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MANAGING MATERIAL RISK

RICHARD BOOKSTABER
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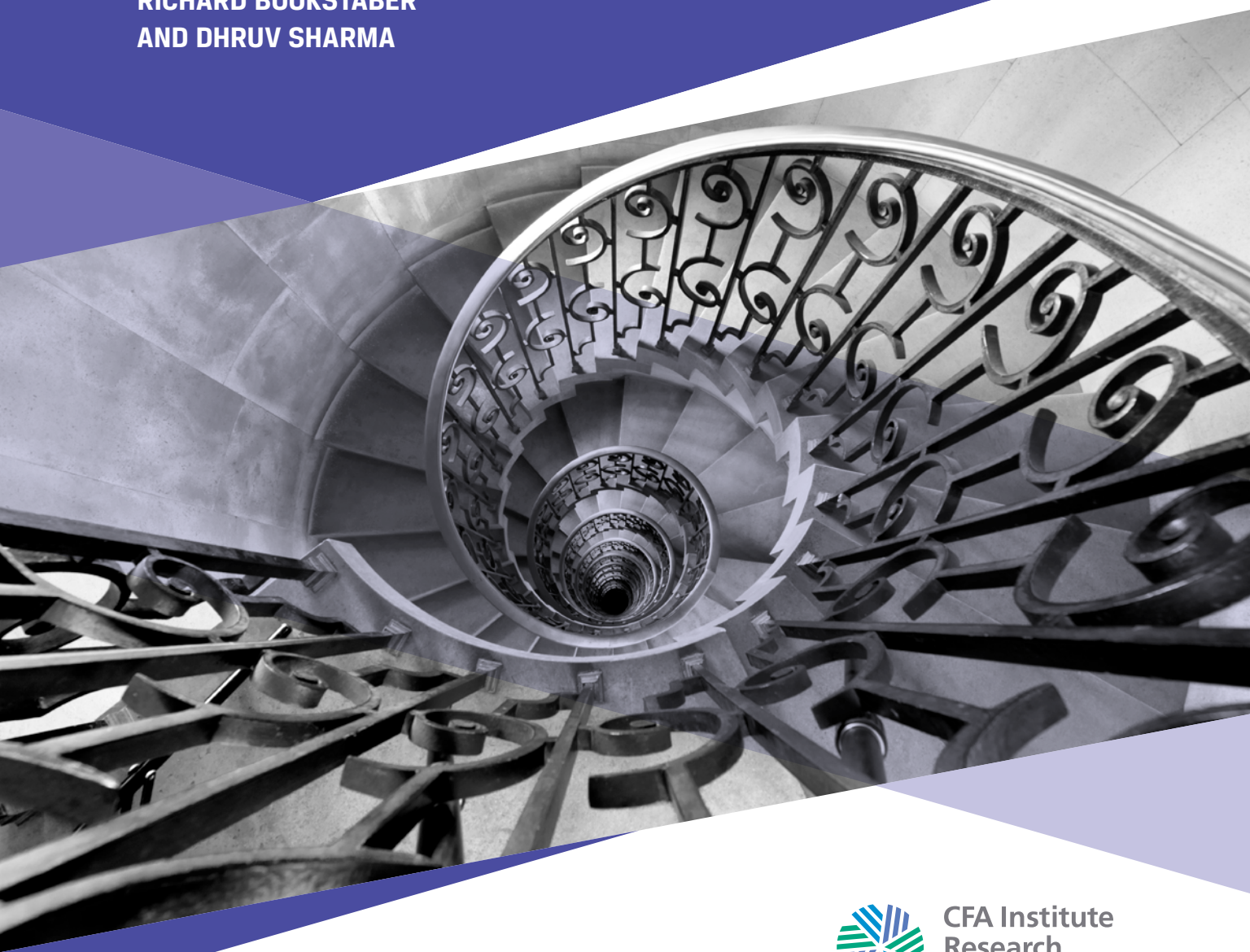

CFA Institute
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MANAGING MATERIAL RISK

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The current methods used to assess market and portfolio risk extend back to the early 1990s. These methods were developed for banks and broker/dealers and then were extended to the portfolio management and hedge fund community. They focus on short-term risk, which is measured in days for the broker/dealer's blotter and in months for hedge funds and investment managers. Perhaps because of this, these methods measure risk using recent history, usually just one or two years, thereby assuming that risk in the future will be the same as in the past. These methods are not appropriate for measuring risk over the long term, and thus they fail for asset owners, such as pension funds, family offices, and individuals. In this paper, I explain how to cast risk management for the asset owners. Although I focus on individuals, these points extend to the range of asset owners.

Banks and hedge funds focus on monthly or even daily variability in their profit and loss, whereas the time horizon of an individual is measured in years or even generations. In such a time frame, the day-to-day variability in the market—as measured, for example, by value at risk—amounts to noise that is best ignored (but usually is not). Rather, what matter are material risks. Material risks are those that can threaten the individual's prospects for meeting their goals, those that can derail financial plans that extend out perhaps 30 or 40 years into the future. Material risks include major market downturns, especially those that take years to recover from. By looking at returns over the past year or two, the current methods fail to reflect the dynamics that become increasingly important over the long term, dynamics that propel the markets over time and generate periods of major downturns and instability. These dynamics cannot be ignored as engines of risk for individuals.

Also, unlike for a bank or portfolio manager, risk comes at an individual from two directions: (1) market risk that directly affects individual wealth and (2) personal risk that comes from the uncertainty of life events and changes in risk tolerance and preferences. These interact to make an individual's risk calculation complex and dynamic. In the face of this complexity, the notion that we can optimize a portfolio is wishful thinking, as is the idea that we can look at the current situation in isolation and "set it and forget it" when it comes to portfolio construction for risk management.

Given that risk management for an individual is a moving target—that it is dynamic, multifaceted, and complex—we need a new approach to address it. One approach is agent-based modeling.[1] Agent-based models are used in fields in which complex dynamics are at work, from modeling traffic congestion on a highway to assessing the adequacy of exits for crowded

[1]The limitations of standard risk methods, and the use of agent-based models to overcome these limitations, appear in R. Bookstaber, *The End of Theory: Financial Crises, the Failure of Economics, and the Sweep of Human Interaction* (Princeton, NJ: Princeton University Press, 2017).

venues, such as stadiums and arenas. It is not surprising that these methods are applicable to financial markets, where crowding and leverage can lead to sudden rushes to exit and where liquidity can dry up at the most inopportune times.

As a starting point, I will highlight some characteristics of the market that are relevant for long-term risk. Then I will explain how to extend or replace current risk methods to deal with risks that develop over time. I then will move to the other side of risk that is not addressed in the current risk models—that is, the risk facing the individual based on personal interests.

THE NATURE OF MARKET RISK

Most financial professionals are already familiar with essential properties of market prices, such as skew (the asymmetry of a price distribution), kurtosis (the "fat tails" of a price distribution), and periods of volatility clustering. More critical for those with a long time frame are the material risks that matter for individuals as they focus on the various components of their financial plan, the risks coming from large and sustained drops in the market that can affect lifestyle goals (e.g., retirement and college obligations), derail aspirational goals (e.g., buying a second home), or even threaten basic financial security and well-being.

