PGIM FIXED INCOME

PERSPECTIVES

October 2017

Can We Predict the Next Market Crash?

Arvind Rajan, PhD
Managing Director,
Head of Global
and Macro

Although the Global Financial Crisis (GFC) of 2008 is almost a decade behind us, its ghost continues to haunt the investment landscape, particularly as risk markets reach new highs. For those searching for signs of the next crisis, the bricks in their wall of worry include, amongst others, high debt levels, tighter central bank policies, a hard landing in China, and heightened geopolitical uncertainty.

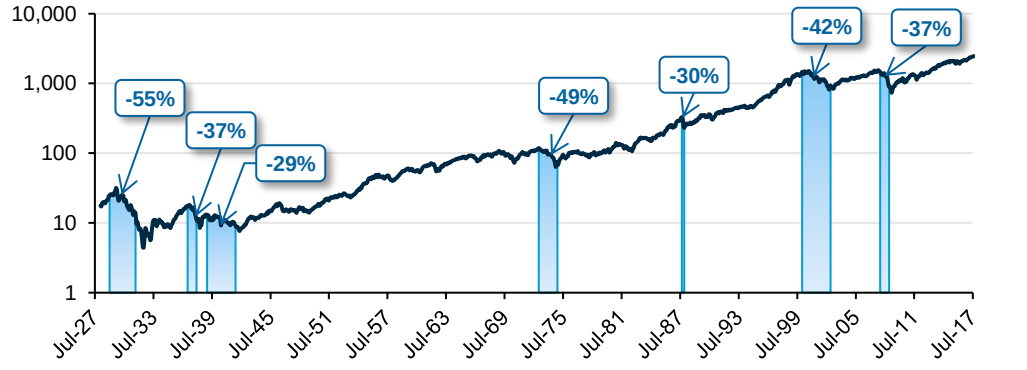
But how likely is it that the next crash can be predicted? In this paper, we examine the research on market crash predictors and macroeconomic early warning systems. We also place them in the context of major risks to the market that we see today.

Our conclusion? While models may sometimes offer insights into overvalued markets as well as help policymakers and investors by highlighting macroeconomic distortions, we argue that the ability to identify specific precursors to the next crisis or to reliably predict a market crash remains out of reach. We illustrate why even the best historically-based predictors would have trouble capturing the vulnerabilities of today's unique macroeconomic and market ecosystem. Therefore, a more practical way of preparing for the next crisis probably lies in scenario analysis and stress testing rather than attempting to predict the next market crash. Finally, when models don't work, the task of crisis anticipation—and avoidance—must fall on the shoulders of active portfolio and risk managers as well as policy makers.

"…Efficient markets theory may lead to drastically incorrect interpretations of events such as major stock market bubbles." —Robert Shiller[1]

"(Behaviorists) define a 'bubble' as an irrational strong price increase that implies a predictable strong decline. But the available research provides no reliable evidence that price declines are ever predictable."— Eugene Fama[2]

FIGURE 1: U.S. STOCK MARKET PRICE DROPS GREATER THAN 25%



Source: PGIM Fixed Income as of August 2017.

[1] *"From Efficient Markets Theory to Behavioral Finance", Robert J. Shiller, Cowles Foundation paper No. 1055, Yale University, 2003. Click here to view the research referenced throughout this article.*

[2] *"Two pillars of asset pricing", Eugene F. Fama, Nobel Prize lecture, December 8, 2013, reproduced in the American Economic Review 2014, 104(6): 1467-1485.*

IN SEARCH OF THE HOLY GRAIL

To some investors, accurately predicting financial crises that cause market crashes is the holy grail of successful investing, but it has remained an elusive goal. Meanwhile, over the past four decades, market crashes—such as the 1987 Black Monday crash, the 1998 LTCM[3] crash, the 2000 NASDAQ crash, and the 2008-2009 GFC—have become frequent and almost familiar. As the world emerges from the trauma of the GFC, investors see plenty to cause worry about future asset bubbles and the next crash, even if they cannot agree about the likely causes, catalysts, timing, or severity of such an event. Others dismiss contemporary worries as surmountable issues that are largely priced into the markets.

We argue that, notwithstanding the implications of efficient markets theory, the structure of financial markets ensures that significant overvaluations, bubbles, panics, and busts will likely occur regularly. These episodes may even carry tell-tale signs, including well documented early signals that may be useful in detecting a market's propensity to crash. We also review the myriad efforts at crash detection, ranging from market valuation metrics to macroeconomic early warning signals.

We explain why we think it is unlikely that any indicator based on the statistical analysis of historical data and current market conditions can **reliably** predict the next market crisis or crash. That said, the study of crisis vulnerability, while it might not make us clairvoyant, has its uses. In particular, paying close attention to macroeconomic vulnerabilities, market indicators, and political developments contributes to better investment and policy decisions. The study of past crises may also help investors to construct useful tail risk scenarios, thus helping to better manage systemic risk.

DEFINING A MARKET CRASH

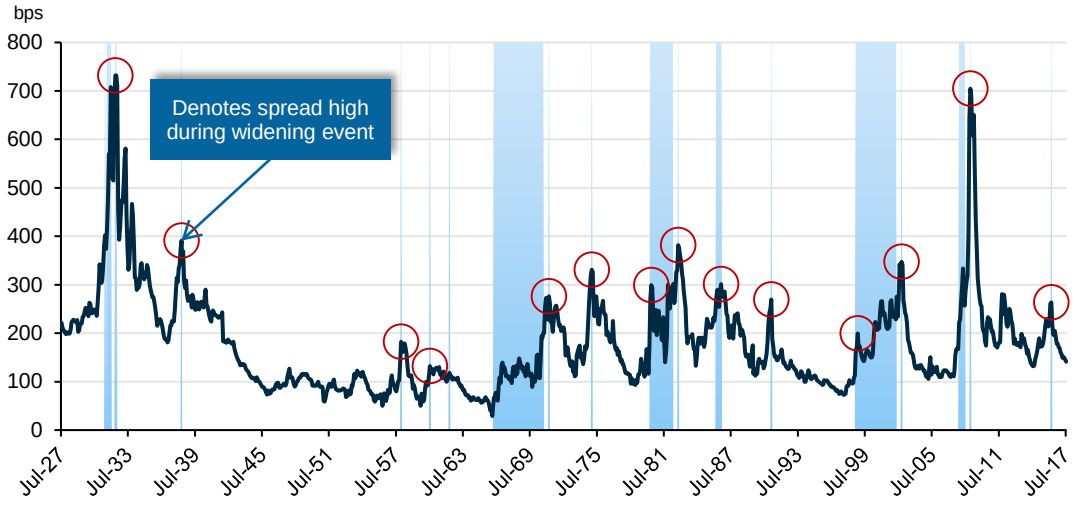
While defining a crash is evidently a subjective exercise, a crash can be distinguished from a run of the mill market correction by its severity, relatively infrequent occurrence, and persistence. The exact definition is not crucial for the discussion here. Based on typical conventions in the literature (see for example Barro and Ursua (2009)), we adopt the following simple definition of a stock market crash: a drawdown in the stock price index of 25% or more.

This definition attempts to catch "true" crashes and skip smaller corrections that are reversed relatively quickly without major consequences. When applied to U.S. stock market data since 1928, the definition yields seven stock market crashes, as seen in Figure 1 on the preceding page, with the most recent decline in 2008 coming in slightly below the group average. The percentages on Figure 1 detail the extent to which the stock market declined during the crash period.

Regarding crashes in bond spread markets, since spread market annual volatility averages around 30-50% of the spread over a market cycle, a trough to peak spread widening of about 2.5 standard deviations corresponds to roughly a doubling of spreads, which is a reasonable working definition of a crash. Since 1928, there have been 14 episodes in the U.S. investment grade corporate market that exceeded this **100% spread widening** threshold, as observed in Figure 2. The timing of significant spread widenings usually overlaps with stock market selloffs, but does not match up exactly.

[3] *LTCM is a reference to Long-Term Capital Management, a former hedge fund.*

FIGURE 2: EPISODES OF INVESTMENT GRADE CORPORATE (BBB) SPREAD WIDENING EXCEEDING 100%



Source: PGIM Fixed Income as of August 2017. Source of spread data: Moody's from July 1927 - June 1989, Barclays from July 1989 – July 2017.

It is noteworthy that, based on our definitions, there have been more frequent spread widening episodes than stock market drops, particularly since the late 1960s. This suggests differently shaped probability distributions and volatility characteristics and may be worthy of further study that is not in scope here. As for the financial crises that underlie these crashes, they can have myriad sources, which we discuss along with the literature on crash prediction in subsequent sections.

