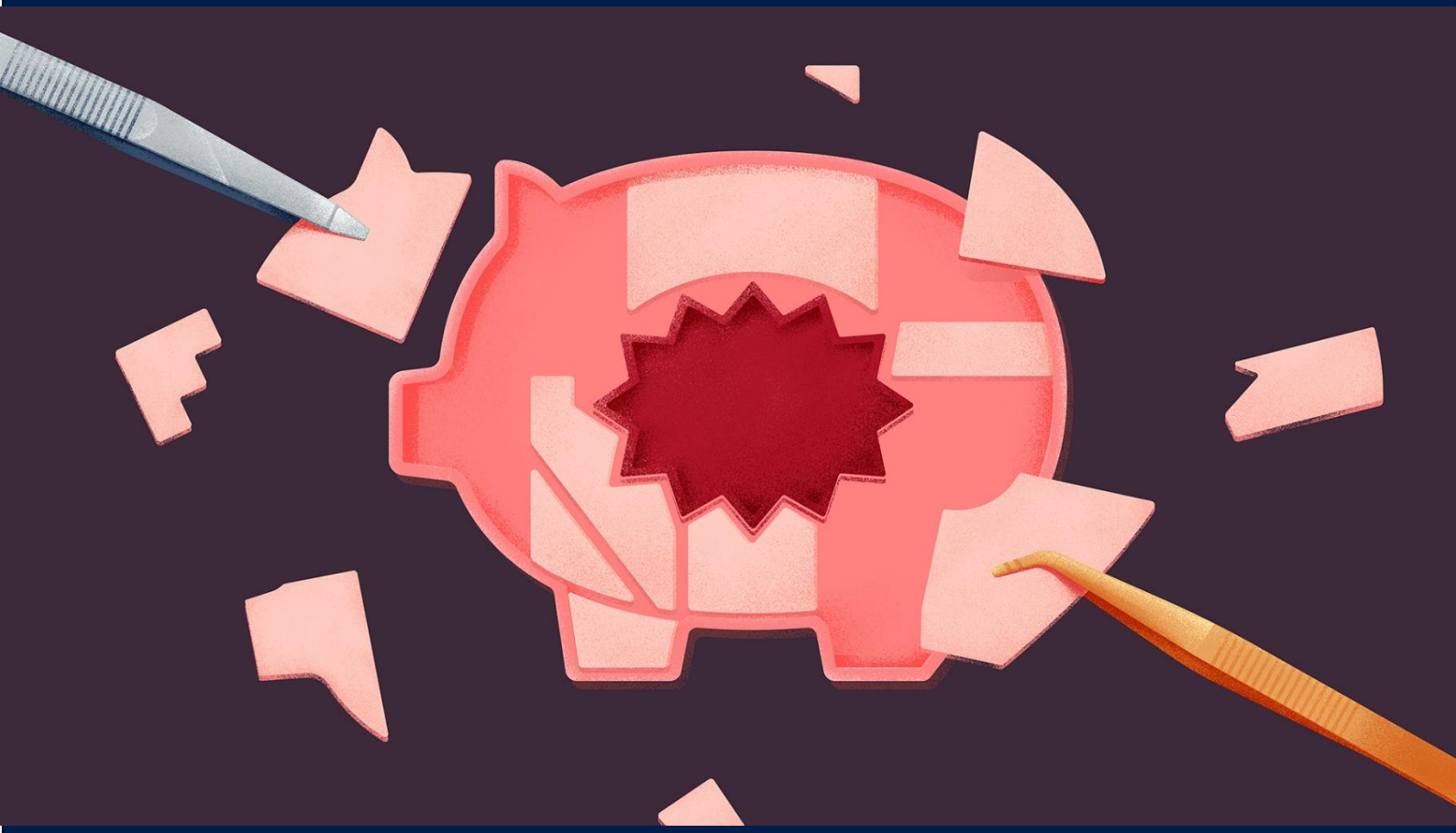

Embracing Uncertainty

Incorporating uncertainty in strategic asset allocation to help overcome shortcomings in traditional portfolio methods

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ABSTRACT

To improve portfolio construction and resilience, GIC and BlackRock outline two approaches to incorporating uncertainty in strategic asset allocation.

Introduction

The significant impact of Covid on the economic and financial markets landscape has brought into focus the importance of incorporating uncertainty into any investment process. The unusual, stop-start nature of activity has no historical precedent, meaning lessons from the past are unlikely to be very helpful. In addition, the world faces several structural changes such as the challenge of combating climate change, the implications of unprecedented monetary-fiscal coordination and the growing role of China.

The uncertain environment we are in warrants some humility around expected asset returns - the building blocks of strategic asset allocation. It is also important to acknowledge that there is no “optimal” portfolio for the wide range of significantly divergent yet plausible economic outcomes. Yet traditional portfolio techniques, such as mean variance optimisation, take the approach of achieving an “optimal” asset allocation by assuming too much certainty in the economic outlook and expected asset returns. This is a significant risk at the current juncture that could impede investors from achieving their objectives.

Both GIC and BlackRock believe strongly in incorporating uncertainty from the outset of any portfolio construction process. In this paper, we set out two alternatives to traditional methods. We study an explicit scenario-based approach and a simulation-based one, and explore ways the two could potentially be combined. The two approaches share a common philosophy – both allow for uncertainty, acknowledge that there is no “optimal” portfolio for all outcomes, and are flexible in a way that an investor’s aversion to uncertainty can be reflected in the portfolio.

This paper provides an overview of how we are looking beyond traditional portfolio construction approaches to prepare for an increasingly uncertain world. It aims to push forward the conversation and stimulate debate around portfolio construction.

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Summary

- Uncertainty is always an acute investment problem, particularly when several economic scenarios are sufficiently different and plausible. The post-Covid world faces uncertainty on a number of fronts – from the monetary and fiscal policy outlook and its impact on the U.S.-China strategic rivalry to structural forces such as sustainability.
- Asset prices and risk profiles are likely to diverge depending on the economic scenarios. Relying on point return estimates to drive strategic asset allocation under such circumstances can be misleading as the "mean" cannot be known with certainty when both the economic scenario and return expectations under that scenario are unknown. Traditional approaches such as "mean variance optimisation" (MVO) that rely on mean estimates assume certainty around how the world may evolve as well as certainty around how asset prices may react.
- The past 18 months have proved that reality can stray considerably from expectations. In this paper we discuss two alternatives to MVO – a scenario-based and a simulations-based approach. Both approaches stem from the same core philosophy that explicitly allows for uncertainty to help overcome some of the shortcomings of MVO.
- A scenario-based approach aims to minimise the opportunity cost – or 'regret risk' – of a macro outlook unfolding differently from its base case. This approach involves an investor contemplating several alternate scenarios, assigning a probability to each and using probability-weighted scenario outcomes to construct a portfolio that is tailored to maximise diversification across macro regimes.
- A simulation-based approach aims to maximise portfolio returns under potential "worst-case" economic and market outcomes around a single base case macro scenario. The uncertainty is directly incorporated in the capital market assumptions (CMAs) – or the long-run

asset return estimates – by simulating multiple pathways for asset returns and choosing the worst set of return estimates that reflect the desired aversion to uncertainty. To be sure, portfolios resulting from a simulation-based approach are also always being stress-tested on specific historical or market-driven scenarios and different sets of simulations calibrated on alternative scenarios can be produced as well. The stress test around emerging market crises we discuss in this paper is one example of using scenarios within a simulation-based approach.