Material risk is often hiding behind the fog of the day-to-day news and commentary that flood the markets, and it changes over time, which is why looking at the market over the past year or two is of only limited value to assess this risk going forward. Discovering the nature of material risk is the root problem we need to solve.

Catalysts for Material Risks

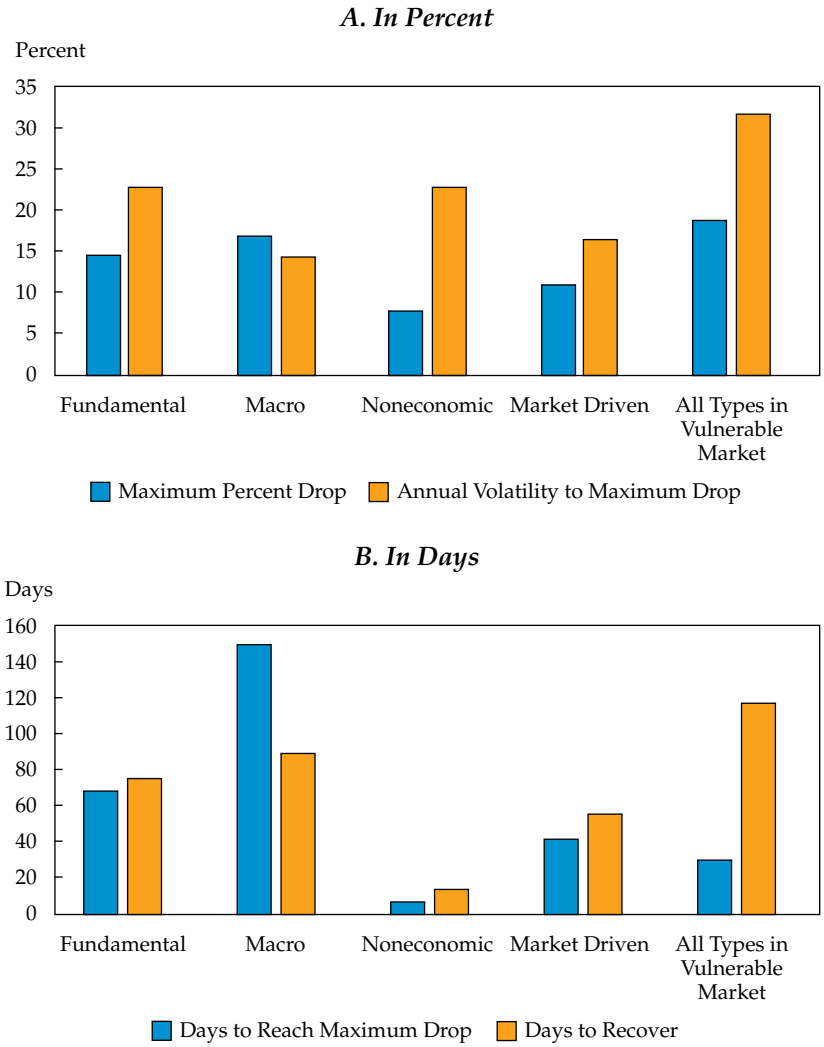
To provide some context for material risk, we need to take a broad sweep and consider the market over the 85 years since the Great Depression and the different types of events that can be catalysts for material risk. These are fundamental events marked by the recasting of earnings and perceptions of value; market-driven, microstructure events (such as leverage and liquidity cascades); macroeconomic events (such as inflation and stagflation, recessions, tight money, or rising rates); and extraeconomic events (such as geopolitical disruptions).

Exhibit 1 provides an overview of these types of events spanning the post–Great Depression period.

EXHIBIT 1. LIST OF SOME MATERIAL MARKET EVENTS POST-WW II

Year	Event
	Fundamental
1946	Reassessment of post–World War II spending
1962	Change in investor sentiment with the flash crash
2001	End of "irrational exuberance"
2010	Credit stresses and Black Monday
	Macro
1948	Recession
1957	Negative earnings and Eisenhower recession
1973	Oil crisis and stagflation
2008	Financial crisis
2018	Fed rate rises
	Noneconomic
1950	North Korea invades South Korea
1962	Cuban missile crisis
2001	September 11 attack
2020	Covid-19 pandemic
	Market-Driven
1970	Tech stock crash
1987	Market crash from forced selling
1994	Bond market crisis and leverage effect
2014	"Flash crash" in US Treasuries

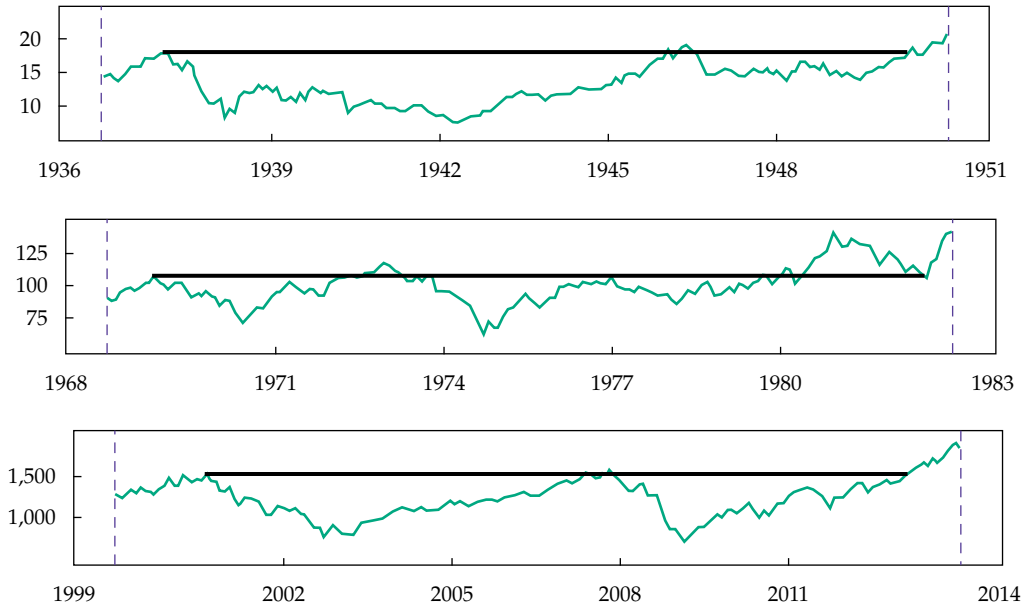
EXHIBIT 2. EVENT DROP STATISTICS



We can see notable differences in how these types of events affect the market. Not surprisingly, noneconomic events trigger the quickest path to the bottom and recovery and have the most shallow bottom, followed by market-driven events and then by fundamental events. As would be expected, macro events have the longest paths and take the deepest course. Generally speaking, the depth of the scenario is greater with the longer the time it takes to reach the bottom. **Exhibit 2** summarizes the behavior of each of these events and is drawn from more than 40 events during the post-Depression period. The right-most set of bars also includes a summary of events during periods of market vulnerability, a topic I will discuss shortly.