MARKET CRASHES AND THE EFFICIENT MARKETS HYPOTHESIS

The definitive paper on the Efficient Markets Hypothesis (EMH) is Eugene F. Fama's "Efficient Capital Markets: A Review of Theory and Empirical Work" (Fama, 1970) where he defines an efficient market as "a market in which prices always 'fully reflect' available information." If one fully accepted the EMH, crashes could still happen because the facts on the ground could change—but one would not look for predictors of crashes, since crashes would always result entirely from new information. However, many researchers have subsequently documented a variety of ways in which markets depart from the EMH (see for example Lo and Mackinlay (1999), Shiller (2003), Lee et. al. (2010), and Sewell (2011)). Although descriptions of financial markets are still dominated by the EMH, an alternative academic body of work, namely Behavioral Finance (BF) has gained legitimacy in recent decades. Buttressed by the behavioral studies of scientists, such as Thaler (1985), Barberis and Thaler (2003), and Nobel Prize winning Kahneman (2003), this literature emphasizes non-rational individual and collective behavior. Other literature explores the role of large institutions and information asymmetries in driving departures from the EMH. *At a macro level, such departures from the EMH can lead to large deviations of market asset prices from fundamental values and, therefore, explain the existence of both bubbles and crashes.*

Failures of the EMH require departures from its assumptions, while prediction requires detecting such departures.

Despite the inroads made by BF, most asset pricing models in finance assume efficient markets. Defenders of the EMH maintain that while real life markets are not strictly speaking, efficient, they are "asymptotically efficient," and the spirit of EMH "is profoundly true (Sewell 2011)." The attempts at crisis prediction models try to prove them false, and the battle continues.

BEHAVIORAL FINANCE AND MARKET STRUCTURE

Failures of the EMH require departures from its assumptions, while prediction requires detecting such departures. In our view, over the past two decades, the adherents of BF have made a convincing case for the non-efficiency of capital markets. The recurrence of frequent financial crises has provided some of the best evidence that they are right. Their most compelling arguments are the following:

Irrationality and Herd Behavior: The first problem that behaviorists cite is with the assumption of *rationality*. Not only can individual investors be irrational, but investors in the market may collectively lose their bearings, at least temporarily. Shiller (2003) documents stock market volatility that is inconsistent with the present value of the stock market implied by the EMH. The development of value indicators that are earnings based, discussed in the next section, is intended to provide a counterpoint to current market values and used to create signals of over and under valuation.

Systematic Risk Build-ups: Even behavior that is rational for individual participants can create systemic risk in the aggregate. These might be financial management techniques used by market participants—techniques that make sense for an individual firm, but which, when employed by a wide swath of participants, can create systemic risks. Examples include various forms of delta hedging; the portfolio insurance techniques used prior to the 1987 crash; widespread use of (pro-cyclical) value-at-risk models; and mark-to-market accounting, which when combined with capital requirements, can become a propagation channel, as it was during the 2008 crisis. Trend and momentum based strategies in the context of strong markets may also create systemic overexuberance, to borrow a term from former FOMC chairman Alan Greenspan.

Moral Hazard: A class of behavior created by the phenomenon of "moral hazard," where a person or business will have a tendency to take risks or alter their behavior because they can avoid the negative consequences of taking the risk, can also cause departures from the rational behavior expected from an investor. Situations that can lead to moral hazard include asymmetric information and principal-agent relationships, where the agent may act against the interests of the principal. The latter is exemplified by the behavior of originators of subprime mortgages and securities in the mid-2000s who had an obligation to ensure the credit quality of those securities, but had no "skin in the game." The aggregation of a large number of such agents, as in this case, could create systemic distortions. Another example is government bailouts that encourage "too big to fail" corporations to take risk at the taxpayer's expense. Moral hazard may be invoked to explain the distorted behavior of many economic agents, from CEOs to government representatives to rating agencies to regulators.

Large Players: The presence of large players can distort the theoretical model of the market, which is based on the interaction of a large number of small, rational, profit-maximizing investors. These large players may include *official institutions,* such as central banks and other regulators that set (and may choose to change) policy, regulations, etc., whose objectives may not involve maximizing profits. They may also include *large private financial institutions*, such as money center banks, that are large enough to cause systemic shocks when they fail and may be interconnected with other such institutions. The largest such entity is the country or *sovereign entity*. Unilateral actions and interactions among sovereign entities, whether military or economic, often initiated by individuals or a small number of individuals, can have systemic effects.

Non-Cooperative Games with Multiple Equilibria: The presence of large entities whose behavior may depart from near-term profit maximization, as defined by traditional finance models, changes the nature of the market from one that can be modeled as the aggregation of small, profit-seeking players to something more akin to a *non-cooperative game* involving a small number of large players. Such games often have *multiple equilibria,* and a switch from one equilibrium point to another may occur rapidly, causing a market crash.[4] Positive feedback loops may make in-between states of the market unstable, so that once a move away from one equilibrium point is initiated, it moves rapidly to the other. A switch may be initiated by triggers, such as a loss of confidence in a large entity (e.g. the EU, as in the case of the 2011 Euro Area crisis or more recently, Brexit), the failure of a large institution (e.g. Lehman or LTCM), a macro event (e.g. an OPEC decision leading to a sudden drop in oil prices), or an election (as in the 2016 U.S. presidential election). Further, triggers including a change in government policy (e.g. exchange rate policy), a terrorist act, or a human or environmental disaster created by commission, negligence, or lax oversight (e.g. an oil spill or a pathogen escape) are distinct from other, more "natural" or random disasters, such as earthquakes, hurricanes, and epidemics.

Incomplete Information: Another source of departures from the EMH is that *information may be partial or asymmetric*. In the presence of information asymmetries, herd-like behavior may be created. Such *opacity* of information may exist in financial or non-financial institutions, in the form of mismatches in liabilities (FX, duration, or credit) and in the opacity of the size and credit quality of balance sheets. Derivatives markets (and over the counter markets more generally) create complex dependencies among market players that

[4] For example, a bank run can even shut down a healthy bank—requiring only that, say 20% of depositors, believe the bank to be insolvent and withdraw their deposits.

are visible to some, but not to all. For example, governments, regulators, central banks, and certain market makers may be privy to information that is unavailable to all market participants. Shadow banking systems add to partial opacity. Countries' economic and financial systems are often partially opaque to one another.

Network Effects: Finally, information technology has introduced *large network effects* whereby information (or misinformation) that is unknown to most or all players can become known and spread quickly to all players. This can speed up the shift between multiple equilibria, creating *contagion*, both within and across markets. Regulatory responses to such crashes, and market anticipation of such responses, are also very powerful movers of markets and can be inherently destabilizing as well. Some examples of these events include the rescue of Bear Stearns followed by the failure of Lehman Brothers in 2008 and the reactions of Chinese authorities to the Chinese stock market's bubble and crash in 2015.

It should be acknowledged that regulations governing banks and other financial institutions in the U.S. and Europe since the GFC, such as those required under the Dodd Frank legislation, have reduced certain risks. For example, banks are much less risk prone overall—they are better capitalized, more liquid, less able and willing to assume off-balance sheet risks, and less willing to extend balance sheets to leveraged players. This makes an exact repeat of the GFC unlikely in the near future.

Yet, one must bear in mind that partly because of such precautions, the next crash—if and when it comes—will probably result from a different set of vulnerabilities than the last one. Furthermore, with hindsight, crashes, such as the 1998 failure of LTCM, the 2000 bursting of the dot-com bubble, the 2008 Lehman crash, the 2011 European crisis, and the 2014-2015 oil price collapse, appear to have been caused by, or at least aggravated by, policy mistakes and market structure anomalies. After each crash, there was much soul searching, redoubled research, new regulation and legislation to prevent a repeat, yet the crashes have kept coming. The global economy and financial markets keep getting bigger and more difficult to fully understand and control. Their complexity and dynamic nature have remained ahead of the ability of finance theory to fully explain their dynamics and of policy makers' attempts to rein in their excesses. None of this suggests that we should give up trying to understand and anticipate market crashes, but it does argue for acknowledging how difficult the exercise is likely to be. The next two sections explore the research that has been done in developing such crash predictors.

TWO STREAMS OF MARKET CRASH RESEARCH

The literature on developing specific predictors for crashes and crises covers both emerging and developed markets and is inspired by economic historians, such as Mackay (1841) and Kindleberger (1978). It generally splits into two streams. The first type, focusing on detecting market bubbles, manias, and panics, is centered on the developed markets, especially the U.S. stock market. It tries to develop over and undervaluation metrics for the market as a whole. There are not a lot of academic papers on this topic, but it commands plenty of commentary and journalism coverage (not to mention extravagant claims). The focus here is primarily on *stock markets*, although discussions of *bond market metrics* also exist. The second stream explores the vulnerabilities of countries and financial systems, which, in turn, can cause markets to crash. It has extensive published literature and tries to use history to determine *early warning signals* that can warn about or predict such crises and crashes.

