INSTITUTIONAL ADVISORY & SOLUTIONS

WHAT TO EXPECT WHEN EXPECTING A RECESSION

A CIO's Guide to Interpreting the Probability of Recession

June 2023

AUTHORS

Noah Weisberger, PhD
Managing Director
noah.weisberger@pgim.com
+1 973 367 7851

Xiang Xu, PhD
Senior Associate
xiang.xu@pgim.com
+1 973 802 3128

The PGIM Institutional Advisory & Solutions (IAS) group provides objective, data-informed analysis to help Chief Investment Officers and Investment Committees manage their portfolios.

To learn more about PGIM IAS, contact IAS@pgim.com or visit pgim.com/IAS.

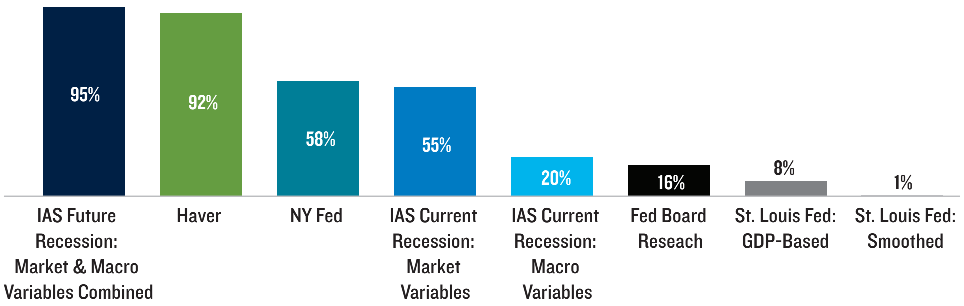
A CIO's Guide to Interpreting the Probability of Recession

Recessions are a regularity of the economic landscape, occurring about once a decade. While each recession has its own unique set of characteristics, recessions share common attributes with broad implications for portfolio allocation and construction decisions.

However, recessions are determined and announced with a lag; we often do not realize we are in a recession until long after it has started. To provide a more up-to-date assessment of recession risk, it is common to turn to models that use current conditions to evaluate the *probability* of a current or future recession.

But interpreting these models is difficult. The probability of recession can vary widely across recession indicators, and seemingly similar indicators can generate vastly different probabilities. As a case in point, in March 2023, recession probabilities from a variety of models ranged from 1% to over 90% (Figure 1). How can a CIO make sense of this? Which signals are more reliable and what, if anything, do these signals foretell about asset class performance?

Figure 1: Estimated Probability of US Recession (as of March 2023)



Note: The PGIM IAS probability models are detailed below; non-IAS model details can be found in Appendix 3. NY Fed recession probability estimates are not official forecasts of the Federal Reserve Bank of New York, its president, the Federal Reserve System, or the Federal Open Market Committee. Source: Bureau of Labor Statistics, Federal Reserve Bank of New York, Federal Reserve Bank of St. Louis, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Such large variations in probabilities are due, in part, to the modeling details of each recession indicator, including time-period, choice of explanatory variables, and degree of forward lookahead. An understanding of these considerations can help CIOs interpret recession probability estimates and steer their portfolios through the ups and downs of the business cycle, particularly given that it is costly to be either indifferent to or overly concerned about a potentially looming recession.

This report is a guide for CIOs to help them assess and interpret recession probability models. To be clear, our purpose is <u>not</u> to build and maintain a better recession prediction model, but rather to demonstrate how to evaluate and utilize such models. That said, we do present our own models (using a straightforward approach), allowing us to explore several issues that CIOs should consider when presented with a recession probability reading:

- What underlying inputs (*e.g.,* financial market and/or macroeconomic variables) drive a model's recession probability?
- Is the model assessing current or future recession risk?
- How strong is the resulting recession signal?
- How are the markets likely to respond to the signal?

For CIOs, evaluating the risk of a recession is not just a macroeconomic curiosity. The probability of a recession – separate from the occurrence of a *realized* recession – is an important tool to shed light on likely forward market performance and to help better position a multi-asset portfolio. We offer five key takeaways:

Key Takeaways

(1) Financial market inputs and macroeconomic inputs contribute to the estimated probability of recession. Recession signals that combine market and macro inputs are more dependable than signals that rely on only one set of inputs.

(2) Elevated recession probability readings are a reliable signal of both current and future US recessions. As a rule of thumb, probability readings above 60% tend to be associated with recessions, but false signals – both positive and negative – can occur.

(3) Signals based on either market or macro inputs alone are often not aligned. Even so, recession warning signals that arise in periods when market and macro models disagree are still of high quality.

(4) By the time recession probabilities are elevated, the stock market has generally already declined and, perhaps after a pause, is more likely to rally than sell off further.

(5) A better indicator for forward stock returns is the <u>change in recession probability</u>, not the level. Specifically, expected excess stock returns are weakest when the probability of a recession is <u>high & rising</u> and are strongest when the probability of a recession is <u>high & falling</u>.