As the top panel of Exhibit 2 shows, macro events on average have the largest drop, followed by fundamental and market-driven events.

EXHIBIT 3. THREE LOST DECADES OF THE S&P 500



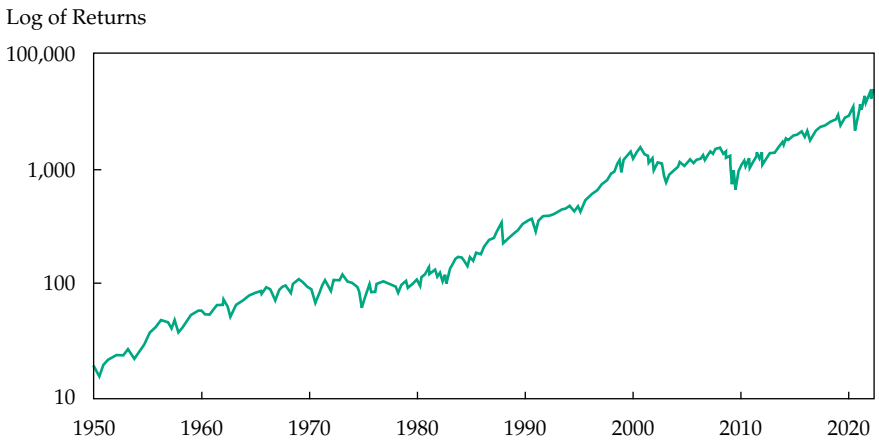
Noneconomic events on average have the smallest drops but have high volatility over the course of the drop. As is shown in the bottom panel, macro events not only tend to have the largest drop but also typically take the longest time to reach the minimum and the longest time to recover as well. At the other extreme, noneconomic events tend to have a very short period of time down and back up. The Covid-19 pandemic is a good example of this; although it was a severe event, it transpired quickly. On average, the maximum percent drop is not notably different among the fundamental, macro, and market-driven events.

Since 1936, there have been equity market declines of 30% or worse every 15 years on average. More significant for individuals, there have been three instances of a "lost decade" in which the market ended a 10-year or greater period at or below where it stood at the beginning of the period. In **Exhibit 3**, the dotted vertical lines in black represent the beginning and end of each of these periods. So, for example, an investor holding the S&P 500 in 1982 can look back 14 years to 1968 and see that the value of their portfolio remained the same over that period.

Yet, just as important as the possibility of lost decades is the stability of equity returns in the very long term. The market has grown at a remarkably stable rate of between 7% and 8% per year, as shown in **Exhibit 4**, which is presented in log scale. This leads to using an actuarial rate for pensions that is typically between 7% and 8% and is critical from a risk standpoint for those who are looking out decades in their goals and financial plans. Indeed, such a trend exists even if we push back to the 1800s, albeit with limited and less representative data.[2]

[2]The remarkable long-term stability of returns of the US equity market going back to the 1800s is presented in W. Goetzmann, R. Ibbotson, and L. Peng, "A New Historical Database for the NYSE 1815 to 1925: Performance and

EXHIBIT 4. LONG-TERM S&P 500 RETURNS



Given that a reasonable expectation is an annual return from equities of 7% to 8%, a long flat period as in the three lost decades is more of a financial planning problem than it might seem, because on that basis, the investor is down more than 50% from expectations. Even with a time horizon of 20 years, the lost decade has a significant effect on goals.

The critical aspects of the market reality for individuals' portfolio risk are as follows.

1. Most of the daily news cycle and day-to-day market variability is noise that largely can be ignored, along with the risk models that are focused on it.
2. In the short term, risk is greater than it might appear if assuming a Gaussian distribution (e.g., the fat tails we grapple with in short-term risk management).
3. In the medium term, there are not only material risks but also the possibility of lost decades.
4. In the long term, risk dissipates and we have a remarkably steady trend.

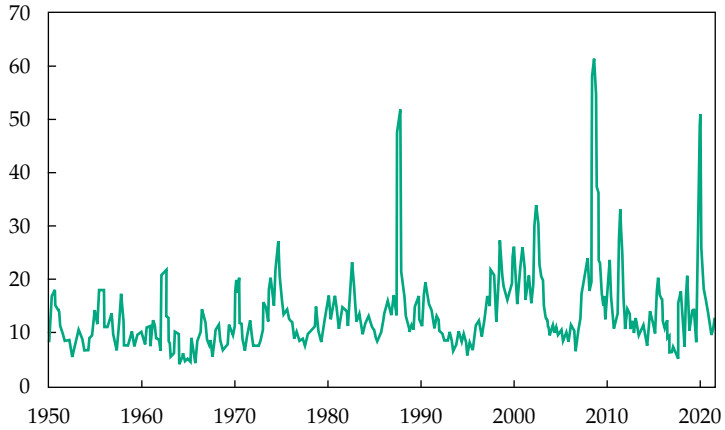
Conventional risk management accounts for only the first of these four aspects.

Material versus Day-to-Day Risk

The contrast between material risk and day-to-day risk is illustrated in **Exhibit 5**, which shows the 100-day volatility of the S&P 500 from 1936 to 2022. Interspersed among the "background radiation" level of volatility of about 12% per year are periods of high volatility that pop up decade by decade: stagflation and the oil shock in the 1970s; the October 19 market break in 1987; the Asia crisis and implosion of Long-Term Capital Management in the late 1990s, which warmed up for the trifecta of the Internet bubble, deflation of irrational exuberance, and earnings scandals of the early 2000s; and then the 2008 financial crisis followed by European credit aftershocks. (The combination of these latter events in this litany, one after the other, is what led to one of the lost decades.) And, of course, another example of this volatility is the violent whipsaw from Covid-19 beginning in March 2020.

Predictability," *Journal of Financial Markets* 4, no. 1 (2001): 1–32, https://www.sciencedirect.com/science/article/abs/pii/S1386418100000136.

EXHIBIT 5. 100-DAY ROLLING VOLATILITY OF THE S&P 500



In terms of market risk, we have two types of volatility. The background level comes from the standard uncertainty surrounding such things as earnings expectations, the economic cycle, and related Fed policy. The occasional bursts come from leverage-liquidity cascades, the return to earth from times of "irrational exuberance," the periods of collapse in credit and economic cycles, and other such events. The first case can be thought of as a period of low vulnerability in the market, and the second case can be thought of as the manifestation of high vulnerability coupled with adverse events.

When it comes to material risk, the current methods of risk management do not account for the realities of the market, especially when they are vulnerable. When the market is vulnerable and an adverse event occurs, markets drop quickly. For the S&P 500, market drops of 30% or more take place over the course of two years or less. By comparison, for standard risk methods, which employ geometric Brownian motion (GBM), on average, such drops take place over the course of four years.[3] Furthermore, the path of market prices is asymmetric; markets tend to fall quickly with the recovery taking longer, whereas for the geometric Brownian motion (GBM) in most risk models, the path down and back up is symmetric. So we find that a systematic flaw in the risk models is being used to evaluate individuals' investment portfolios: assets erode in value more quickly than what is suggested by traditional models, and they take comparatively longer to recover. That longer recovery has real-life implications, especially for investors whose financial plans tend to be centered around achieving distinct goals at discrete periods in time.