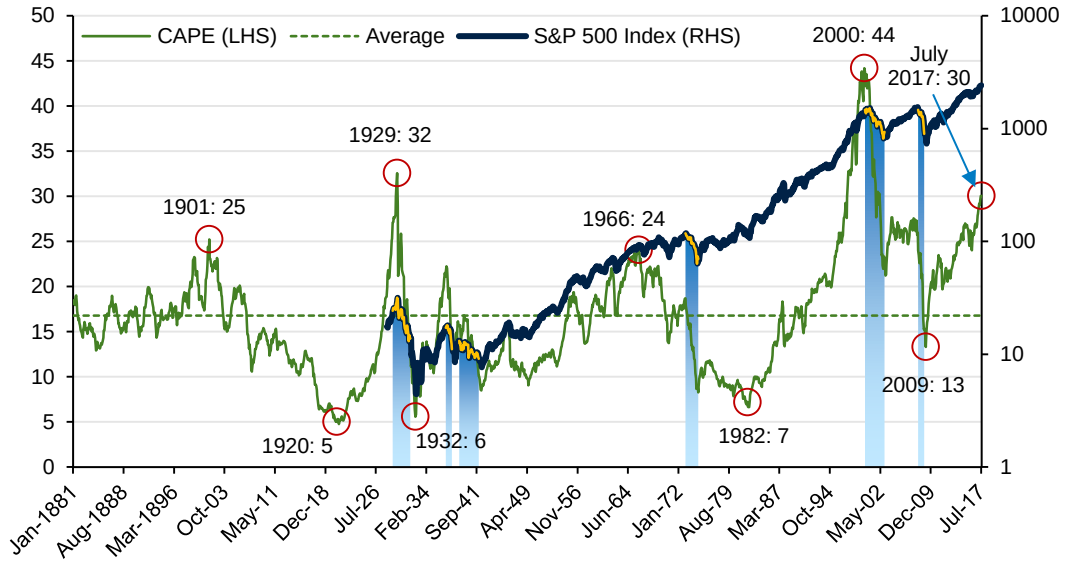
MARKET BASED VALUATION PREDICTORS

The concept of a market valuation metric to measure bubble or crash propensity is driven by the idea that markets can depart significantly from their "fundamental fair value." Such fair value metrics have primarily been proposed for equity markets and attempt to predict good and bad prospective returns and, in some cases, to predict the likelihood or corrections or crashes. Given the inherent difficulty of forecasting the stock market—and without an agreed-upon definition of fundamental value—authors of such metrics must rely considerably on some element of judgment and on empirical evidence.

In the case of equities, with the price-to-earnings ratio as the fundamental value indicator, it is natural to base a fair value metric on this ratio. With both trailing and forward looking versions of this ratio available, one can calculate a PEG (price earnings/growth) ratio—high values of which indicate overvaluation. Tobin's Q is an alternative measure of value, obtained by dividing the aggregate stock market value by the replacement cost (book value) of its constituent companies.

Because earnings fluctuate—and are also subject to the vagaries of the business cycle—attempts have been made to smooth the ratio to make it less cyclical. The best known metric was proposed by Robert Shiller, and is labeled the CAPE, or the Cyclically Adjusted Price Earnings ratio. It is available from the author's web site (Shiller 2015) and is derived by dividing the level of the S&P 500 Index by the 10-year average of reported earnings. Figure 3 shows that the ratio fluctuates around a long-term average of 16 and reached 30 in July 2017, indicating an overvalued market.

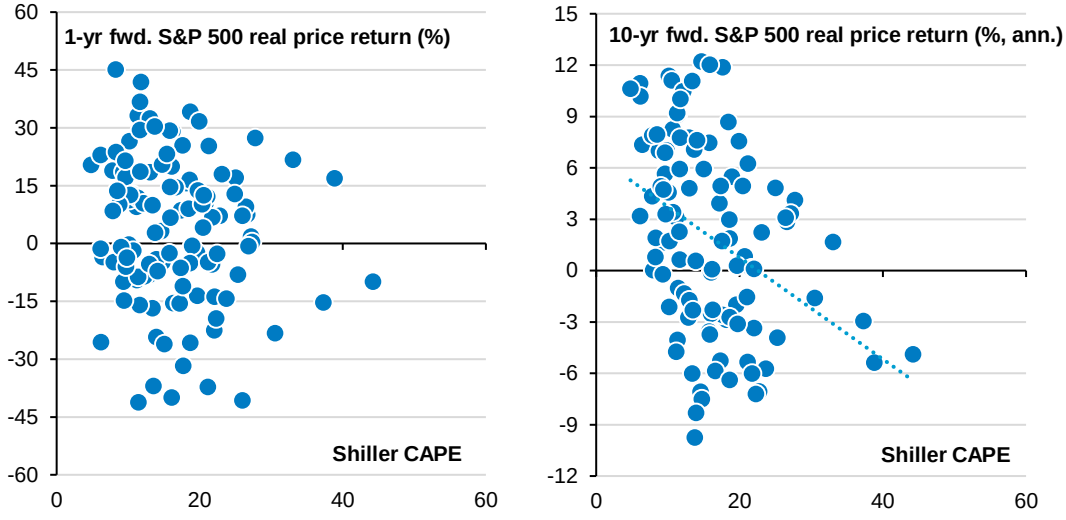
FIGURE 3: SHILLER'S CYCLICALLY ADJUSTED PRICE TO EARNINGS RATIO (CAPE)



Source: Robert Schiller, Yale University and Yale School of Management. http://www.econ.yale.edu/~shiller/data.htm. Data retrieved as of August 2017.

Since the late 1800s, the CAPE has been higher only in 1929 and during the period of 1997-2000. When starting from such high valuation levels, long-term have historically been extremely weak. However, it does not have a good track record of forecasting near-term, say one-year, returns—i.e., shifting to a cautious stance in 1997 would have proven premature. The predictive power is better when longer horizons are considered, especially at the extremes of the distribution (see Figure 4). However, the CAPE model has spent most of the last two decades above its historical average. It should therefore be emphasized that these types of indicators are general measures of value, rather than precise timing signals for predicting downturns.

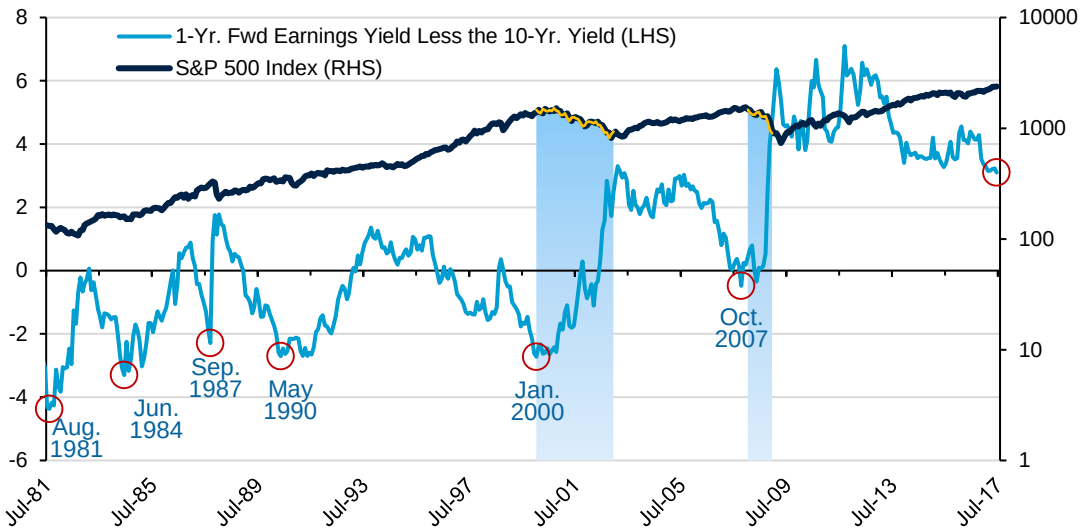
FIGURE 4: CAPE VS. 1-YR (%) AND 10-YR (%, ANNUALIZED) FORWARD REAL PRICE RETURN FROM 1900-2015



Source: Robert Schiller, Yale University and Yale School of Management. http://www.econ.yale.edu/~shiller/data.htm and Bloomberg. Data retrieved as of August 2017.

Other criticisms of the CAPE model have been made with regard to changes in historical practices of how earnings are reported. Finally, the approach is also criticized for not considering bond market-risk premia, a drawback that the next indicator discussed is supposed to correct.

FIGURE 5: 1-YEAR FORWARD EARNINGS YIELD LESS 10-YEAR YIELD



Source: PGIM Fixed Income and Bloomberg as of August 2017.

An alternative set of metrics compares stock and bond yields. For example, market practitioners introduced a metric, called the "Fed model,"[5] comparing equity yields (the earnings/price ratio, which is the reciprocal of the P/E ratio) to bond yields. A variant of this is also called the BSEYD (Bond-Stock Earnings Yield Differential) model, a version of which is shown in Figure 5. The theory is that this metric drives the optimal asset allocation between bonds and stocks, and when the bond yield is high relative to equity yields, a market adjustment ensues, with investors shifting from stocks to bonds. Similar metrics have been proposed by William Ziemba, who claims his metric predicts crashes (Lleo and Ziemba 2014). Some studies rely on historical statistics to claim that a strategy that bases entries and exits into equities using this type of differential can considerably outperform more static approaches to asset allocation. Some researchers even consider BSEYD as a potential risk indicator that may correctly signal market corrections (Berge et. al. 2008 and Consigli et. al 2009).