- We adopt a case study of potential emerging market crises to compare and contrast the two approaches using a hypothetical, U.S.-dollar based multi-asset, institutional portfolio investing on a 10-year horizon. We use BlackRock CMAs for the third quarter of 2020 in this case study to reflect a period of high uncertainty in global markets when the path out of the Covid shock was particularly unclear.
- One key difference between the approaches is that the simulation-based approach focuses more on portfolio resilience, while the scenario-based approach is designed to minimise regret risk – that captures both potential underperformance and missed upside opportunities.
- What's next? Both approaches have their advantages and disadvantages yet we believe both offer a higher chance at achieving portfolio resilience for the years ahead than an approach that ignores the uncertainty inherent in investing. Ongoing work at BlackRock in evolving the CMAs involves more direct linkages to a macro scenarios and blending in elements of a scenario-based approach in allowing for multiple scenarios, while using simulation techniques.

Incorporating uncertainty

Both GIC and BlackRock believe explicitly accounting for uncertainty about the economic outlook and that the behaviour of asset prices should form an integral part of the portfolio construction approach. In this paper, we illustrate the importance of incorporating uncertainty – typically ignored in traditional techniques such as MVO – through a case study. We consider the macro environment in the third quarter of 2020 – a period of acute uncertainty around how the world might emerge from the Covid shock – for our case study.

Incorporating uncertainty serves two important purposes. First, it acknowledges that most investors might not have full conviction on a specific value for expected returns. More plausible is that asset prices may follow a few potential pathways. Accounting for these pathways can either be done by adding uncertainty to the input variables – that is the expected return itself – or by employing bespoke capital market assumptions for different macroeconomic scenarios. Second, we can capture the variability in levels of uncertainty across time and asset classes by attaching different probabilities to certain macroeconomic environments or varying the level of uncertainty by asset class. Why is this important? A lower ability to estimate returns for one asset class - for instance when an asset's returns are poorly explained by well-known public market factors – should warrant higher uncertainty around its expected returns.

We study two approaches to incorporating uncertainty – a scenario-based approach and a simulation-based approach. Both share a common framework that allows for uncertainty in mean returns, do not aim to design portfolios optimal for a single specific economic outcome and seeks to afford investors the flexibility to express uncertainty. A scenario-based approach assumes a small set of explicit macro scenarios beyond a baseline that may be sufficiently differentiated and constructs a portfolio that minimises the 'regret risk' of getting the macro outlook wrong. The simulation-based approach focuses on a base case macroeconomic scenario but allows for uncertainty in the mean return estimates corresponding to the base case and aims to minimise the downside risks under potential worst-case asset return outcomes. The simulation-based approach also uses an element of scenario analysis by stress-testing, for

instance, portfolio implications under specific economic and market outcomes. It allows for an analysis of different simulations based on alternative central views. Yet the preference in this approach is to design an asset allocation mix for a single set of simulations that represents a core view rather than the scenario-based approach that aims for a trade-off between different yet specific scenarios. The table below summarises key commonalities and differences between the two approaches and MVO.

Both approaches have their own advantages and disadvantages and are not mutually exclusive. One commonality is that both use a systematic and well-defined process to portfolio construction that accounts for the fact that the only certainty we have is that assumptions (point estimates) will likely be wrong. Yet they come at the problem from different perspectives. GIC looks to apply the mean-variance approach for a few different scenarios and combine the results in a way that seeks to reduce regret risk. There is still an eye to the upside and on the idea of not missing out on opportunities. BlackRock focuses on portfolio resilience and maximising the outcome in adverse scenarios. This approach aims to remain conservative by guarding against over-estimating returns.

Distinguishing between uncertainty and risk is important. We define uncertainty as the range of outcomes for the mean and risk as the range of outcomes around the mean. For example, instead of saying an asset has a mean return of 6%, we describe it as having a mean return in the range of 5-7% even if the risk, or volatility, of the asset stays the same.

Exhibit 1: Summary of approaches

Key features, similarities and differences of three portfolio construction approaches

	MVO	Simulation-based approach to minimize downside	Scenario-based approach to minimize regret risk
Allow for uncertainty in mean expected returns	NO	YES	YES
Allow for multiple explicitly defined scenarios	NO	NO (alternative scenarios implicit)	YES
Allow for full range of plausible outcomes	NO	YES	NO
Asset allocation aimed at single specific outcome	YES	NO	NO
Risk of concentrated portfolios	Higher	Lower	Lower
Flexibility to reflect investor aversion to uncertainty	Lower	Higher	Higher

Source: GIC, BlackRock Investment Institute, December 2021. For illustrative purposes only.

Minimising regret

GIC's scenario-based approach comprises two key components: scenario building and portfolio construction. Most investors have experiences in scenario building, particularly for risk management and stress testing. To apply scenario-based approach in strategic asset allocation, it is important to pay attention to how scenarios are defined and have some sense of likelihood of these scenarios occurring. For this paper, we won't delve into the details of scenario construction but rely on BlackRock's CMA and scenario returns. The paper Portfolio choice with path-dependent scenarios paper illustrates one systematic framework to construct scenarios and estimate their probabilities[1].

For illustration of the case study, we propose three plausible long-term scenarios beyond the base case embedded in BlackRock's CMAs as of the third quarter of 2020. The baseline scenario assumes a reflationary (strong growth and rising inflation) environment. The three additional scenarios capture stagnation (low growth and low inflation), stagflation (low growth and high inflation) and "goldilocks" (good growth and muted inflation) environment. See Appendix for a brief description of these scenarios. Return expectations for each of the selected assets are shown in the chart below. For illustrative purposes, we assign 40% probability to the baseline and 20% each to the three alternative scenarios in our hypothetical case study. In practice, investors can adopt quantitative models or apply qualitative judgements, considering internal views and external consensus to estimate scenario probability.