Ironically, at the same time that current methods underestimate material risk in the market, they overestimate the long-term risk. In the very long term, returns don't dive to zero, nor do they go into outer space. A mechanism of mean reversion is at play. Yet, extend out the standard methods, which assume risk grows with the square root of time, and you end up with truly fantastic possibilities. Looking out 50 years—a

[3]For Wiener processes, the frequency and distribution of times to reach a particular drop level can be found in D. Landriault, B. Li, and H. Zhang, "On the Frequency of Drawdowns for Brownian Motion Processes," *Journal of Applied Probability* 52, no. 1 (2015): 191–208.

time period that matters to someone currently in their 20s—the chance that an initial investment of $10,000 will turn into $1,300,000 is 5%. At the same time, the chance that the investment turns into just $90,000 is also 5%. Compare that range of outcomes with the long-term stability of returns for the S&P 500 shown in Exhibit 4.

MEASURING MATERIAL RISK: AGENT-BASED MODELS

We need to take a new approach to risk to deal with these market realities: one that works for those with a long-term horizon. The methods to do this have only recently been gaining traction in finance. They are based on agent-based models (ABMs).

ABMs have been employed successfully to model many different kinds of phenomena within economics and finance. The Bank of England, for example, uses an ABM to stress-test the country's banking system. The ABM approach has proven to be useful in unraveling the dynamics that played out in the interbank market during the 2008 financial crisis, a task canonical models of banking were ill-equipped to do.[4] Similarly, the cycles of leveraging/deleveraging and the cyclical nature of debt dynamics have been well captured through ABMs, as have the intraday liquidity dynamics of the limit-order book.

An ABM can look at the actual structure of the market and the actual institutions that operate in it. These institutions comprise the agents of the model. As in the actual market, they are heterogeneous—they vary in terms of their time frames for investing and acting in the market, the level of risk they are willing to take, and the strategies they employ. Agents in this context may include, for example, Wall Street market makers in high-yield bonds who stop answering their phone when the credit markets crack, hedge funds whose investor liquidity terms are mismatched to the liquidity of the assets they own, or individuals who may have piled much of their net worth into cryptocurrencies or nonfungible tokens.

Each agent observes the market environment and takes action based on its particular heuristics. True to the heterogeneous nature of agents in the market, heuristics can vary from one agent to the next. No single set of rules or universal optimization program dictates what the agent will observe and how it will act.

Agents' actions change the market environment, most notably asset prices and portfolio holdings. The cycle moves from observing the market to taking action and to thereby altering the market environment. The feedback loop between agents' actions and the movement in the markets generates a complex dynamic system that can display emergent phenomena where the actions of individual agents can lead to surprising effects that are not evident through a simple, linear aggregation of their actions.

At their core, ABMs explain the behavior of a system by simulating the individual constituent agents that take actions in that system and how these agents interact with each other and with their environment. When building an ABM, these interactions are distilled into a set of rules called heuristics that capture how agents react to changes in the system. Thus, ABMs take a bottom-up approach in which simulating the individual agents' interactions leads

[4]An agent-based model developed for the US Treasury to assess the dynamics of financial crises is presented in R. Bookstaber, M. Paddrik, and B. Tivnan. "An Agent-Based Model for Financial Vulnerability," *Journal of Economic Interaction and Coordination* 13, no. 2 (2018): 433–466.

to an understanding of the emergent dynamics of the system itself.[5]

ABMs and Behavioral Characteristics

Defining the agents and their behavioral characteristics is the most critical task in designing an ABM. The choice of agents and their heuristics is determined by the system we are trying to understand. An ABM can be complex and granular, modeling every individual agent operating within a system in great detail, or agents within an ABM can be understood at a more granular level. The art of developing an ABM is determining the level of abstraction to take, trading off complexity with transparency while still giving an accurate representation of the agents operating in the real world. The key goal is to closely reflect reality. For financial applications, that means the actual institutions, markets, and investor strategies and behavior. This goal is in contrast to current, standard approaches, which skirt most market realities and attempt to be so general and abstract as to work for a market we might find on Mars.

The most studied ABM in the finance literature is the two-type model, called this because it employs only two types of agents. Surveys and other empirical studies suggest that two basic trading styles are present among financial actors. The first is the fundamentalist type of agent, which stabilizes the markets and produces mean-reverting behavior. The second broad category of financial agents are the chartists or trend-followers who are responsible for the establishment of short- and long-term trends in the markets.

Of course, there are more than two investment strategies. As we move from academics to practice, other strategies and behaviors need to be taken into account to capture the dynamics of the markets, especially in times of crisis. One such agent type is the leverage agent. The leverage agent, as the name suggests, is representative of different financial agents' sensitivity to leverage in the market. These agents can be forced to liquidate their positions because of margin calls. Another is the market-making agent, which sets prices based on net inventory. Finally, a noise agent represents other strategies, such as volatility targeting, that are not modeled explicitly. These five agent types provide enough richness in the model to reproduce the important characteristics of the markets crucial for understanding the nature of forward-looking risk.[6]

With the agents and their heuristics in place, the operation of an ABM can be summed up as the following four steps:

1. Each agent observes the market price and makes buy/sell decisions based on its heuristic.
2. These decisions lead to interactions with other agents.
3. This changes the market environment, most notably, asset prices.
4. Observing the new information and updated asset prices, each agent follows its heuristic to make another round of decisions.

[5]A recent survey of agent-based models and their application in economic and finance is presented in M. Steinbacher et al., "Advances in the Agent-Based Modeling of Economic and Social Behavior," *SN Business and Economics* 1 (2021). https://doi.org/10.1007/s43546-021-00103-3.

[6]Passive investors, although a large part of the equity market, are not included as an agent because they do not react to prices. Rather, they affect liquidity by effectively reducing the float—the percent of assets available to meet liquidity demand—and they add to noise because of their idiosyncratic liquidity needs.

ABMs and Market Reality

Agents' heuristics are a function of multiple parameters, such as their risk tolerance, their levels of leverage, and how quickly they respond to market conditions. These agent parameters along with other model parameters determine the parameter space of the model that needs to be calibrated and estimated. The starting point for calibration is to have the model closely match the statistical moments of the market—that is, the volatility (as measured by the standard deviation), skew, and kurtosis. A model founded on GBM will not be a faithful representation of market dynamics because the returns follow a Gaussian distribution that has no skew and zero excess kurtosis, whereas equities have fatter tails than a Gaussian distribution and a negative skew.[7] If only fit to these three moments, the model is overspecified; that is, it has more parameters than the values to be fit, so other market characteristics also are considered that capture the dynamics of the markets. One well-documented dynamic is volatility clustering. The volatility of the markets is not fixed in time, and, as one might intuit, periods of high volatility tend to be followed by more periods of high volatility. Along with skew and fat tails, this is another facet of the markets that is not taken into account by models founded on a Gaussian distribution.