We note that the CAPE and BSEYD indicators are currently out of sync. In contrast to the CAPE model, the BSEYD model, shown in Figure 5, is not flashing a danger signal because as bond yields have dropped, they have diverged from stock earnings yields. While adherents might argue for a convergence, history does not help us determine, even if it occurs, whether a convergence will be caused by a stock rally or a bond selloff.

The gap between the equity earnings yield and the bond yield could decrease in three ways: by increases in the bond yield, by an increase in stock prices, or by a drop in stock earnings. The first mechanism, an increase in nominal bond yield, may be driven either by an increase in inflation expectations or an increase in real yields. An inflationary selloff in the bond market is unlikely to result in convergence, since cross-country research suggests that unexpected inflation bursts, beyond certain thresholds, result in poor stock returns and higher earnings yields. Hence, the possibility of convergence via rising bond yields rests mostly on rising real yields—and because these are very low or even negative, many believe this is the most likely mechanism for convergence. We are skeptical of this belief, however, noting that there are good structural reasons—e.g. demographics, globalization, and financial repression—why global bond risk premia may remain low and range bound. The second possibility is that equities' valuations and multiples may continue to rise, driven by higher productivity and global growth while inflation remains benign, driven by structural factors, which is certainly

[5] *The so-called "Fed Model" was not authored by the Federal Reserve or its staff, but by certain market participants who proposed it based upon a chart that once appeared in the Federal Reserve Bulletin. However, the name stuck.*

plausible. Lastly, convergence is unlikely to result from a drop in equity earnings, because history suggests that an earnings recession would probably result in a higher, rather than lower, earnings yield due to an even sharper drop in equity values.

Of course, the investment implications in these cases are quite different, and they highlight why the BSEYD indicator is unlikely to be a reliable crash warning predictor. The Fed and BSEYD models have been criticized for their lack of short-term predictability and have also been called into question because they compare earnings yields, which are a "real" quantity, to nominal yields in the bond market. We can also try to modify the CAPE measure to account for yields in the bond market by subtracting a measure of real yield, such as one derived from TIPs (Treasury inflation-protected securities) from the inverse of the CAPE. However, doing so does not improve the historical predictive power of the CAPE measure. Further, they have been criticized as descriptive tools, rather than predictive ones (Asness 2003). Others have questioned the predictive abilities of these models when applied to a panel of several countries with careful out-of-sample testing (Giot and Petitjean 2006).

Other proposed predictors of future stock returns, also with questionable track records, include trailing values for dividend yields and economic growth, profit margins, and past stock returns. The academic literature surrounding these models suggests that, at least to some degree, equity-risk premia are not constant and may be only partially predictable. Ultimately, while these types of valuation models are both useful and interesting to keep in mind, **we doubt that there is any simple market-based indicator that can reliably predict future stock returns or that can predict the timing or extent of market corrections and crashes.**

Finally, market participants routinely watch a number of risk indicators, such as options volatility and skew (e.g. the VIX), the DXY (a broad measure of the U.S. dollar) and CVIX (currency volatility). Measures that combine these into a single "fear index" are also popular. Usually, these are concurrent rather than leading risk indicators and are not expected to be predictive. Similarly, the spread between riskier bonds (such as high yield and emerging market bonds) and government securities may also be used as an indicator of market risk. The idea is that an overexuberant "reach for yield" causes such yield differentials to narrow prior to crises. **The evidence, however, indicates that credit spreads, like stock market returns, are concurrent rather than predictive measures of crises and crashes (that is true by definition for spread market widening, but likely for stock market selloffs as well), and success in systematically predicting future credit spreads remains as elusive as the oracle that can predict future stock returns.**

The evidence…indicates that credit spreads, like stock market returns, are concurrent rather than predictive measures of crises and crashes, and success in systematically predicting future credit spreads remains as elusive as the oracle that can predict near-term stock returns.

We conclude by emphasizing that **measures of long-term valuations can be very useful**, even if they cannot predict the timing or likelihood of a crash. For example, as the CAPE increases, the prospective distribution of predicted market returns shifts continuously lower, suggesting lower allocations to stocks. It may be possible to build even better indicators by using valuation indicators, such as CAPE and bond yield spreads with other factors. Indeed, all such valuation aids help active asset allocators to de-emphasize overvalued assets in a portfolio—an activity that arguably reduces crash vulnerability.

MACROECONOMIC EARLY WARNING SIGNALS AND PREDICTORS

The literature studying the use of macroeconomic indicators as early warning signals of crises is considerably more extensive than the studies on market valuation metrics. The motivation is that vulnerability or resilience to a shock depends on the fundamental macroeconomic health of a country's market or economy. Although underlying changes in a market or economy may not immediately cause a shift from one equilibrium point to another until a trigger event occurs, measuring such fundamental shifts may still be useful and may provide *early warning indicators* **at a country level** that future shifts are more likely.[6]

[6] *The observations in this and the following section are based on a synthesis of the contents of the following references: Frankel and Saravelos (2012), Reinhart and Rogoff (2008, 2011), Demirguc-Kunt and Detragiache (1997), Kaminsky and Reinhart (1999), Gourinchas and Obsfeld (2011), Reinhart and Rogoff (2011), Drehmann and Juselius (2013), Abiad (2003), El Shagi et. al (2012), and Alessi and Detken (2009).*

The literature classifies country-based crises as *currency crises*, including those in which a managed currency falls to speculative pressure, *banking crises*, involving bank runs and capital flight, including instability in the shadow banking system, *fiscal and growth crises*, and *sovereign crises*, involving default or fears of default on internal or external sovereign debt. Crises may also occur in combination, for example, countries can get into trouble rescuing their banks. Therefore, banking crises often occur in conjunction with currency crises, and sovereign crises often have elements of both currency depreciation and bank failures. These crises may have systemic implications, and when they do, they generally cause a market crash, initially in the affected country that then feeds through—depending on the size and strength of the crisis—to related countries, relevant asset classes, and even the global markets.

Taking a global view, it is useful to distinguish between emerging market and developed market crises. Emerging markets studies have focused on specific vulnerabilities, such as reduced debt sustainability, political and economic instability, weak governance and institutions, underdeveloped and unstable financial markets, weak currencies, high levels of dollarization, currency mismatches between assets and liabilities, and occasionally over-regulated or government controlled non-financial sectors. These studies were historically designed to focus on **sudden stops of capital inflows**, which have the potential to be tracked by specific metrics and can be tested statistically for their ability to presage crashes and crises. Unfortunately, these crisis models have a weak record in predicting the timing of crises, although they have arguably done a good job of identifying susceptibility and severity of outcomes (Ahuja et. al. 2017).

In the case of developed economies, there were fewer major country-specific crises between World War II and 2008, making it difficult to draw conclusions statistically. However, the Asian crisis of 1997 and a few other instances make it clear that fixed exchange rates or currency pegs can create vulnerabilities. A combination of shadow banking system growth, rapid financial innovation or liberalization, and lax supervision can lead to vulnerabilities as well.

The literature on crisis indicators is vast and it is difficult to do it justice in a short space. However, many common themes and variables can be extracted that are identified as the most useful for crisis prediction. Frankel and Saravelos (2012) have done us a service by surveying 83 distinct studies and surveys of such variables up until 2008 and then collecting the results in one spot. Their main results are summarized in Figure 6.

Across developed and emerging economies, certain variables stand out as clear indicators of crisis vulnerability. A large number of studies have shown that key drivers of crisis vulnerability across both kinds of economies include the real exchange rate (expensive is worse), strong growth in domestic credit (% of GDP), and high current account deficits (% of GDP). Knowledge of the underlying studies allows us to separate out variables from Figure 6 that may be of more relevance to emerging market countries, for whom low FX reserves (as a % of GDP), prior financial liberalization, and large amounts of short-term maturing external repayments are also danger signs.

FIGURE 6: SUMMARY OF PRE-2008 EARLY WARNING INDICATORS: NUMBER OF STUDIES FINDING VARIABLES AS A STATISTICALLY SIGNIFICANT PREDICTOR OF CRISES

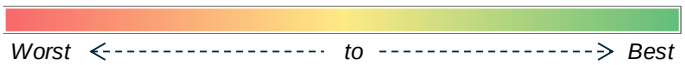
Leading Indicator	No. of Studies	Variable(s) Typically Employed
Reserves	50	Reserves relative to GDP, M2, short-term debt, 12-month change
Real Exchange Rate	48	Real exchange rate change, over/under valuation
GDP	25	GDP growth, level, output gap
Credit	22	Credit—nominal or real growth
Current Account	22	Current Account/GDP, Trade Balance/GDP
Money Supply	19	Money supply growth rate, excess M1 balances
Exports or Imports	17	Exports or imports relative to GDP, growth
Inflation	15	Domestic core or headline inflation
Equity Returns	13	Equity returns
Real Interest Rate	13	Real interest rate: domestic or differential

Based on reviews of more than 80 papers conducted by KLR (1998) for studies up to 1997, Hawkins and Klau (2000) for studies up to 2000 and Abiad (2003) for studies up to 2001. Additionally, the table includes the findings from seven further papers published between 2002 and 2009.
Source: Frankel, J. and Saravelos, G. (2012): "Can Leading Indicators Assess Country Vulnerability? Evidence from the 2008-2009 Global Financial Crisis," Journal of International Economics, Volume 87, Issue 2, July.