With the probability aware set of scenario returns ready, we adopt a two-step portfolio optimisation process. First, we find the portfolio with the strongest expected return for the least amount of regret risk in each scenario using investors' specific objective functions. In the case study we use return maximisation subject to risk and other constraints. Next, we combine all the scenario-specific optimised portfolios into the robust asset allocation. The objective of robust asset allocation is to minimise expected "regret risk", taking all scenarios into account. In particular we are searching for a portfolio that has the smallest possible

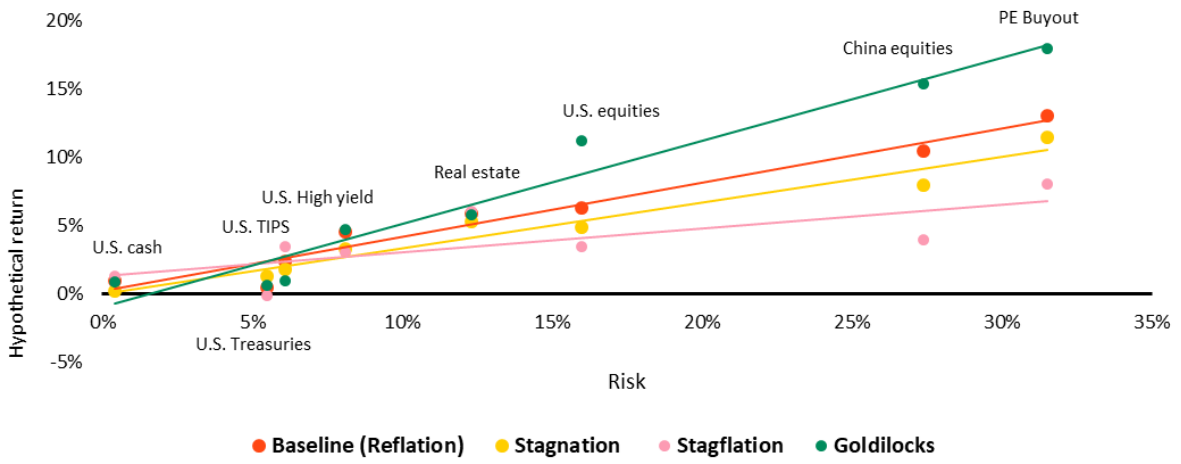
[1] Kritzman et. al. (2020). *Financial Analysts Journal, 77(1)*

investment regret under our plausible range of scenarios, particularly those we believe have a reasonable likelihood of materialising. In GIC's view, a portfolio constructed this way may not be optimal for any specific scenario but represents a well-rounded outcome.

Such a scenario-based approach has the flexibility to generalise and reflect an individual investors' objectives. Here we define "regret" as the gap between the highest returns achievable under each scenario, and the overall "regret" is measured as the probability weighted sum of the squared gap in each scenario. Investors with an absolute return target for example, can define "regret" as the underperformance from that particular target under each scenario, which exhibits an asymmetric penalty function with respect to underperforming versus outperforming that target.

Exhibit 2: Illustrative scenario returns

Hypothetical expected risk and return for selected asset classes under various scenarios



The figures shown relate to past performance. Past performance is not a reliable indicator of current or future results. *Sources: GIC, BlackRock Investment Institute, October 2021. Notes: The chart shows expected risk and return for selected asset classes under four hypothetical scenarios for an illustrative portfolio construction exercise undertaken at the end of Q3 2020. We have used this period in our study as we believe it marked a period of particularly high uncertainty about the economic and market outlook post-Covid as there was yet to be any confirmation of effective vaccines. The figures are for illustrative purposes only and results cannot be guaranteed. There are frequently sharp differences between a hypothetical performance record and the actual record subsequently achieved. Therefore, hypothetical performance records invariably show positive rates of return. Another inherent limitation of these results is that the allocation decisions reflected in the performance record were not made under actual market conditions and, therefore, cannot completely account for the impact of financial risk in actual portfolio management.*

A scenario-based approach

We now show how a scenario-based approach may have been applied during the third quarter of 2020 – a period of particularly high uncertainty as the path out of the Covid crisis remained unclear. The chart below captures the hypothetical asset allocations that would have been optimal for our assumed

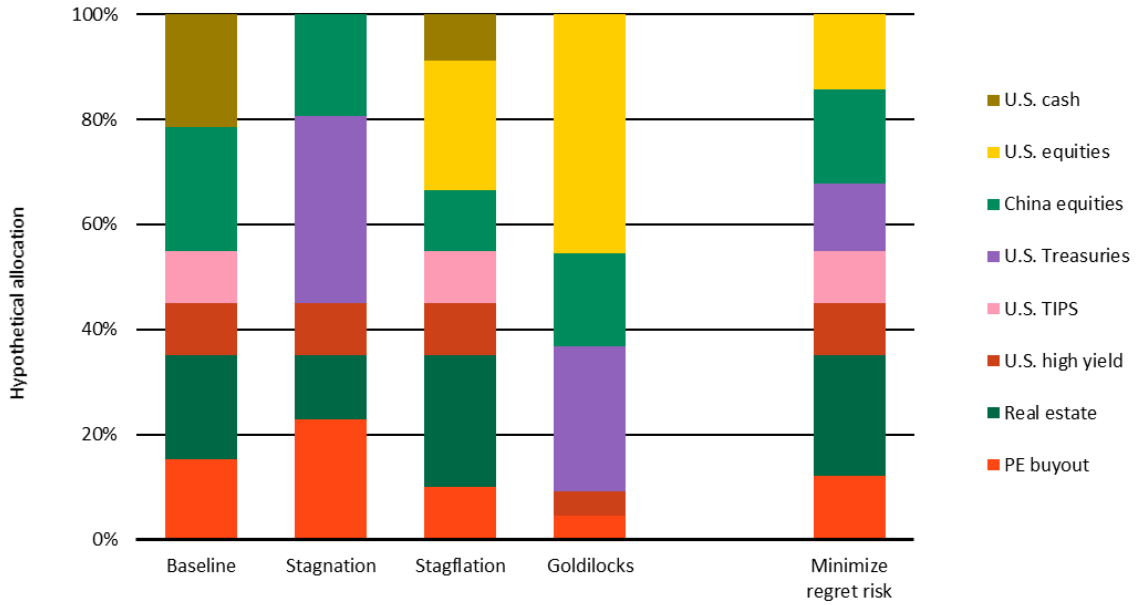
scenarios. The optimised portfolio under each proposed scenario aims to maximise returns subject to volatility and other constraints. The first notable observation is that the optimised allocation differs significantly across scenarios, even though they all face the same risk target and set of constraints.

For instance, the proposed baseline portfolio shows a large allocation to both U.S. cash and Chinese equities. Cash and inflation-linked bonds replace nominal government bonds due to the latter's poor expected returns under a reflationary scenario. Chinese equities were favoured over U.S. equities at the time given better starting valuations and continued strong growth under globalisation. The optimised portfolio under a "stagnation" outcome, on the other hand, has a large allocation to government bonds. Public equity exposure is also reduced, replaced with private equity exposure. The stagflation optimised portfolio leans heavily into real assets and inflation-linked bonds. Government bonds are not attractive given negative excess returns amid rising inflation and inflation uncertainty. The public equity allocation becomes more concentrated in the U.S., rather than China as the relative outperformance of Chinese equity narrows substantially in this environment. Lastly, the optimised portfolio for a "goldilocks" scenario leans heavily into public equities. High economic growth and low inflation are conducive for equity and growth assets. With low inflation, government bonds also retain their role as portfolio diversifiers.

The chart below compares hypothetical allocations for the different scenarios and one optimised to minimise regret risk. Overall, the "minimise regret risk" allocation – or the robust allocation – is more diversified and balanced. How? In terms of diversifiers, it allocates to cash, inflation linked bonds and nominal government bonds. The latter remains attractive under a low-inflation, lower-for-longer interest rate environment. In terms of public equity, it has a balanced allocation in the U.S. and China, rather than concentrated solely in China. It also has a marginally higher allocation to real estate at the expense of private equity, given more uniform return expectations under different macro regimes.