Exhibit 6 shows volatility clustering for the S&P 500. Periods of large returns—whether positive or negative—are clustered with other large returns. In the second panel of Exhibit 6, we show a simulation from an ABM like that described earlier. We observe that the return time series produced by the ABM also contains clusters of high and low volatility, with amplitudes of the high-volatility periods similar to those observed for the S&P 500. By comparison, as seen in the bottom panel of Exhibit 6, no such clustering occurs for the GBM process, which reflects the results that obtain for the standard methods based on draws from a normal distribution.

As a final comparison, in **Exhibit 7**, we show how the 100-day rolling volatility of the S&P 500 compares with that of an ABM.

We observed earlier in Exhibit 5 that there is a background level of volatility of the S&P 500 of around 12% with occasional spikes. Once again, we observe a remarkable similarity between the actual S&P 500 and the output for one simulation of the ABM. The bottom panel shows the rolling volatility for GBM, which represents the picture for the standard method that draws from a normal distribution. This clearly misses the point when it comes to reflecting the nature of market volatility.

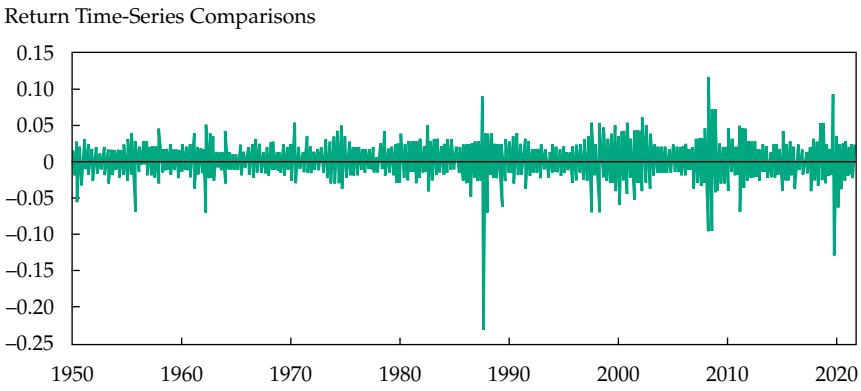
UNCOVERING MATERIAL RISKS: BUILDING SCENARIOS FOR LONG-TERM RISK MANAGEMENT

Scenarios are the key tool when we think of risk as a "what-if" exercise, when we look at a future that is distinctly not like the past. Scenarios are a way of positing the material risks that come from the combined effect of events and market vulnerability and that can propagate across the markets. Once we have employed an ABM as a method for dealing with the realities of the market, including the potential for cascades and contagion, we are in a position to develop market scenarios.

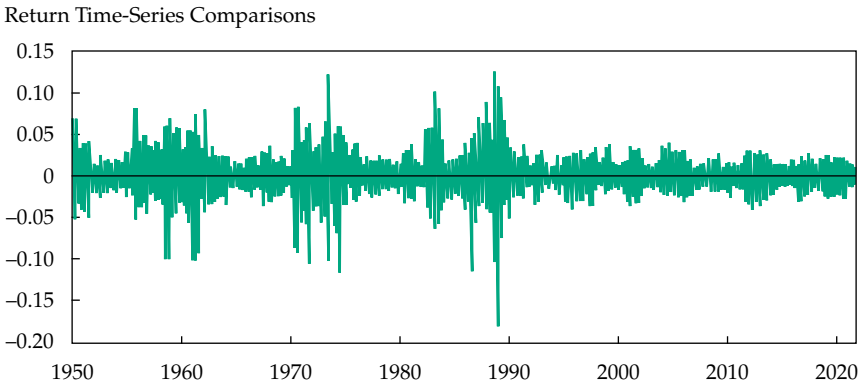
[7]A detailed analysis of what are called stylized facts for equity markets, such as fat tails and heteroskedastic volatility, can be found in T. Lux, "Stochastic Behavioral Asset-Pricing Models and the Stylized Facts," chapter 3 in *Handbook of Financial Markets: Dynamics and Evolution*, edited by Thorsten Hens and Klaus Reiner Schenk-Hoppé (London: North-Holland, 2009), 161–215, https://www.sciencedirect.com/science/article/pii/B9780123742582500075.

EXHIBIT 6. VOLATILITY CLUSTERING: RETURN TIME-SERIES COMPARISON

A. S&P 500 since 1950



B. Sample Run from Agent-Based Model



C. Sample Run from Geometric Brownian Motion

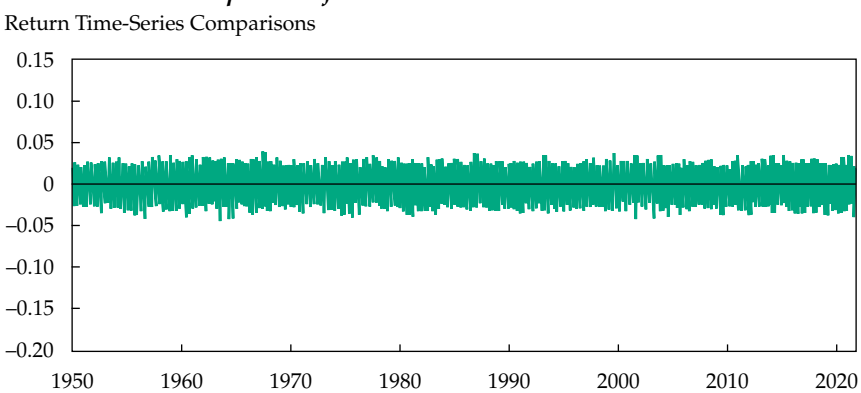
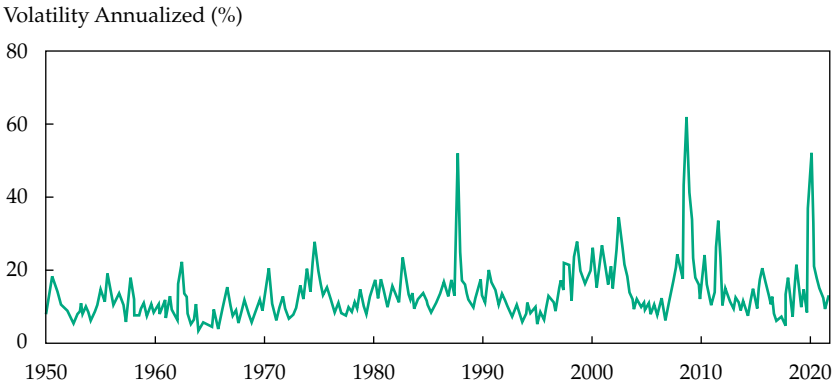
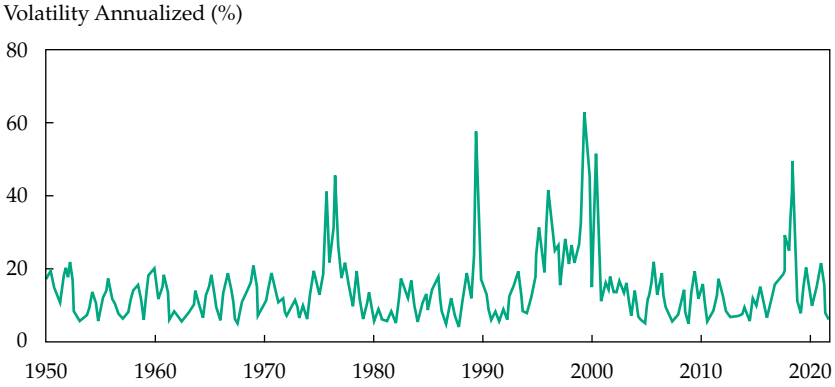