What do these types of indicators tell us about the state of the world in 2017? The following table (Figure 7) shows the values of the top five indicators from Figure 6 for a broad swath of emerging economies, and the heat map compares the level of the variable in each country versus its peers, with red indicating the worst values. To assess whether a particular variable is truly in danger territory, one must look at both its relative and absolute levels and then examine the economy for other signs of trouble. When we have gone through that exercise, the only country that merits close attention as a potential source of systematic risk is China, not because its metrics in Figure 7 are signaling an imminent problem, but due to its size and importance (second largest in the global economy with $12 trillion in GDP) combined with its credit growth led by its banking and shadow banking systems. We continue to monitor China closely; however, the concerns listed have been mitigated by a relatively closed capital account, China's structure as a closed centrally managed economy with authorities who are actively working to pivot the economy to a sustainable model, and the markets' broad recognition of the risks posed by China. The other boxes that are flashing red in Figure 7 are associated with smaller countries, such as Venezuela, where the problems are obvious and widely recognized. Other red boxes are isolated, mitigated by other factors, or not globally important, systemic or alarming for a variety of reasons. Some examples in this latter group include credit growth rates in Mexico and in the Philippines, or the current account deficits in Colombia, Turkey, and Ukraine. **In fact, our conclusion from this Figure 7 is that no country other than China is large enough to create a global crisis on its own, and the levels of these specific variables are not concerning once the relevant countries are viewed from a country-specific, bottom-up perspective and folded into an overall global macroeconomic outlook.**

FIGURE 7: COMPARISON OF LEADING INDICATOR VARIABLES AMONG EM COUNTRIES (DATA ARE AS OF YEAR-END 2016.)

Country	GDP Balance ($ billion)	Reserves/M2 Coverage	REER Change 2016 vs average (2011-2015)	GDP Growth %YOY	Real Credit Growth %YoY	CA
China	11,940	0.13	8.2%	6.70	8.8%	1.75
India	2,440	1.09	4.6%	7.10	8.3%	-0.92
Brazil	2,080	0.49	-13.3%	-3.60	-2.5%	-1.31
South Korea	1,530	0.18	4.2%	2.83	6.1%	6.99
Russia	1,470	0.49	-21.9%	-0.20	-3.9%	1.73
Mexico	1,140	0.28	-19.2%	2.30	14.8%	-2.19
Indonesia	1,010	0.3	-0.6%	5.02	4.0%	-1.75
Turkey	841	0.23	-6.4%	2.88	8.1%	-3.80
Argentina	620	0.32	-20.2%	-2.30	-5.9%	-2.60
Poland	510	0.36	-7.6%	2.83	4.1%	-0.30
South Africa	438	0.21	-17.5%	0.28	0.2%	-3.27
Thailand	438	0.32	-1.7%	3.23	3.8%	11.41
Israel	348	0.36	3.5%	4.00	5.8%	3.63
Singapore	344	0.63	-0.5%	2.00	5.8%	19.03
Hong Kong	334	0.24	15.9%	1.95	-0.7%	5.08
Philippines	321	0.39	4.5%	6.84	14.1%	0.20
Malaysia	310	0.25	-10.5%	4.24	3.1%	2.05
Colombia	307	0.37	-21.3%	1.96	4.2%	-4.44
Chile	263	0.25	-6.1%	1.56	4.0%	-1.45
Venezuela	215	0.01	292.5%	-18.00	-54.8%	-2.42
Czech	210	0.57	-4.7%	2.41	6.1%	1.12
Peru	210	0.77	-2.7%	3.90	0.6%	-2.80
Romania	205	0.5	-3.6%	4.79	2.5%	-2.44
Hungary	132	0.37	-6.1%	2.00	-0.6%	4.32
Ukraine	104	0.29	-20.3%	2.31	-10.9%	-3.61



Source: PGIM Fixed Income as of December 2016. Note: REER refers to Real Effective Exchange Rate, GDP refers to Gross Domestic Product, and CA refers to Current Account surplus (+) or deficit (-) as a percentage of GDP. GDP balances represent most recent data as provided by the IMF. Data for Argentina is based on sources believed to be accurate, however it cannot be guaranteed.

What about the advanced economies? Here, most studies have focused on specific sectors, such as housing or banking, usually in hindsight. There are also fewer of these studies, which led in part to the failure of such models and systematic approaches to predict and prevent the 2008 crisis (although a few prescient observers did issue warnings). Today, the advanced economies face slow growth, high debt levels, high levels of private debt and leverage, financial complexity, and unprecedented degrees of inventive monetary management. This suggests a whole host of new challenges, leading to the development of risk models focused on the developed world and **assessing vulnerabilities across their different sectors** (Ahuja et. al., 2017.) Multi-national institutions, such as the Bank

for International Settlements (BIS) and the International Monetary Fund (IMF), have assumed the task of monitoring and reporting risks across both advanced and emerging economies.

The most comprehensive of these efforts is the IMF Global Financial Stability Report, issued twice a year. The version from April 2017 (IMF (2017)) reports on a series of risk indicators, including those pertaining to emerging markets, excessive credit growth, unstable monetary and financial conditions, risk appetite, and market volatility and liquidity. It finds that while "threats to financial stability are growing due to elevated political and policy uncertainty" and that a few indicators, such as volatility risk and sovereign risk, have edged higher, the majority of indicators are improving, and the report does not identify any specific country or area where a crisis indicator is presently flashing red among the advanced (or developed) economies. It remains to be seen whether this more global and eclectic approach will do any better in predicting the next crisis.

WHAT CLOUDS THE REAR-VIEW MIRROR

In the previous two sections, we have seen that many of the existing signals meant to warn us about the next market crash or country crisis are not presently signaling danger or that they are giving off mixed signals that are hard to interpret. But beyond current conditions, we believe there are fundamental reasons why it remains difficult, if not impossible, to construct a practical history-based crisis predictor:

1. It is obvious, but worth noting, that it remains difficult for any successful crash indicator **to lead market prices**, and if one does exist, by definition, the market must not consider it authoritative **a priori**, or else the market would have already reacted.

2. Each bubble and crash is different in its particulars, and so we may **miss monitoring the right signals** for the next crisis. For example, leverage may build up in a market, sector, or country that is not monitored by the indicator. **There is often no measurement of, or only poor measures of, the most useful crisis variables, i.e. those leading to the next crisis.** It is often precisely the poor reporting or lack of accuracy in these metrics that lulls the market into complacency. In the case of the 2008 crisis, the relevant data for the market to focus on beforehand included the sharp run-up in home prices, the percentage of subprime loan originations that were defaulting, the level of maturity and credit mismatches in the asset-backed commercial paper (ABCP) market, the run-up in system-wide leverage more generally, the status of Lehman Brother's balance sheet, and the probability that the U.S. government would bail Lehman out. These data were, of course, underestimated, ignored, misunderstood, or not widely reported.

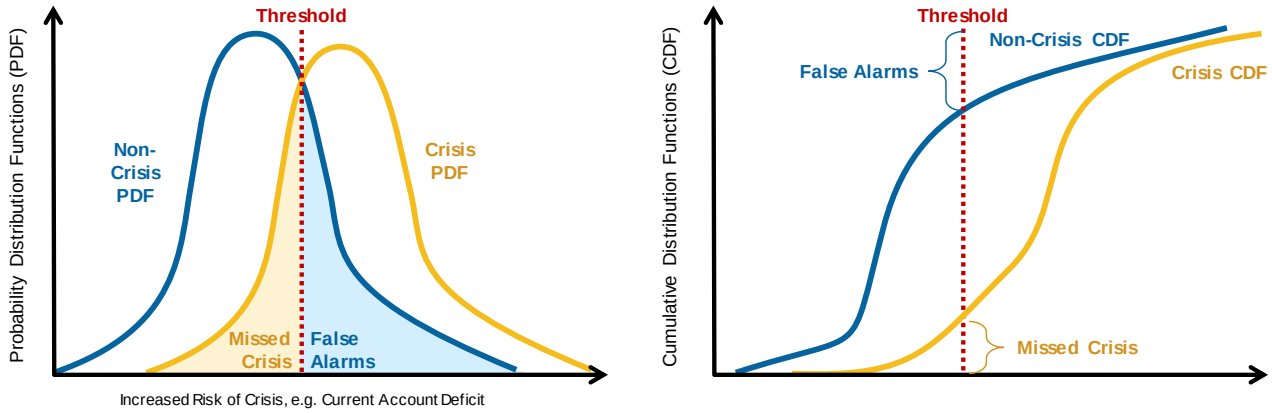
3. The **Lucas critique** may apply (Lucas 1976). It argues that it is naive to try to predict a future response entirely on the basis of relationships observed in historical data, especially highly aggregated historical data, because the optimal decision rules of investors adjust to changing policy, **causing previously unobserved behavior**. In particular, much of the academic crisis literature is in fact aimed at policy makers rather than investors; if policy makers were to heed these signals, they may act on them and stave off a crisis, making the signal moot—with all due respect, however, we may be giving policy makers too much credit here, given their track record.