Exhibit 3: Scenario-based optimisation

Hypothetical allocations for scenarios vs robust allocation in Q3 2020



Sources: GIC, BlackRock Investment Institute, November 2021. Notes; The chart shows hypothetical, asset allocations under four potential, likely macro scenarios as of Q3 2020. The "minimise regret risk" allocations shows the result of a scenario-based approach that seeks to limit the opportunity cost of the actual economic outcome being different from the assumed baseline scenario. These allocations are hypothetical and purely for illustrative purposes and are built using BlackRock's Q3 2020 CMAs. They do not represent actual portfolios and do not constitute investment advice. The allocation is hypothetical, is not representative of allocation that any investor actually employed and is not indicative of future results. The results are based on assumptions integral to the model which may or may not be testable and are subject to losses. These allocations do not reflect actual trading or the effect of material economic and market factors on the decision-making process. Since trades have not actually been executed, results may have under- or over-compensated for the impact, if any, of certain market factors, such as lack of liquidity, and may not reflect the impact that certain economic or market factors may have had on the decision-making process.

Portfolio resilience

An alternative approach is to focus on building in portfolio resilience with an emphasis on the level of return in adverse cases. BlackRock currently does this by using at the core a simulation-based approach. A simulation-based approach also has the benefit of allowing a more explicit exploration of the term structure - or pathways – of asset return expectations. These pathways would already encompass several different scenarios. Such an approach also involves scenario analysis to gauge the portfolio implications of specific economic outcomes when applied in practice. See our paper Building resilience: a framework for strategic asset allocation[2] for more.

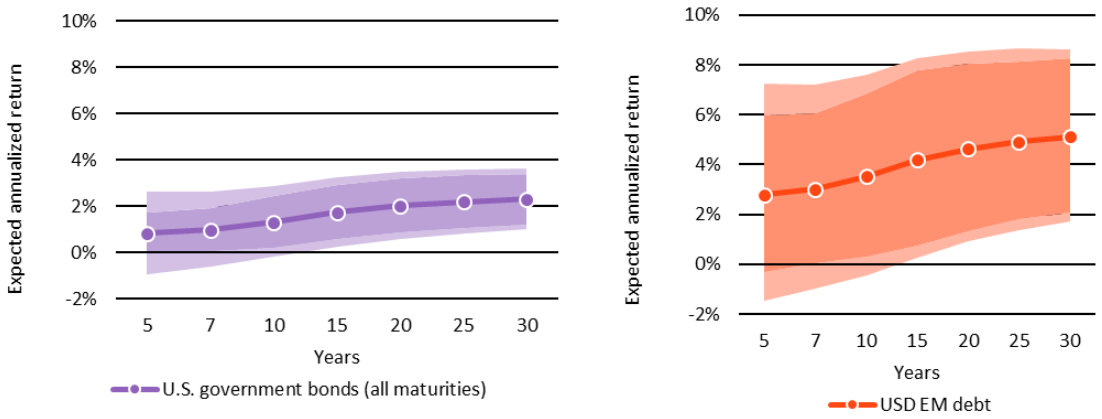
Asset return simulations are first run using a single set of CMAs, calibrated based on a central baseline macro scenario. While using a single set of CMAs, variability due to asset risk, or volatility, is of course taken into account, but this is not the only

[2] Blackrock Investment Institute (2018). *Building resilience: a framework for strategic asset allocation*

source of variability. Uncertainty in the mean returns – that is, the CMAs themselves – is also accounted for by simulating the mean return expectations as well as the asset returns around those means. We show an example of this in the Banding Together chart that illustrates our expected returns for U.S. government bonds and emerging market (EM) debt.

Exhibit 4: Banding together

Mean return uncertainty and potential return pathways on a 5- to 25-year horizon



The figures shown relate to past performance. Past performance is not a reliable indicator of current or future results. *This information is not intended as a recommendation to invest in any particular asset class or strategy or as a promise - or even estimate - of future performance. Source: BlackRock Investment Institute, August 2021. Data as of 30 June 2021. Notes: Return assumptions are total nominal returns. U.S. dollar return expectations for all asset classes are shown in unhedged terms, with the exception of global ex-US Treasuries and hedge funds. Our CMAs generate market, or beta, geometric return expectations. Asset return expectations are gross of fees. For representative indices used, see the Assumptions at a glance table. There are two sets of bands around our mean return expectation. The darker bands show our estimates of uncertainty in our mean return estimates. The lighter bands are based on the 25th and 75th percentile of expected return outcomes – the interquartile range for more detail read Portfolio perspectives of December 2018. Indices are unmanaged and used for illustrative purposes only. They are not intended to be indicative of any fund or strategy's performance. It is not possible to invest directly in an index.*

The central path of mean returns here is informed by central long-run expectations of macro factors and the five-year return estimates derived from various asset class models. Using a Monte Carlo simulation, thousands of potential return pathways are generated, centred around a distribution of mean pathways. The lighter shaded areas show an interquartile range between the 25th and 75th percentile of these return pathways. The difference in the size of mean return uncertainty between government bonds and EM debt in the chart above comes down to facets of each asset class. Well-understood factors can explain much of the returns from US government bonds but less so for EM debt. EM debt also has higher volatility than US government bonds. Together, these dampen our conviction in the mean path of returns for EM debt relative to US government bonds.

Once these asset return simulations have been run, the asset allocation decision is approached by choosing the appropriate tenor based on the investor's time horizon. The aim is to find the portfolio that maximises returns at that tenor for a set of portfolio outcomes that fall in the bottom-half of outcomes at the target risk level. One reason to advocate for such an approach is loss aversion bias – a well-known tenet of behavioural finance – that states that investors have a tendency to prioritise avoiding losses over gains as they feel the pain of the former more deeply than the joy of the latter.

A simulation-based approach

To recap, we have multiple simulation paths of asset returns for each asset of interest. Let's use 15,000 for purely illustrative purposes. These pathways take into account both variability in expected returns (uncertainty) and historic volatility of the asset class (risk). For any given portfolio, we can compute the portfolio's return expectation (or any other metric or objective of interest) for each path giving us 15,000 potential outcomes in this instance. We can sort and pick say the bottom decile, quartile or any other percentile of our choosing and search for the portfolio allocation that maximises returns for those outcomes. Choosing the entire set of 15,000 potential outcomes to optimise over will effectively amount to MVO and allocations will tend to exhibit all the symptoms of the approach such as concentrated positions and corner solutions in the absence of subjective constraints or heuristics.

As we choose lower percentiles for the distribution of outcomes – or more adverse expected returns – to optimise over, we expect to see more diverse portfolios, though this comes at the cost of some reduction in return expectation if the central outcome materialises in practice. Please refer to the paper Understanding uncertainty[3] for more. The chart (see exhibit 5) illustrates how we may expect allocations to change as lower percentiles of the distribution of outcomes are chosen to optimise over.