EXHIBIT 7. VOLATILITY COMPARISONS: 100-DAY ROLLING VOLATILITY ANNUALIZED

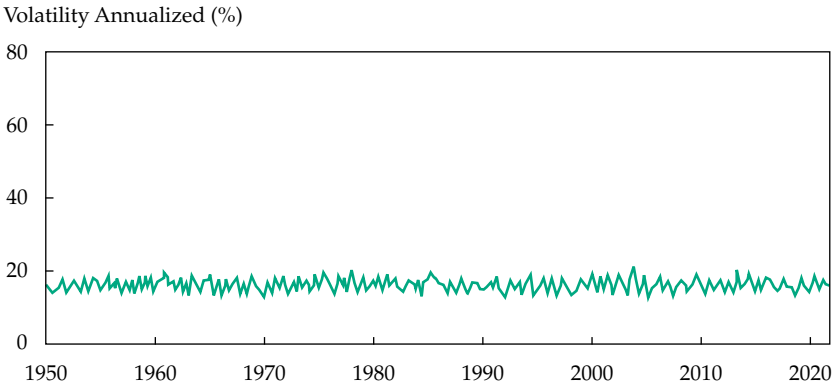
A. S&P 500 since 1950



B. Sample Run from Agent-Based Model



C. Sample Run from Geometric Brownian Motion



Components of a Well-Specified Scenario

A scenario is dynamic and multidimensional. A well-specified scenario, one that is open for a narrative, has three components.

First, there is a proposed event. Some events occur without warning, but most events of material import do not come out of nowhere. We do not know if they will occur or even have a good read on the probability they will occur—that is why they are risks—but markets that are overheated and laden with "irrational exuberance," periods of overstretched credit, and looming recessions are there to be seen. It is not as if we have dozens of scenarios to track. At any time, only a handful are of material concern. Indeed, a risk management approach that lists and follows dozens of scenarios is not of much value; it is like having a risk manager who comes into the morning meeting with the pronouncement: "Be careful; anything might happen."

A cloud of uncertainty not only hangs over the likelihood that the event will occur but also surrounds the impact the event might have on the market. The consequent market movement is uncertain and will vary based on the vulnerability of the market. Without understanding the market environment, we can't get a good read on the market implications of a scenario. For example, if there is more leverage or concentration in the market than in the past or if liquidity is strained, the market will be more vulnerable. Leverage will amplify any need to sell, concentration will lead more investors to run for the door, and illiquidity will crimp the exit.

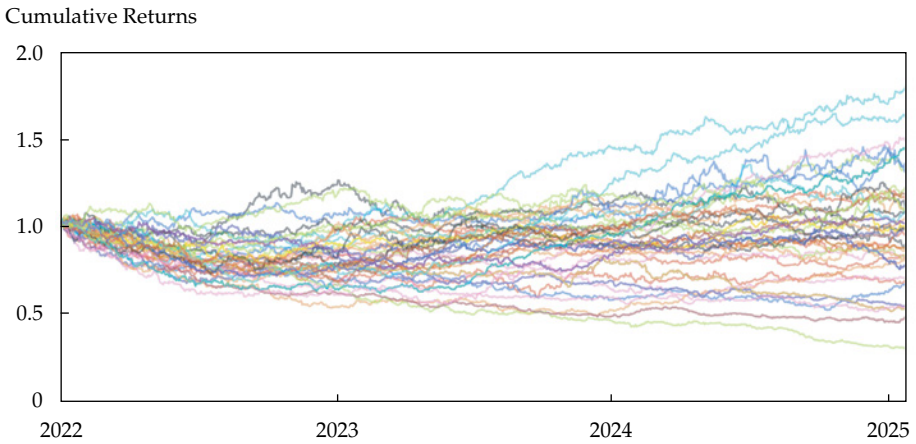
Second, a scenario does not affect the market uniformly. Depending on what occurs, different parts of the market will bear the brunt of the effect. To understand how a specific portfolio will evolve under a scenario, we must look at the underlying risk factors. For example, consider inflation. Companies with high leverage will be at high risk because many may need to refinance at a higher interest rate. Smaller companies will be at higher risk because they tend to have less bargaining power to pass on their rising costs. And some sectors will have a more entrenched cost structure than others.

This illustrates the value of using a factor-based approach. Risk factors are the building blocks of risk, so they give an intuitive sense of where risks are coming from and are valuable vocabulary for building a risk narrative. By looking at the factor weights across a portfolio's assets, we can see which risks thread through the portfolio. Also, the relationship across risk factors, such as correlation, is more stable than for the assets.

Third, the scenario does not occur in one fell swoop. It follows a course over time: the time to the bottom and the time to the recovery. The scenario can have a range of possible responses over time. A representation of a scenario that embodies these points is shown in **Exhibit 8** for an inflation scenario on US equities, with the paths generated using an ABM along the lines of the one described previously. Many paths, some with sizable drops, can reflect the event occurring during a period of vulnerability, with others skimming closer to the surface. Some paths recover quickly, whereas others linger. Compare this with the standard approach to scenarios, which asserts a fixed drop, with no sense of uncertainty around that drop and no representation of the time to the drop and recovery.

Also important is that a scenario is going to add vulnerability to the market, and thus subsequent events will have a greater impact. This is reminiscent of the TV medical series *House*, in which a patient comes in with one problem and over time—usually just before each commercial

EXHIBIT 8. INFLATION SCENARIO PATHS



break—the initial malady leads to a string of complications.

Scenarios and Long-Term Risk Management

Scenarios are the key tool for understanding and preparing for material risks. A key risk objective in developing scenarios is to be armed in terms of expectations and planned responses and approach the inevitable disruptions with the perspective of, "Yeah, I've seen this movie before; I know what to do," rather than overreacting to events in the moment. Building and rehearsing scenarios is a what-if exercise that moves risk management beyond the frame of the everyday ups and downs of the market and into the realm of material risk.

Scenarios are more than numbers; they are narratives of how things might unfold, how they might progress over time, with the host of uncertainties and market effects. These scenarios are needed to provide a personalized discussion based on the client's interest and financial expertise and on the specifics of their portfolio, risk tolerance, and risk capacity, as well as about where they currently are in achieving their financial goals. This means looking at scenarios in the context of how long they might take to resolve, what parts of the markets will be most affected, and how bad (or good) the scenario might be.

To understand how a scenario is a narrative, think of it like a novel, a story that drives forward with twists and turns. A scenario has an opening chapter with the event that gets the action going; it has the current market environment as its setting. It has a main character that threads itself through the story plotline, tracing the path of the relevant markets as the scenario gathers force and then dissipates. And just as in novels, potential negative scenarios rest within various themes. These themes might be driven by overstretched fundamentals, by market forces of leverage and illiquidity, by the macro cycles of recession, and by noneconomic shocks, such as geopolitical instability.