4. What if the above criticisms do not apply to the next crisis? What if we get lucky and happen to be watching the right country and the right variables? Even then, one of the most important drawbacks of historical modeling is that **individual signals are modest in effect, noisy, time-varying, and difficult to combine into a useful forward looking signal**. This issue is so important that we devote the entire next section to explaining the difficulties.

THE CHALLENGE OF COMBINING WEAK SIGNALS INTO A RELIABLE CRASH PREDICTOR

The effect ("coefficient") and statistical significance of crisis signals vary, depending on the data used, and the results are modest. In individual cases, for example, a higher level of domestic credit may increase the likelihood of a crisis from 4% to 8%, but when should one act on such a signal? There is also a relatively high noise-to-signal ratio. In other words, these variables put out a lot of **false positive signals**. It is far from clear that acting on these signals would ensure better returns for the investor. Effectively combining indicators is crucial; while a given indicator may have very different **expected** values in a crisis versus a non-crisis environment, as Figure 8 shows, noise would cause its crisis and non-crisis **probability distributions** to overlap substantially, so a crisis signal from a single variable will lead to an unacceptably high percentage of false alarms and/or missed crises.

FIGURE 8: OVERLAP OF CRISIS AND NON-CRISIS DISTRIBUTIONS OF INDIVIDUAL VARIABLES CAUSES FALSE ALARMS AND/OR MISSED CRISES



Source: IMF and Ahuja (2017).

Combining predictive factors to get an effective and useful early warning is also tricky because it may be hard to predict which particular combinations will be dangerous. The most straightforward way to combine variables is through panel regressions, where the indicators are the independent variables and are used to predict the likelihood of a crash (defined as a large and rapid market or macro-variable change) in a cross-sectional set of countries. Panel studies comparing crisis and non-crisis countries represent another similar approach. Other models do this with a "signals" approach. This can be done in a non-parametric model by setting thresholds for key variables and combining the signals from variables that cross their thresholds. Yet another approach is to extract common risk factors from predictive variables—using, for example, principal component analysis. All these involve composing a linear or non-linear combination of signals.

However, a fire requires an accumulation of fuel *and* a spark, and many "correct" signals—or a composite signal—may be flashing red for a prolonged period before a specific event or catalyst causes a crash. For example, debt levels around the world are at historically high levels, yet debt service is perfectly manageable due to very low interest rates and inflation levels. Therefore, today's high levels of debt are benign unless combined with a shock that raises borrowing rates and lowers growth expectations. The risks of such **"contingent bubbles**" are hard to assess, since their bursting requires a shift to a new equilibrium.

One way to address this drawback is the use of binary choice models, where these variables are used to predict a binary crisis indicator. One approach involves the use of so called Markov switching (or regime switching) models. The regimes in these models are an attempt to directly account for and detect the existence of multiple equilibria. The indicator variables can be combined to come up with a probability of switching between regimes, indicating the crisis probability. One consequence of this approach is that the crisis definition falls out of the model specification, rather than being defined in advance.

Even when combined, crash indicators that actually improve investment performance tend to be constructed with lots of hindsight and back testing and have rarely been predictive **out-of-sample**. Trigger levels for binary indicators are made unreliable by the **non-stationarity** (time variation) of relationships. Underlying economic and financial processes are dynamic. For example, in a given industry or country, leverage ratios at a particular level may trigger a flight-to-quality or an inability to refinance in one instance, but that level may be different at another time.

Therefore, the bottom line remains that such indicators, while potentially promising avenues of research, do not have a track record of successfully predicting most crises. Given that the structure of the economy and financial relationships are complex and shifting through time, these vulnerability models are, at best, only a stylized form of broader economic relationships and developments. Hence, we tend to see lots of missed crises and false alarms (Type 1 and Type 2 errors), and with just historical data, it may not be possible to eliminate such errors, i.e., these models will always be probabilistic at their core.

WHY NEXT TIME MIGHT BE DIFFERENT—THE VIEW FROM 2017

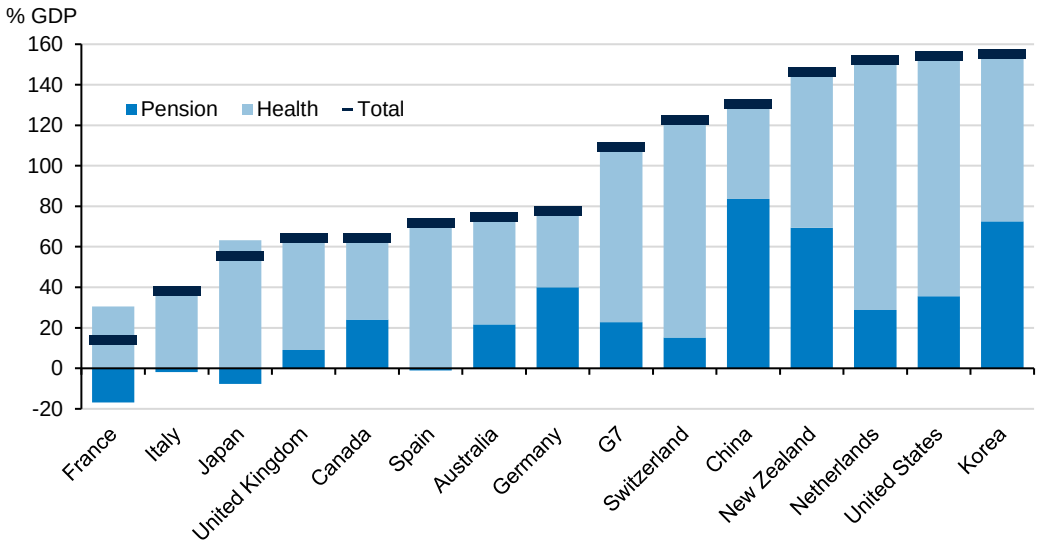
Further compounding the limited effectiveness of predictive models is today's global macroeconomic and political environment, which is both unique and historically unprecedented in a number of ways. The risks we see from these factors cannot be easily extracted from historical data, as we highlight next. **Active portfolio and risk managers, knowing that the genesis of the next crisis is unlikely to be found in the dying embers of last night's fire, must actively scour this new landscape and seek out the new global threats to markets and portfolios.** This suggests that value can be added by ongoing global macro analysis.

THE DEMOGRAPHIC TIME BOMB

The rapid aging of populations in the developed world and in some emerging economies, such as China, presents a historically unique challenge to governments that face an entitlements crisis of epic proportions, as seen in Figure 9. The problem is focused on the public sector. Barring a sharp, unexpected surge in productivity, the steep bills from social security and health care entitlements will have to be resolved in one of three ways—by reneging on the promised benefits, by increasing taxes on a shrinking worker base, or by borrowing. Something has to give, and the consequences for financial markets are likely to be difficult, if not severe. The difficulties of factoring this risk into market valuations center on policies that can massively affect the outcomes, which are long-term in nature, making their timing extremely uncertain. For example, one mitigant is that fiat money and financial repression through regulation may allow governments to borrow cheaper (although this does not apply to countries in common currency zones like the euro zone or to states or provinces).

FIGURE 9: PRESENT VALUE OF INCREASES IN PENSION AND HEALTH COSTS

NET PRESENT VALUE OF INCREASE IN BUDGET COSTS FOR HEALTH CARE AND PENSIONS THROUGH 2015-2050, AS PERCENT OF GDP.



Source: Gerard Minack, Down Under Daily, July 2017, Bloomberg, and the IMF.

INTEREST-RATE SHOCKS AND CENTRAL BANK POLICIES

As long-term rates have stayed low and drifted lower over the past two decades, governments and private sector entities have accumulated historically high debt levels, which are serviceable only so long as borrowing costs remain low. In attempts to recover from the GFC, the world needed zero or negative interest rates and extraordinary balance sheet expansion by the G4 central banks. Yet, global economic growth remains historically modest, albeit positive, and the "normalization" (raising) of rates combined with the unwinding of quantitative easing presents a dilemma to policymakers and poses risks to investors. Both the Fed and the ECB appear set on tightening in an environment where inflation is still running below official targets, increasing the risks of overtightening going forward. That said, policy makers have been very prudent and cautious thus far, so this remains a tail risk rather than a base case.

- The Fed poses significant overtightening risk—one that may ultimately pull the next recession forward. The risks from the Fed stems from the reduction in U.S. labor overcapacity, which underscores the concern that the reduction will spill over into

inflation pressures. Resolving the wide gap between the Fed's median dot at the end of 2019, at 2.68%, and the market's implied policy rate, at about 1.69%, could prove painful. These risks could rise if potential replacements for Chair Yellen and other FOMC voters carry more hawkish policy views.

- With ECB asset purchases reaching self-imposed limits and a formal tapering decision possible by October 2017, this shift could weaken some of the key supports that have bolstered European and global growth over the past several years.

- Elsewhere, Chinese authorities may well choose to reduce the economic credit stimulus of approximately a quarter turn of GDP per year after they have held their 19th Congress, slated to begin on October 18th, and the retiring members of their Politburo have been replaced.