All three portfolios have an assumed target risk level of 11.5% for illustrative purposes. The advantages of the 75th percentile

[3] Blackrock (2019). *Understanding uncertainty.*

and 50th percentile portfolios over the MVO portfolio are readily apparent from the U.S. equities and U.S. cash allocations. MVO does not make any allocation to U.S. equities and just over 20% to U.S. cash. As we focus on the more adverse outcomes in our simulations, we see an attractive reduction in U.S. cash and increasing allocation to U.S. equities. We also see more modest allocations to China equities.

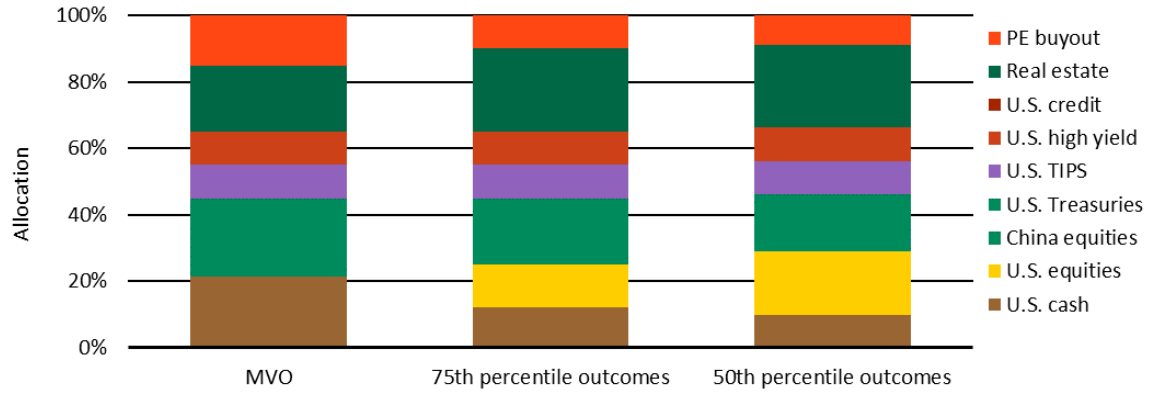
We believe that optimising over the more adverse simulation outcomes results in more diverse portfolios and helps to avoid corner solutions. If asset class A and asset class B, for example, have the same volatility but asset class A has a 0.1% higher expected return, an MVO optimiser will only allocate to A but not B despite the only marginally greater return expectation. If the optimisation process is conducted across multiple simulated pathways, A may dominate B in 51% of the scenarios, for example, but there is still a sufficient number of simulated pathways where B will dominate. An optimal solution will feature allocations to both A and B. The resulting portfolio will be more robust and resilient, in our view.

Two other points are worth noting:

1. The focus on return expectation in the most adverse set of cases is equivalent to expressing a confidence band or range of uncertainty around the return expectations. Choosing a lower percentile of cases is equivalent to choosing a wider confidence band or range of uncertainty.
2. The aversion to uncertainty represented by the choice of the percentile level of returns in the distribution of outcomes across which the optimization is run is related to the target risk levels. For instance, claiming a high aversion to uncertainty and yet also target a relatively high risk level would be inconsistent.

Exhibit 5: Minimising downside

Hypothetical allocations for simulation-based optimisation vs MVO



Sources: BlackRock Investment Institute, November 2021. Notes: The chart shows hypothetical asset allocations made at the end of Q3 2020 using erstwhile BlackRock Investment Institute CMAs using a robust optimisation approach that incorporates uncertainty around mean return estimates and a path of return expectations around a mean. These allocations are contrasted with a traditional MVO-based allocation. Two BlackRock hypothetical allocations are shown – the 75th percentile allocation that considers the bottom 25% of return pathways and the 50th percentile allocation that considers the bottom 50% of return pathways in the simulations. These allocations are hypothetical and purely for illustrative purposes and are built using BlackRock's Q3 2020 CMAs. They do not represent actual portfolios and do not constitute investment advice.

Comparing the approaches

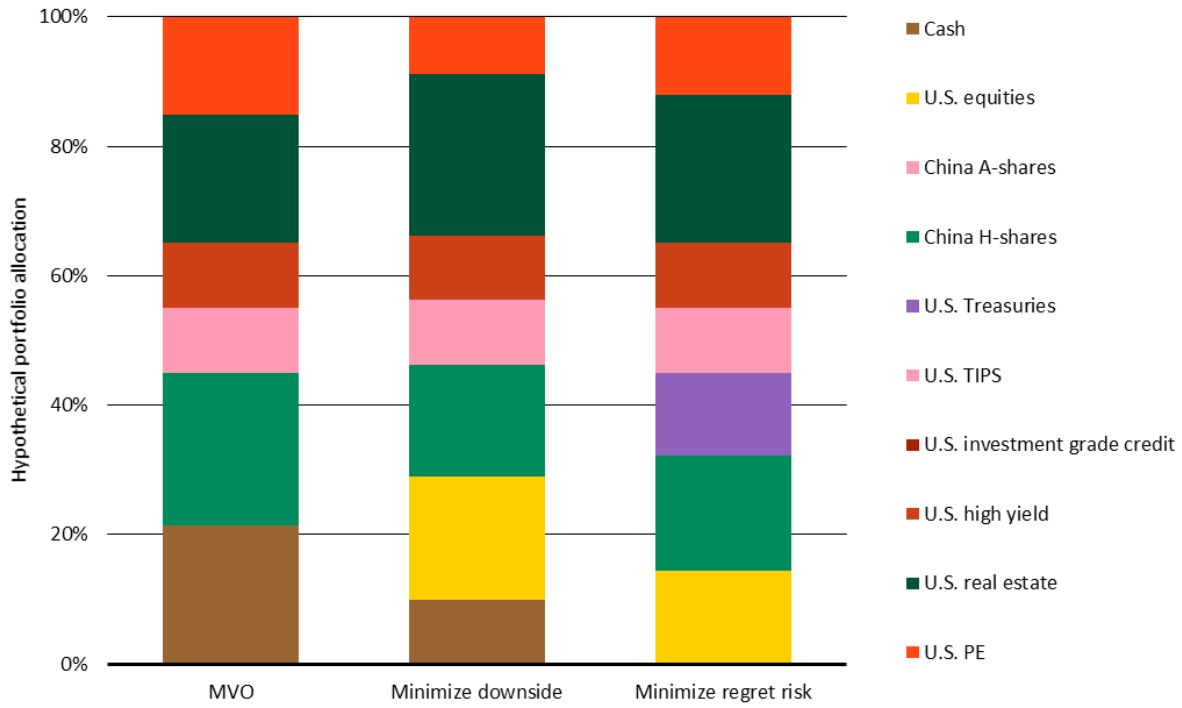
We compare and contrast the two approaches via a case study using a hypothetical asset allocation exercise for a long-term, multi-asset, U.S.-dollar institutional investor targeting a 11.5% risk level at the end of the third quarter of 2020. The chart below shows the results of the two approaches discussed earlier – one that aims to minimise the downside and one that looks to minimise the regret risk and the asset allocation using a traditional MVO approach. We also assume certain constraints such as a maximum allocation to a particular asset class to make the case study more realistic. The list of assets considered, capacity constraints and hypothetical expected returns for each portfolio are outlined in the appendix.