For the individual, these scenarios are an exercise in "forewarned is forearmed." They allow for a mental rehearsal of the ebbs and flows of

investment markets, a "pre-mortem" of material events that might occur and how these events could affect their portfolio. Consequently, they reveal how these events could affect attaining their goals, which can engage the client's decision making to overcome an emotional response during the actual event.

Market Vulnerability

A scenario is a combination of an event and the market's vulnerability to that event. So, without understanding the market environment, we can't get a good read on the market implications of a scenario. Thus, once we have determined the type of scenario, we need to put it into our current market context. We need to adjust it for the current market reality.

Unfortunately, all of the approaches that have been available to individual investors for risk measurement use historical returns. They calculate the standard deviation of returns over the past year or two and use some variant of that as the measure of risk. Some of these calculations can be quite sophisticated, but the fact is that no matter how much you try to spruce things up, you still are using historical returns and your assessment of risk will be useful only insofar as the future is reflected in the past. When risk is the dominating concern, it usually is precisely because markets are not following past patterns. As a result, these methods are at their worst when it matters the most.

The obvious remedy for this shortcoming is to look at the market now rather than in the past—that is, to include current market data in the development of scenarios. I find four types of data to be most relevant: leverage, illiquidity, concentration, and credit conditions. Leverage forces selling. Illiquidity leads prices to move with that selling. Concentration means enough people are selling for it to matter. Credit conditions determine the robustness of the market to backstop the ensuing cycle of cascades and contagion.

The interplay of these types of data is similar to the interactions that compound fire risk for a nightclub. The leverage is how fast the fire will move—the flammability of the building. The illiquidity is the size of egress—how fast people can get out. Concentration is the crowding of the nightclub—the number of people who have to get out. Credit conditions perhaps best fit into the analogy as a measure of the discipline and resolve of those within the building as well as those fighting the fire.

Assessing the vulnerability of the market is critical for getting a good read on the path of a scenario. In the historical analysis summarized in Exhibit 2, the speed of the drop to the bottom is nearly twice as fast, the time to recover is nearly twice as long, and the market is twice as volatile over the course of the path down when vulnerability is high compared with times when the market is not vulnerable. The catalytic event is the "if such-and-such happens," and the scenario is the "then what?" A scenario describes how the aftershocks, the dynamics of a given event, will unfold in each of the relevant assets and risk factors. Usually at the top of the list are those with exposure to equities, credit, and rates.

A scenario is dynamic; it has a story line. So we can't describe it with just one number. "US equities might drop 20%" is not a scenario. At a minimum, we have to realize that a scenario has a dimension in time as well as in price. It has a path with a start, a bottom, and a recovery. One way to show this is using a simulation that generates various paths in the face of the scenario, such as those depicted in Exhibit 8. Each path has a particular time from the start to its minimum and from its minimum to recovery and has a level of volatility that typically will differ from the period before the scenario.

FROM KNIFE TO SCISSOR: ADDING THE PERSONAL EDGE TO FINANCIAL RISK

Even with improvements to risk modeling that can deal with the market realities of long-term risk, trying to apply standard risk management methods to the risk problem of an individual is like bringing a knife to a scissor fight. Risk issues for portfolios have one edge, returns. Those for an individual add another edge, personal goals. As with a pair of scissors, these edges interact; the individual's goals will be affected by the market's effects on their portfolio, and the structure of the portfolio might be changed in turn. To make matters more complicated, financial planning is not static or one dimensional. People's priorities change, as do their time frames, as do the risks they are willing to take in life. Thus, we look at risk within a goals-based approach to investing, in which market risk is viewed in the context of an individual's time horizon and objectives.

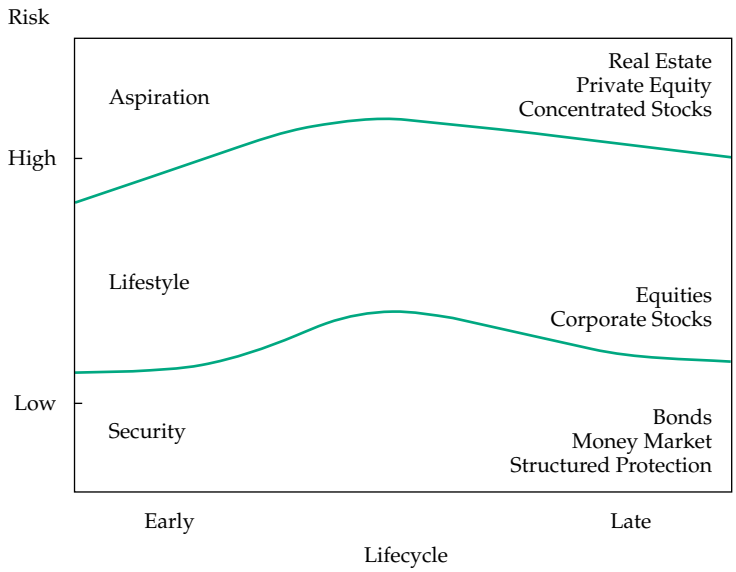
One way to look at goals-based investing is a financial take on Maslow's hierarchy of needs. The bottom rung is owning investments that are a bulwark against deprivation, against being thrown out on the street—perhaps metaphorically, perhaps literally. With this concern satisfied, individuals hope to have the investments to maintain their lifestyle. As they go farther up the rungs of the ladder, they might pursue more ambitious objectives, "self-actualizing" goals, such as having a second home, retiring early, or having the resources to provide generous support for children or charities. So we have financial needs—and thus financial risk—associated with security, lifestyle, and aspirations.[8]

These come with varying time frames. Meeting next month's mortgage payment is not only a high priority but also requires thinking for the very short term, while an objective like "I want to live at least at my current standard of living when I retire 20 years from now" can be contemplated and planned only from a distance. Investment choices and their related risk characteristics also change with the investment horizon. Markets can move violently in the short term, but in the long term, capital market assumptions become an increasingly reliable guide for expectations. So, the time horizon determines which risks can be considered noise and which are material. For goals that are very far off, most market dislocations can be bypassed without taking action. For goals that are not quite so far away, the prospects of a lost decade may be an issue. And for goals that are short term, any material risk will be a concern.

Also, the difference in investment risk can become stark as an individual moves from the lower to higher rungs. The security rung will be oriented toward bonds with low risk and high liquidity, the lifestyle rung will be oriented by a standard bond/equity mix, and the aspirational rung will be oriented by high risk and low liquidity through such alternatives as private equity, real estate, and hedge funds or through concentrated and possibly levered stock positions.

[8]There are any number of ways to categorize and type goals and to map assets accordingly. The approach presented here is detailed in A. B. Chhabra, "Beyond Markowitz: A Comprehensive Wealth Allocation Framework for Individual Investors," *Journal of Wealth Management* 7, no. 4 (2005): 8–34. Other presentations of goal-based investing include J. L. Brunel, *Goals-Based Wealth Management: An Integrated and Practical Approach to Changing the Structure of Wealth Advisory Practices* (New York: Wiley, 2015); S. Das, H. Markowitz, J. Scheid, and M. Statman, "Portfolio Optimization with Mental Accounts," *Journal of Financial and Quantitative Analysis* 45, no. 2 (2010): 311–334; and D. Nevins, "Goals-Based Investing: Integrating Traditional and Behavioral Finance," *Journal of Wealth Management* 6, no. 4 (2004): 8–23.