Furthermore, with far fewer monetary and fiscal tools available to react to a fresh recessionary downturn than in the past, the markets may be extra sensitive to recessionary risks going forward. At the same time, the market is totally unprepared for an inflationary spike. This suggests that risky assets could be unusually sensitive to a spike in rates or inflation. Nevertheless, it is hard to see large risks from rising rates—**provided one sees low inflation and interest rates as structural phenomena,** as we have argued—see Tipp (2015, 2016, 2017) and Rajan (2015, 2016). The past decade has seen no shortage of bond bears, who have, **so far**, been uniformly and resoundingly wrong. Thus, despite the obvious risk from rising rates, there are equally obvious difficulties in predicting its magnitude and likelihood.

GEOPOLITICAL RISKS

While the sources of geopolitical risk are ever changing, the Middle East and North Korea are two locations of particular concern. It is difficult to quantify these risks because they are new, constantly shifting, contingent, and inherently political. Many benign outcomes are possible, yet it is challenging to estimate the probabilities of these outcomes along with their market implications.

- The recent ultimatum issued to Qatar by other Gulf states is just one symptom of a more fractious Gulf, with rising tensions between the Saudi Arabia/Gulf Cooperation Council (GCC) and other players including Qatar, Turkey, and Iran. This deepens the stakes and risks in a region already beset by weak oil prices. Near-term risks include escalation of regional political tensions, while longer term—unless oil prices recover—the region faces high internal social and political tensions, falling FX reserves, budget strains, and weakness in the banking sector.

- North Korea's ongoing tests of its nuclear and missile capabilities pose a challenge to the Trump administration, and the risks remain that Chinese and other diplomatic efforts will fail to rein in the regime, triggering a military confrontation.

- Additional risks emanate from the Trump agenda in the U.S. and the upcoming Italian elections in Europe. However, Trump bump expectations have subsided, while near-term risks in Europe have also faded somewhat due to the pickup in growth, consolidation of the political center in Germany and France and the potential for reforms in the latter.

EXOGENOUS EVENT RISKS

These types of risk are hard to enumerate, let alone quantify, but they are no less real than threats that are in plain sight. Here are two examples that bear watching. We would note that in each scenario, we have little data on which to base a market reaction.

- A global pandemic from diseases, such as Zika, Ebola, or a respiratory virus, such as SARS, remains a concern due to growing global populations and urbanization, human encroachment into new environments, increasing frequency of heat waves and flooding, international travel, civil conflict zones, and poor medical coverage in frontier countries.

- As a whole, global cyberattacks, unplanned IT or communication outages, and data breaches constitute a growing threat to markets, which are vulnerable to attacks on e-services or on entities that provide critical physical or financial infrastructure. For example, the Wannacry attack in May 2017 crippled computers in 100 countries, including those used by the UK's National Health Service.

The bottom line is that we live in a dynamic and in many ways unprecedented macroeconomic environment, in which global regulation, trade, banking, and politics have all changed substantially over the past few decades and especially since the 2008 crisis—and partly in response to it. While historical data remain very useful in understanding our current macroeconomic conditions and relationships, it is unreasonable to expect that the challenges facing market participants will likely be captured by primarily looking at variables and relationships derived from only past history and prior crises. When models don't work, the task falls on the shoulders of humans.

CONCLUSION

When evaluating the state of risk markets a decade after the Global Financial Crisis, it is probably too early to call an end to the current, long-lasting phase of gradual growth and abundant liquidity. That said, risk assets are climbing a wall of worry, and we believe that these risks will likely mount in the coming quarters while higher valuations and tighter spread levels reduce comfort margins.

When we evaluate the historical data-driven tools that have been developed to predict crashes and crises, it seems difficult to build a reliable future indicator even when good data and time-tested relationships are available. Further, markets face many new risks, increasing our skepticism about historically-based crash predictors. **As active investors, it falls to us to anticipate, identify, track and evaluate these new risks.**

In short, crashes exist precisely because they are unexpected and cannot be forecasted. However, we have argued that a crisis requires fuel as well as a spark, and that crisis predictors may generally provide a barometer, albeit an incomplete one consisting of only the fuel. We have also argued that certain valuation indicators do a good job of predicting returns over long timeframes, but do poorly on shorter timeframes. Finally, we have listed the major macro risks that market participants face today.

This suggests three useful activities for active portfolio managers and risk managers. The first is to search for that potential catalyst or spark that could ignite the identifiable fuel. This task falls to global macro analysts, whose job is to watch the current set of global flare-up risks, such as those identified in the final section. The second role is to actively identify long-term value and reduce allocation to overvalued assets, which can be the result of bottom-up valuation as well as overall assessments of the risk-reward of entire markets and sectors, an activity aided by those very same valuation indicators. By modulating the overall level of portfolio or active risk to the size of the available attractive opportunity set, investors can mitigate the difficulties of actually predicting the timing and magnitude of crashes.

Third, but not least, recognizing that what lights the fuel may be an unpredictable lightning strike, a simple, yet practical, approach to potential recognition is to build tail-risk scenarios of investment outcomes. When applied to bank capital, this summarizes the stress-testing approach taken by both U.S. and European banking regulators in the wake of the 2008 crisis. This is also the approach PGIM Fixed Income uses as one element of our risk-management framework. We create scenarios that apply stresses to current prices using data drawn from historical experience (or in certain special cases, interpolated or inferred). These should be based on where the fuel has accumulated—i.e., on those scenarios that pose the highest risks to markets and are deemed most probable. Portfolios can then be stress tested using these scenarios and constructed to limit losses in the event of such scenarios. In the end, this approach, while simpler than the more sophisticated crash prediction methodologies, may prove to be more **reliable**.

REFERENCES

Abiad, Abdul. 2003. “Early Warning Systems: A Survey and a Regime-Switching Approach.” *IMF Working Paper* 03/32.

Ahuja, Ashvin, Kevin Wiseman, and Murtaza Syed. 2017. “Assessing Country Risk—Selected Approaches—Reference Note.” *IMF Technical Notes and Manuals*.

Alessi, Lucia and Carsten Detken. 2009. “Real Time Early Warning Indicators for a Costly Asset Price Boom and Bust Cycles: A Role for Global Liquidity.” *ECB Working Paper* No. 1039.

Asness, Clifford. 2003. “Fight the Fed Model.” *Journal of Portfolio Management, Fall*.

Barberis, Nicholas and Richard Thaler. 2003. “A Survey of Behavioral Finance.” *NBER Working Paper* No. 9222.

Barro, Robert J. and Jose F. Ursua. 2009. “Stock Market Crashes and Depressions.” *NBER Working Paper* No. 14760

Berge, Klaus, Giorgio Consigli, and William T. Ziemba. 2008. “The Predictive Ability of the Bond-Stock Earnings Yield Differential Model.” *Journal of Portfolio Management*.

Campbell, John Y and Robert J. Shiller. 1991. “Yield Spreads and Interest Rate Movements: A Bird's Eye View.” *Review of Economic Studies* 58.

Consigli, Giorgio, Leonard C. MacLean, Yonggan Zhao, and William T. Ziemba. 2009. “The Bond-Stock Yield Differential as a Risk Indicator in Financial Markets.” *Journal of Risk*.

Drehmann, Mathias and Mikael Juselius. 2013. “Evaluating Early Warning Indicators of Banking Crises: Satisfying Policy Requirements.” *BIS Working Papers* No. 421.

Demirguc-Kunt, Asli and Enrica Getragiache. 1997. “The Determinants of Banking Crises: Evidence from Developing and Developed Countries.” *IMF Working Paper* No. WP/97/106

El Shagi, Makram, Tobias Knedlik, and Gregor von Schweinitz. 2012. “Predicting Financial Crises: The Statistical Significance of the Signals Approach.” *IWH Discussion Papers*, Halle Institute for Economic Research.

Fama, Eugene F. 1970. “Efficient Capital Markets: A Review of Theory and Empirical Work.” *The Journal of Finance* 25(2), pp 383–417.

Fama, Eugene F., and Robert R. Bliss. 1987. “The Information in Long-Maturity Forward Rates.” *American Economic Review* 77, pp 680-692.

Fama, Eugene F. 2013. "Two Pillars of Asset Pricing." Nobel Prize Lecture, as reproduced in the *American Economic Review* 2014, 104(6): pp 1467-1485.

Frankel, Jeffrey and George Saravelos. 2012. “Can Leading Indicators Assess Country Vulnerability? Evidence from the 2008-2009 Global Financial Crisis,” *Journal of International Economics*, Volume 87, Issue 2, July.

Giot, Pierre and Petitjean, Mikael. 2006. “The information content of the Bond-Equity Yield Ratio: Better than a random walk?,” CORE Discussion Papers; 2006/89, *https://dial.uclouvain.be/downloader/downloader.php?pid=boreal:4542...PDF_01.*

Gourinchas, Pierre-Olivier and Maurice Obstfeld. 2012. “Understanding Past and Future Financial Crises.” Centre for Economic Policy Research, http://voxeu.org/article/understanding-past-and-future-financial-crises.