Two observations about the asset mix in the non-MVO portfolios are worth highlighting. First, the portfolio that seeks to minimise regret risk retained a sizable allocation to U.S. Treasuries due to plausible alternative macro scenarios under which nominal government bonds have further room to rally and play the diversifier role. In contrast, the portfolio that seeks to minimise downside risks has no allocation to U.S. Treasuries reflecting the view that the asset class' diversification properties were

diminished in a world where interest rates were poised to remain lower for longer. Second, the private equity allocation is reduced to a lesser degree in the portfolio minimising regret risk. This is because a broad macro environment, in GDP and inflation terms, does not necessarily lead to a varying relative performance by private equity versus public equity. These observations highlight the key difference of the two approaches: a scenario-based approach is designed to build macro resilience into the portfolio while a simulation-based approach sacrifices returns on account of a greater aversion to overall uncertainty.

Exhibit 6: Uncertainty and diversification

Hypothetical asset allocation for US dollar-based institutional investors under different approaches



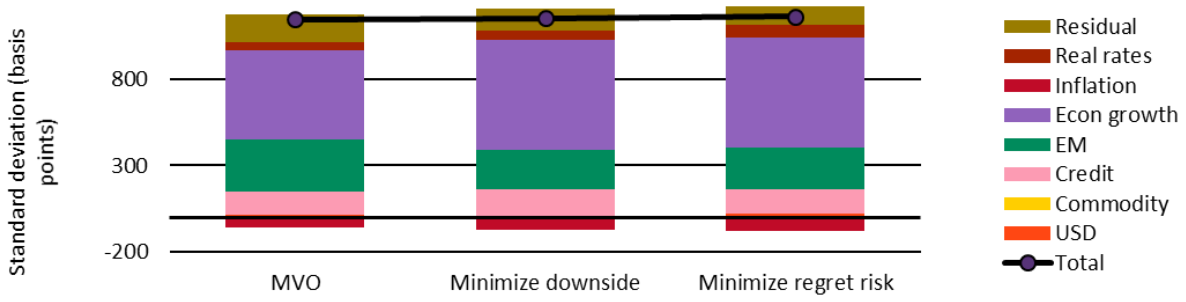
Source: GIC, BlackRock Investment Institute, November 2021. Notes: the chart shows three hypothetical asset allocations constructed at the end of Q3 2020 using three approaches: mean variance optimisation (MVO), minimising downside risk – or a simulation-based approach – and minimising regret risk – a scenario-based approach. These allocations are purely illustrative to demonstrate the different portfolio techniques and approaches, and are based on BlackRock's capital market assumptions as of 31 August 2020. They do not represent actual portfolios and should be not considered investment advice or recommendations. The allocation is hypothetical, is not representative of allocation that any investor actually employed and is not indicative of future results. The results are based on assumptions integral to the model which may or may not be testable and are subject to losses. These allocations were not made under actual market conditions and do not reflect actual trading or the effect of material economic and market factors on the decision-making process. Since trades have not actually been executed, results may have under- or over-compensated for the impact, if any, of certain market factors, such as lack of liquidity, and may not reflect the impact that certain economic or market factors may have had on the decision-making process.

Stress tests

Taking different scenarios into consideration also means looking at portfolios through different lenses. One helpful lens can be that of risk factors: the building blocks of a portfolio are decomposed into explaining risk factors and these are then aggregated again at the portfolio level. Such a factor view enables better understanding of the underlying risk and return drivers of a portfolio. The chart below shows the decomposition of the various portfolios using macro risk factors. Compared to the MVO portfolio, the scenario optimised portfolios take more "economic growth" risk and less "emerging and private market" risk.

Exhibit 7: Risk factors

Decomposition of risk factors for each hypothetical, back-tested portfolio



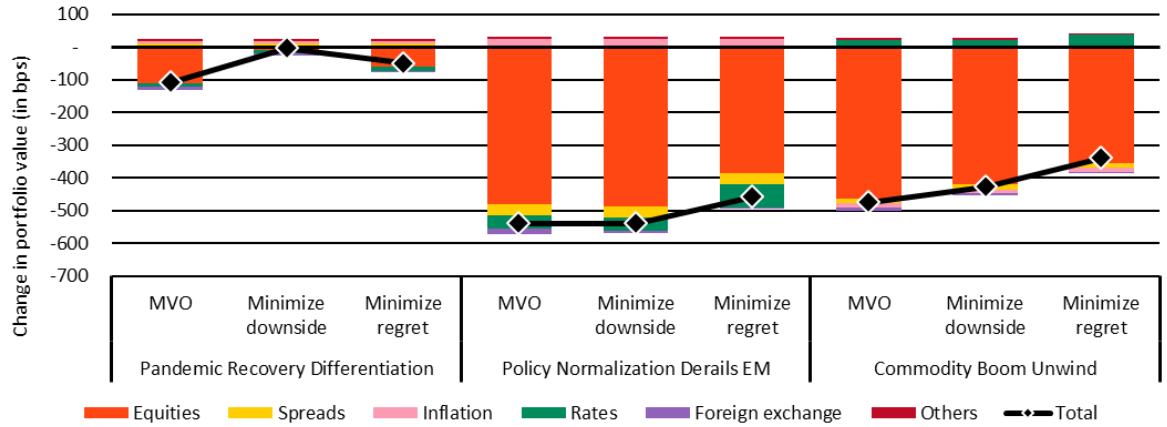
Source: BlackRock, data as of 30 August 2020. The chart shows the historical volatility (and its factor decomposition) of the various portfolios based on 240 equally weighted monthly data points. Portfolio return decomposition assumes constant exposures and shows the decomposition of return explained by risk factors. This is different from the experienced portfolio performance and excludes the unexplained factors. Back-tested results are hypothetical, not representative of results that any investor actually attained and is not indicative of future results. See Appendix for descriptions of the macro factors.

With this factor exposure of a portfolio at hand, various single or multi-factor shocks, historical or hypothetical, can be applied. Portfolios, which might look similar if only judged using expected return and risk, can be materially different from a factor exposure angle. For instance, the chart below calculates the hypothetical, back-tested performance of the various portfolios in three hypothetical emerging market crises. Please refer to the appendix for more details on these scenarios. This exercise can help identify key variables or main scenarios, which could be beneficial or adverse to a specific portfolio. Having identified the key macroeconomic or market risk factor that drives performance can help identify whether a portfolio is adequately reflecting the macroeconomic and market views of an investor.

The "Emerging Market Crisis" stress test below illustrates how the portfolios which incorporate uncertainty using the approaches outlined in this paper would be expected to fare relatively better in emerging market crises than an MVO portfolio.