EXHIBIT 9. ALLOCATION BUCKETS



Breaking up risks in this way suggests a target portfolio distribution that is a departure from the symmetric, bell-shaped normal distribution usually assumed for risk analysis. For security, the individual will dampen the downside tail to buttress against big losses, while aspirational gains will extend the upside tail. The downside tail is skinnier and the upside tail is fatter than with a Gaussian process.

These rungs do not have clear lines of demarcation, changes for investment choices over time are likely to be gradual, and considerations will vary from one individual to the next.

Understanding the Path of Priorities

Consider the path projected for Cynthia, a 32-year-old single parent with two grammar-school-age children. Cynthia works as a graphic designer making $150,000 a year with good job security, health benefits, and a steady path for earnings increases. Security is top of her list; she is laser focused on maintaining financial stability and having her children go to the college of their choosing without needing student loans. In terms of lifestyle, she is happy to raise her children in her current apartment, and she describes herself as having a dinner-and-a-movie lifestyle, spending time with friends and taking a few trips each year with her kids to go hiking in Utah or sharing a beach house with another family in the Carolinas. As for aspirations, when pressed to look out to her empty nest years, to her 50s and beyond, her ideal is to gradually move to working part time and to have a second home in the Rocky Mountains where she can spend her free time hiking, skiing, and gardening.

Exhibit 9 shows Cynthia's relative allocation to security, lifestyle, and aspirations over the course of her life, from the early period—from now to her early 40s—and extending to the late period of her life, postretirement. The area

under the lower of the two lines is the amount of allocation to the security bucket. A relatively large baseline of her investments are in this lower-risk bucket to fill in her security needs. The area under the line drops over time because her allocation for security diminishes with expected portfolio growth and with reduced security needs once her children are done with college and she needs to account only for her own expenses. In the meantime, her allocation to the lifestyle bucket, which is the area between the two lines, rises. Once her lifestyle concerns are met for her relatively modest needs, the aspiration portion—the area above the top line—rises, along with the portfolio's risk.

Cynthia's path does not conform to the standard approach of taking higher risk early on and then increasing bond allocation in later years (e.g., target date funds), because her security bucket remains fairly constant. With security dealt with, Cynthia can allocate more aggressively for lifestyle and aspirational goals. This is a snapshot for the current time based on one path of future market behavior, typically using the actuarial capital market assumptions. If life events or the markets take an unexpected turn, the picture will change. In an agent-based simulation, the various paths will be represented to give a sense of the risk not only of her portfolio but also of each of these buckets related to her financial objectives. This path of priorities over time is a key difference in the investment choices of individuals and other asset owners more generally as opposed to institutions.[9] As an individual ages, their time frames change. And with that, objectives that were once uncertain move into focus. The individual's time frame also changes as they come to points of consumption along life's path. A material market event will matter for someone who is about to fund their child's college, even though retirement is well down the road. And the scissors bring with it another dimension for correlation. So, to the correlation between assets, add the correlation between the market and personal events—for example, market downturns may be accompanied by one's retirement date being involuntarily pushed forward.

Putting these dimensions into practical portfolio choices helps an individual investor understand the rationale of the resulting portfolio, engage with their adviser on specifics, and have confidence in the process and the likelihood of results. Whether following this Maslow-like approach or another, this perspective for an individual's risk argues against a black-box exercise operating in abstractions, such as risk tolerance. There are multiple dimensions to risk, with those dimensions all extending on a path over time. Thus, the notion of putting risk into a single number, such as value at risk, will miss the essentials of the personal side of risk, how it maps into portfolio decisions, and how portfolio risk feeds back into the individual's financial planning.

Adding Personal Risk into the Risk Structure with ABMs

Just as the markets have dynamics, the individual does as well. The feedback from the market to the individual in a model adds the individual into the mix. Although an individual's actions have little feedback into the market, similar actions across many individuals will.

And just as the market features multiple strategies and agent types, each with separate heuristics, so too do individuals. Indeed, just as

[9]During my tenure as the chief risk officer at the University of California, we essentially had two rungs: a "lifestyle" rung by acting as agent for pensioners and a "security" rung of maintaining a reserve for any bumps in the road in the university's operating expenses.

one institution can have a mix of strategies, expressed through its range of portfolio managers or traders, an individual's heuristic can be multilayered as they work through the implication of the market for the various rungs of their goals.[10] Thus, an ABM provides a natural structure for adding the components of personal risk into the overall risk management process and portfolio rebalancing. Individuals and other asset owners can be treated as agents in the ABM, with their heuristics encompassing their investment decisions.

CONCLUSION

With its exclusive focus on short-term portfolio risk of financial institutions, risk management has pushed individuals and other asset owners to the side. The demands of risk management for these market participants not only are different from those of financial institutions but also are, in fact, more complex. They reside in a multidimensional world. They face periods of vulnerability coupled with events that lead to material risks that are not informed by recent market history and that might manifest over a longer time horizon. They are bound up with the shifting menu of an individual's goals, which change with life circumstances as well as with the ups and downs of their portfolio.

These multidimensional dynamics point to the limitations of portfolio optimization and the perfunctory questionnaires about risk tolerance completed at the beginning of an advisory engagement and then filed away. Suspicion of optimization methods among practitioners is widespread, and for good reason. Optimizing based on the historical market conditions and an individual's personal situation is not going to work if the future is not like the present. If correlations change, if the market moves into a new regime, or if the individual changes direction, the optimization will fail. Risk tolerance measures also will fail because an individual is looking at risk across a range of objectives, from security to lifestyle to aspirations, and all of these will change over time with personal circumstances and market effects. That is why advisers cannot approach risk management as a "set it and forget it" exercise. Decisions now should recognize the inevitability of midcourse corrections as the individual travels along their path.

How do we look at risk for those with a long time frame, be it a decade, a generation, or a lifetime? We use forward-looking models that reflect market dynamics and depict the interaction between market vulnerability and events. We represent the multidimensional nature of resulting scenarios. We focus on both edges of risk facing the individual—that is, the market and the personal.

All of this requires a fresh mindset and new tools. The approach I propose is the technology of ABMs. These models can incorporate the current market environment, project forward risk, and employ scenarios by incorporating market dynamics. Because the individuals can be incorporated as agents with their own heuristics, these models embrace both the market and the individual, thereby providing a framework that is best suited to the long-term investor's decisions and goals.

[10]There is strong evidence that people use heuristics for decision making that are coarse (i.e., that avoid fine-tuning and ignore information) and adaptive, in contrast to the notions of rational decision making in the finance and economics literature. The simple approach of risk surveys misses many aspects of these heuristics. A survey of heuristics is presented in G. Gigerenzer and W. Gaissmaier, "Heuristic Decision-Making," *Annual Review of Psychology* 62 (2011): 451–482, https://www.annualreviews.org/doi/10.1146/annurev-psych-120709-145346.

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