Gourinchas, Pierre-Olivier and Maurice Obstfeld. 2012. “Stories of the Twentieth Century for the Twenty-First.” *American Economic Journal: Macroeconomics* 4(1), pp 226–265.

Hawkins, John and Marc Klau. 2000. "Measuring Potential Vulnerabilities in Emerging Market Economies." *BIS Working Papers* 91.

International Monetary Fund. 2017. “Global Financial Stability Report.” *IMF Publications*.

Kahneman, Daniel. 2003. “Maps of Bounded Rationality: Psychology for Behavioral Economics.” *The American Economic Review*, Volume 93, No. 5, pp 1449-1475.

Kaminsky, Graciela and Carmen Reinhart. 1999. “The Twin Crises: The Causes of Banking and Balance of Payments Problems.” *The American Economic Review.*

Kaminsky, Graciela, Saul Lizondo, and Carmen Reinhart. 1998. "Leading Indicators of Currency Crisis." *IMF Staff Papers* via *Palgrave Macmillan Journals*, Vol. 45(1).

Kindleberger, Charles P. 1978. “*Manias, Panics, and Crashes: A History of Financial Crises*.” Wiley Investment Classics.

Lee, Chien-Chian, Jun-De Lee, and Chi-Chuan Lee. 2010. “Stock Prices and the Efficient Market Hypothesis: Evidence from a Panel Stationary Test with Structural Breaks.” *Japan and the World Economy* Vol. 22(1), pp 49–58.

Lleo, Sebastien and William T. Ziemba. 2015. “Some Historical Perspectives on the Bond-Stock Yield Model for Crash Prediction Around the World.” *International Journal of Forecasting*.

Lo, Andrew W. and A. Craig MacKinlay. 1999. “*A Non-Random Walk Down Wall Street*.” Princeton University Press, Princeton, NJ.

Lucas, Robert. 1976. “Econometric Policy Evaluation: A Critique.” *In* Brunner, K.*; Meltzer, A. The Phillips Curve and Labor Markets. Carnegie-Rochester Conference Series on Public Policy.* ***1****. New York: American Elsevier. pp. 19–46.* ISBN 0-444-11007-0.

Mackay, Charles. 1841. “*Memoirs of Extraordinary Popular Delusions and the Madness of Crowds*.” Volume I and II, London.

Rajan, Arvind. 2015. “Five Over Five: Major Global Themes Expected to Shape Markets Through 2020,” *PGIM Fixed Income Global Insights*. http://www.pgimfixedincome.com/pramerica/fi/pdf/pgim-fixed-income-five-over-five-0615.pdf.

Rajan, Arvind. 2016. “Key Fault Lines in the Global Earthquake Zone,” *PGIM Fixed Income Perspectives*. http://www.pgimfixedincome.com/pramerica/fi/pdf/pgim-fixed-income-earthquake-zones-0916.pdf.

Reinhart, Carmen and Kenneth Rogoff. 2011. “*This Time is Different: Eight Centuries of Financial Folly.*” Princeton University Press, Princeton, NJ.

Sewell, Martin. 2011. “History of the Efficient Market Hypothesis.” *UCL Research Note* 11/04.

Shiller, Robert J. 2003. “From Efficient Markets Theory to Behavioral Finance,” *Cowles Foundation Paper* No. 1055, Yale University.

Shiller, Robert J. 2015. “U.S. Stock Markets 1871-Present and CAPE Ratio,” Database. http://www.econ.yale.edu/~shiller/data.htm.

Thaler, Richard H. 1985. “Mental Accounting and Consumer Choice,” *Marketing Science*, Vol. 4(3), pp 199-214.

Tipp, Robert. 2015. “The Totally Mad World of Low Rates…and Why It’s Here to Stay.” *PGIM Fixed Income Global Insights*. http://www.pgimfixedincome.com/pramerica/fi/pdf/pramerica-fixed-income-mad-world-1215.pdf.

Tipp, Robert. 2016. “Central Banks of the World: Yield to the Markets!” *PGIM Fixed Income Perspectives*. http://www.pgimfixedincome.com/pramerica/fi/pdf/pgim-fixed-income-central-banks-yield.pdf.

Tipp, Robert. 2017. “The Bond Bull’s Twain Moment.” *PGIM Fixed Income Perspectives*. http://www.pgimfixedincome.com/pramerica/fi/pdf/pgim-fixed-income-bond-bull-0417.pdf.

NOTES

NOTES

NOTICE: IMPORTANT INFORMATION

Source(s) of data (unless otherwise noted): PGIM Fixed Income, October 2017.

PGIM Fixed Income operates primarily through PGIM, Inc., a registered investment adviser under the U.S. Investment Advisers Act of 1940, as amended, and a Prudential Financial, Inc. ("PFI") company. PGIM Fixed Income is headquartered in Newark, New Jersey and also includes the following businesses globally: (i) the public fixed income unit within PGIM Limited, located in London; (ii) PGIM Japan Co., Ltd. ("PGIM Japan"), located in Tokyo; and (iii) the public fixed income unit within PGIM (Singapore) Pte. Ltd., located in Singapore. Prudential Financial, Inc. of the United States is not affiliated with Prudential plc, which is headquartered in the United Kingdom. Prudential, PGIM, their respective logos, and the Rock symbol are service marks of PFI and its related entities, registered in many jurisdictions worldwide.

These materials are for informational or educational purposes only. The information is not intended as investment advice and is not a recommendation about managing or investing assets. In providing these materials, PGIM is not acting as your fiduciary as defined by the Department of Labor. These materials represent the views, opinions and recommendations of the author(s) regarding the economic conditions, asset classes, securities, issuers or financial instruments referenced herein. Distribution of this information to any person other than the person to whom it was originally delivered and to such person's advisers is unauthorized, and any reproduction of these materials, in whole or in part, or the divulgence of any of the contents hereof, without prior consent of PGIM Fixed Income is prohibited. Certain information contained herein has been obtained from sources that PGIM Fixed Income believes to be reliable as of the date presented; however, PGIM Fixed Income cannot guarantee the accuracy of such information, assure its completeness, or warrant such information will not be changed. The information contained herein is current as of the date of issuance (or such earlier date as referenced herein) and is subject to change without notice. PGIM Fixed Income has no obligation to update any or all of such information; nor do we make any express or implied warranties or representations as to the completeness or accuracy or accept responsibility for errors. **Your capital is at risk and the value of investments can go down as well as up. These materials are not intended as an offer or solicitation with respect to the purchase or sale of any security or other financial instrument or any investment management services and should not be used as the basis for any investment decision. No risk management technique can guarantee the mitigation or elimination of risk in any market environment. Past performance is not a guarantee or a reliable indicator of future results and an investment could lose value. No liability whatsoever is accepted for any loss (whether direct, indirect, or consequential) that may arise from any use of the information contained in or derived from this report. PGIM Fixed Income and its affiliates may make investment decisions that are inconsistent with the recommendations or views expressed herein, including for proprietary accounts of PGIM Fixed Income or its affiliates.**

The opinions and recommendations herein do not take into account individual client circumstances, objectives, or needs and are not intended as recommendations of particular securities, financial instruments or strategies to particular clients or prospects. No determination has been made regarding the suitability of any securities, financial instruments or strategies for particular clients or prospects. For any securities or financial instruments mentioned herein, the recipient(s) of this report must make its own independent decisions.

Conflicts of Interest: PGIM Fixed Income and its affiliates may have investment advisory or other business relationships with the issuers of securities referenced herein. PGIM Fixed Income and its affiliates, officers, directors and employees may from time to time have long or short positions in and buy or sell securities or financial instruments referenced herein. PGIM Fixed Income and its affiliates may develop and publish research that is independent of, and different than, the recommendations contained herein. PGIM Fixed Income's personnel other than the author(s), such as sales, marketing and trading personnel, may provide oral or written market commentary or ideas to PGIM Fixed Income's clients or prospects or proprietary investment ideas that differ from the views expressed herein. Additional information regarding actual and potential conflicts of interest is available in Part 2A of PGIM Fixed Income's Form ADV.

In the United Kingdom and various European Economic Area (`EEA') jurisdictions, information is issued by PGIM Limited with registered office: Grand Buildings, 1-3 Strand, Trafalgar Square, London, WC2N 5HR. PGIM Limited is authorised and regulated by the Financial Conduct Authority of the United Kingdom (registration number 193418) and duly passported in various jurisdictions in the EEA. These materials are issued by PGIM Limited to persons who are professional clients or eligible counterparties for the purposes of the Financial Conduct Authority's Conduct of Business Sourcebook. In certain countries in Asia, information is presented by PGIM Singapore, a Singapore investment manager registered with and licensed by the Monetary Authority of Singapore. In Japan, information is presented by PGIM Japan, registered investment adviser with the Japanese Financial Services Agency. In South Korea, information is presented by PGIM, Inc., which is licensed to provide discretionary investment management services directly to South Korean investors. In Hong Kong, information is presented by representatives of PGIM (Hong Kong) Limited, a regulated entity with the Securities and Futures Commission in Hong Kong to professional investors as defined in Part 1 of Schedule 1 of the Securities and Futures Ordinance.

2017-55538