Exhibit 8: Stress testing

Hypothetical, back-tested portfolio performance under simulated scenarios of an emerging markets crisis



Source: BlackRock, data as of August 2020. The chart shows the change in portfolio value (and its factor decomposition) of the respective portfolios in various scenarios defined in the appendix. These allocations are purely illustrative. The back-tested performance and allocation is hypothetical, is not representative of allocation that any investor actually employed and is not indicative of future results. Back-tested results are calculated by the retroactive application of a model constructed on the basis of historical data and based on assumptions integral to the model which may or may not be testable and are subject to losses. The back-tested allocation is developed with the benefit of hindsight and has inherent limitations. Specifically, the back-tested allocation do not reflect actual trading or the effect of material economic and market factors on the decision-making process. Since trades have not actually been executed, results may have under- or over-compensated for the impact, if any, of certain market factors, such as lack of liquidity, and may not reflect the impact that certain economic or market factors may have had on the decision-making process. Further, back-testing allows the security selection methodology and portfolio allocation to be adjusted until past returns are maximised.

Moving to the best of both worlds

We see the two approaches incorporating uncertainty as two sides of the same coin. Both aim to address issues with traditional mean-variance optimisation – particularly the over reliance on single point estimates of expected returns and accepting the inherent “unknown unknowns” in investing. Yet there are some differences worth exploring.

The first difference in approach is philosophical, reflecting different preferences and objectives. The scenario-based approach aims to find the portfolio that is “well-rounded” under different macro scenarios. It minimises probability weighted regret risk, which in our case study is defined as the return gap from the highest possible return achievable under each scenario. An asset class can be rewarded or penalised under

such macro uncertainty, depending on whether it performs better or worse under different scenarios. A simulation-based approach focuses in contrast on portfolio resilience, aiming to find the portfolio that maximises the expected return in a lower percentile of the asset return simulations. Choosing a smaller percentile of the simulations is analogous to reflecting a higher aversion to uncertainty and a wider confidence band around the capital market assumption. Since this approach does not differentiate between upside and downside uncertainty, an asset class with high uncertainty will be penalised in terms of allocation.

The second difference in approach is perhaps more technical. A scenario-based approach forms a handful of explicit macro scenarios, with separate sets of CMAs underlying each scenario and a probability assigned to each scenario. This approach explicitly accounts for macro uncertainty, but perhaps not other types of asset return uncertainty under each of these scenarios. A simulation-based approach assumes only one single central base case macro scenario. Yet multiple simulations of asset returns are generated to reflect the uncertainty in the asset return estimates due to model error, manager dispersion and other factors, and only implicitly for uncertainty in the macro scenarios.

Setting out explicit macro scenarios provides more transparency around the impact that alternative macro scenarios may have. Macro narratives and intuitions also facilitate effective communication and decision-making. The challenge of course is formulating these alternative macro scenarios and associated capital market assumptions, and estimating the probability associated with each scenario. This approach also does not really allow for uncertainty in the capital market assumptions associated with a given scenario. A simulation-based approach avoids the challenge of forming explicit alternative macro scenarios by simulating uncertainty in the mean asset returns, while simultaneously allowing for uncertainty in the macro scenarios and in the associated asset return estimates. However, the impact of different alternative macro scenarios is less transparent unless multiple sets of simulations are run and calibrated to different macro scenarios. This can be computationally resource-intensive and complicated.

A potential evolution of both approaches could see the two come closer together. One way would be to incorporate uncertainty in the capital market assumptions underlying each macro scenario in a scenario-based approach. This would involve using robust optimisation techniques to determine an optimised portfolio for each separate scenario rather than MVO, before then finding the single portfolio that minimises the probability weighted regret risk. Another way could be to use a more explicit macro model and simulate uncertainty in these key macro variables, combined with a model linking these macro variables and asset returns in the main asset return simulation engine in the simulation-based approach. Allowing for uncertainty in the capital market assumptions underlying any given macro scenario, while also enabling other macro scenarios to be explored in a convenient way – would effectively combine elements of both approaches. A well-calibrated macro model may also provide some useful sense of the likelihood of other macro scenarios occurring, relative to a central base case and help the calibration of capital market assumptions under different scenarios.

Our research indicates how important it is to incorporate uncertainty when constructing portfolios - particularly during times when many future pathways are plausible. Uncertainty can manifest itself across different macroeconomic scenarios and within a main macroeconomic scenario. The composition of scenario-based optimisations can be materially different to that based on MVO. It is important that portfolio construction is conducted before the veil of uncertainty is lifted. The future state of the world and the economy will most likely be different and with hindsight, other portfolios would have fared better. Hence, the objective of scenario-based optimisations is not to maximise returns in positive scenarios but to be prepared for a variety of different scenarios and to reduce losses.

We believe both approaches outlined in this paper are better than MVO. Seeking out ways to best combine both the scenario- and simulation-based approaches remains an area of active research for us and is how we plan to undertake portfolio construction in the future.

Appendix

Hypothetical portfolio returns for case study

The table below summarises the expected, hypothetical annualised returns under a base case and for the worst 10% of simulated outcomes of the three portfolios. The traditional MVO approach exhibits a higher return expectation in the base case – this is intuitive as it has been optimised assuming it is certain the exact scenario will play out. Yet the "minimising downside" – built on a scenario-based approach – and the "minimising regret" portfolio – built on a simulation-based approach – show better outcomes in the worst 10% of cases on account of a more diverse allocation that leads to better resilience.

Exhibit 9: Returns comparison

Summary of hypothetical expected returns under base case and worst 10% of outcomes

	MVO	Hypothetical portfolio minimizing downside	Hypothetical portfolio minimizing regret
Portfolio risk target	11.5%	11.5%	11.5%
Dispersion	5.3%	4.8%	5.0
Expected return, base case	5.9%	5.8%	5.8%
Expected return, worst-case	-3.4%	-2.7%	-2.9%

Source: GIC, BlackRock Investment Institute, November 2021. Notes: the table summarises the expected, hypothetical annualised returns under a base case and for the worst 10% of simulated outcomes of the three portfolios. For illustrative purposes only. This information is not intended as a recommendation to invest in any particular asset class or strategy or as a promise - or even estimate - of future performance.

Exhibit 10: Macro assumptions for a scenario-based approach

Summary of assumptions used for the four scenarios considered

	U.S. growth	U.S. inflation	Terminal U.S. cash rate	Terminal U.S. 10-year Treasury yield
Baseline	2.0%	2.5%	2.0%	2.5%
Stagflation	1.2%	3.7%	2.75%	4.0%
Stagnation	1.5%	1.2%	0.25%	0.5%
Goldilocks	3.0%	1.5%	1.75%	2.25%

Source: GIC, BlackRock Investment Institute, November 2021. Notes: the table summarises the broad macro assumptions underlying the four stylised scenarios used in the scenario-based approach study. Terminal rates refer to long-term estimates at equilibrium. These are stylised figures and do not represent actual estimates – past or present – for any of the metrics shown above. This information is not intended as a recommendation to invest in any particular asset class or strategy or as a promise - or even estimate - of future performance.

Exhibit 11: Constraints applied on hypothetical portfolios shown on pages 11, 15 and 16.

	Capacity Constraint
US Cash	100%
US EQ	100%
China EQ	25%
US Govt Bond	100%
US ILB	10%
US HY	10%
RE Core	25%
PE Buyout	25%

Macro factors definitions

- *Economic Growth: Broad developed market equity*
- *Real Rates: Inflation-linked bonds*
- *Inflation: Nominal bonds vs. inflation-linked bonds*
- *Credit: Long corporate vs. nominal bonds*
- *Emerging Market: Equally weighted basket of emerging market assets*
- *Commodity: Weighted GSCI commodity*
- *FX: FX basket dependent on portfolio base currency*
- *Idiosyncratic: The risk unexplained by the 2,200+ risk factors in the BRS risk model*
- *Residual: The sum of the macro factors and idiosyncratic contribution should match the total risk / return as modelled by the complete set of underlying risk factors (2,200+); the difference is identified as the residual factor*

Index proxies

- *U.S. cash = Citigroup 3-Month Treasury Bill Index*
- *U.S. TIPS = Bloomberg Barclays U.S. Government Inflation-Linked Bond Index*
- *U.S. Treasuries = Bloomberg Barclays U.S. Government Index*
- *U.S. high yield = Bloomberg Barclays U.S. High Yield Index*
- *Real estate = BlackRock proxy**
- *U.S. equities = MSCI USA index*
- *China equities = MSCI Emerging China (CNY)*
- *PE buyout = BlackRock proxy**

** We use BlackRock proxies for selected private markets because of lack of sufficient data. These proxies represent the mix of risk factor exposures that we believe represents the economic sensitivity of the given asset class.*

Exhibit 12: Descriptions, assumptions for market-driven scenarios considered in the stress test on page 17 and 18

BlackRock's Risk and Quantitative Analysis team produces Market-Driven Scenarios, which seek to model how topical macroeconomic regimes or geopolitical events could affect markets and portfolios.

"Emerging Market Crises" explores three potential paths for an emerging market ("EM") crisis	
Scenario 1: Pandemic recovery differentiation	Description: Regional recovery differences emerge across EM, driven by disparities in vaccine rollouts, challenging fiscal backdrops, and the possibility of political unrest. Catalysts: EM countries, which manage to contain the pandemic, benefit from increased global demand as a result of economies reopening. EM regions, which fail to contain COVID-19, struggle with greater debt burdens and fiscal sustainability concerns. EM regions, which are hard hit by COVID-19, also experience outflows due to political uncertainty amid upcoming elections and populations' flagging trust in government institutions. Market Reaction: EM equities underperform developed markets ("DM"). Latin America ("LATAM") lags broad EM. Asian pacific ("APAC") cyclical stocks and LATAM consumer staples rally in line with how the regions have managed to control the pandemic. Oil rallies on increased DM demand. The US dollar strengthens as nominal rates increase.
Scenario 2: Policy normalisation derails emerging markets	Description: High growth in developed markets leads to monetary policy normalization, making EM assets less attractive. Catalysts: Fiscal stimulus in the US accelerates growth and triggers US monetary policy tightening, driving outflows from EM assets. China tightens monetary policy with the aim of achieving financial stability and de-levering the economy, leading to lower growth in EM. EM central banks become more hawkish due to currency weakness. Market Reaction: DM rates and break-evens rise on the back of central bank yield curve control. EM equities and credit sell-off over fears of a 2013 Taper Tantrum replay. The US dollar strengthens and broad EM currencies weaken. EM rates sell-off as policymakers respond to currency weakness.
Scenario 3: Commodity boom unwind	**Description:** The commodities rally triggered by rapid global economic restart expectations runs out of steam, damaging recovery prospects for EM commodity exporters. **Catalysts:** Policymakers in China tighten policy quicker than anticipated and turn their focus to domestic imbalances in credit, real estate, and financial markets. China's hawkish posture dampens growth and demand for industrial metals and mining projects, harming EM regions and sectors sensitive to commodity exports. OPEC and allied oil producers continue to ramp up production despite muted global demand, and oil prices fall. **Market Reaction:** Chinese equities underperform as policy normalizes. Broad EM equities underperform DM. Industrial commodities and oil sell-off on from combined supply and demand shocks. EM commodity exporters suffer as commodities sell-off. DM rates and the Japanese yen rally in a flight-to-safety.

Source: BlackRock, October 2021. Note: The hypothetical scenarios represent an assessment of the market environment at a specific time and are not intended to be a forecast of future events or a guarantee of future results. This information should not be relied upon by the reader as research or investment advice regarding any funds or security in particular. Individual portfolio managers for BlackRock may have opinions and / or make investment decisions that may, in certain respects, not be consistent with the information contained in this presentation.

Exhibit 13: Index proxies

Asset	Index
	MSCI Developed - US Gross TR Index
	MSCI Developed - United Kingdom
	MSCI EMU Index
	MSCI Developed Europe ex UK Gross TR Ind
Equities	MSCI Developed - Japan Gross TR Index -
	MSCI Daily TR Gross Developed Pacific Ex
	MSCI China A Inclusion NET Index
	MSCI Emerging - China in CNY
	MSCI Emerging Markets ex China (Net)
	Bloomberg Barclays U.S. Treasury 1-10 Yr Index
	Bloomberg Barclays U.S. Treasury 10+ Yr Index
	Bloomberg Barclays Euro Treasury 1-15 Year Index
	Bloomberg Barclays Euro Treasury 1-15 Year Index
Fixed Income	Bloomberg Barclays Sterling Aggregate Gilts (1-10)
(Sovereign bonds and investment grade)	Bloomberg Barclays Asian Pacific Japan Treasury
	Bloomberg Barclays China Treasury + Policy Bank Total Return Index
	Bloomberg Barclays US Government Inflation-Linked Bond 1-10yr Index
	Bloomberg Barclays U.S. Tips Index 10Yr Plus - USD GROSS TR
	Bloomberg Barclays Euro Government Inflation-Linked 1-10 Years Index
	Bloomberg Barclays Inflation Linked Eurozone Inflation 10+Y
	Bloomberg Barclays MBS Index
	Bloomberg Barclays U.S. Credit Index
	FTSE Actuaries UK Index-Linked Gilts up to 5 Years Index
	FTSE Actuaries UK Index-Linked Gilts over 5 Years Index
	Bloomberg Barclays Euro Aggregate Corporate Index
	Bloomberg Barclays Sterling Aggregate Corporate Bond Index
	Bloomberg Barclays U.S. Credit Index
Fixed income	Bloomberg Barclays Euro Aggregate Corporate Index
(High yield)	JP Morgan EMBI Global Diversified Index
	JP Morgan GBI-EM Global Diversified Index
	U.S. private equity
	Global direct lending
	Global Infrastructure equity
Income and growth private markets*	U.S. core real estate Real estate mezzanine debt
	Hedge funds (global)
	U.S. infrastructure debt
	Developed markets infrastructure debt

** We use BlackRock proxies for selected private markets because of lack of sufficient data. These proxies represent the mix of risk factor exposures that we believe represents the economic sensitivity of the given asset class.*

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