Estimating the Probability of a Recession: Financial Market & Macroeconomic Variables Both Matter

We focus on two alternative definitions of recession risk: (1) the estimated probability of a *current* US recession and (2) the estimated probability of a *future* US recession anytime in the next 1-12m (not including the current month).[1]

We are keen to know how these recession probability estimates relate to two types of input variables: (1) financial market variables and (2) macroeconomic variables. Using macroeconomic variables as inputs seems reasonable as recessions are characterized by the behavior of macroeconomic aggregates. However, it is not clear, *a priori*, if macro data – given their measurement lags – provide a reliable hint of a current or future recession.[2] In contrast, although financial market variables are not part of the formal definition of a recession, these variables may be more forward-looking and could prove helpful.[3] Specifically, for macroeconomic variables we use the trailing 12m percent changes in US industrial production (IP) and in private non-farm payrolls (PAY), and for financial market variables we use the US yield curve (YC, defined as 10y Treasury yield – effective Fed funds rate) and trailing 12m S&P 500 returns (SP500). Using monthly data from July 1954 to December 2019 (excluding data leading up to the 2020 recession), we estimate six recession probability indicators:[4]

- The monthly probability of a *current* recession based on:
  (1) both financial market and macroeconomic variables together ("combined model");
  (2) financial market variables alone ("market model"); and
  (3) macroeconomic variables alone ("macro model").

- The monthly probability of a *future* recession (in the next 1-12m) based on:
  (4) both financial market and macroeconomic variables together ("combined model");
  (5) financial market variables alone ("market model"); and
  (6) macroeconomic variables alone ("macro model").

The results suggest that (Figure 2):

- Weaker economic activity (IP or PAY), weaker equity returns (SP500), and a flattening yield curve (YC) are associated with an increase in the probability of a current and of a future recession.[5]
- Both YC and SP500 are (statistically) significant in all models where they are used. In contrast, the significance of the two macro variables – IP and PAY – differs across models, although at least one of these two macroeconomic variables is always significant.
- In determining the probability of a *current* recession, the goodness of fit is highest when combining market and macro variables together, with an (adjusted) R^2 of 58%.[6] Using market variables alone or macro variables alone delivers models with a worse fit than the combined model, but still with reasonable R^2's of 42% and 27%, respectively.
- Estimating the probability of a *future* recession, we find that the goodness of fit is also highest (R^2 of 50%) when using market and macro variables together. However, market variables alone have far more explanatory power than macro variables alone (R^2's of 41% and 1%, respectively).

1 While our analysis focuses on the probability of a *US* recession, the broader lessons of how to interpret such models can be generalized to other geographies. Although the formal modeling could be extended to other countries, note that *local* financial market variables may carry with them a good deal of US and/or global information unrelated to the risk of a *local* recession. See *Stock-Bond Correlation: A Global Perspective* (PGIM IAS, June 2022) for a discussion on local *vs.* global influences.

2 J.H. Stock and M.W. Watson, "A Procedure for Predicting Recessions with Leading Indicators: Econometric Issues and Recent Experience," in: *Business Cycles, Indicators, and Forecasting*, J.H. Stock and M.W. Watson, eds., The University of Chicago Press, 1993, pp. 95–156.

3 Campbell Harvey, "The Real Term Structure and Consumption Growth," *Journal of Financial Economics* 22 (1988): 305-334. The issue of what financial data say about future macroeconomic conditions is also discussed in *What Can Markets Tell Us about Future Economic Growth? Historical Predictive Power of the Bond, Stock and Real Estate Markets* (PGIM IAS, September 2018).

4 We use a logit regression model for estimation. Data construction details, model specifications, and estimation results are in Appendix 1. Note, as mentioned above, our purpose is not to extensively test data specifications and functional forms to find the best recession prediction model. We are looking for a parsimonious way to describe recessions. Also, our concerns are explanatory, and hence we are not concerned with issues of what was known to market participants in real time, and we use revised data in our regression analysis, not "as of data." We discuss our choice of included explanatory variables and the issue of revised *vs.* contemporaneous data in *The Probability of Recession: A Critique of a New Forecasting Technique* (PGIM IAS, May 2020).

5 The estimated marginal effects of the explanatory variables on the probability of a future recession tend to be larger (in absolute value) than the estimated marginal effects on the probability of a current recession. This may be due, in part, to the cumulative nature of the probability of a recession occurring in any one of the next 1-12m (even though those events are not independent) as opposed to the probability of a recession occurring in the current month alone.

6 Unlike linear regression models, logit regressions do not yield a true R^2 measure. Instead, we report "pseudo" R^2's based on the ratio of the likelihood function assuming the null hypothesis to the likelihood function assuming the model. To account for differences in the number of explanatory variables across the models, we adjust the pseudo R^2's for the number of estimated parameters as if the R^2's were from a linear regression. As shown above, the adjusted R^2's of the Combined Models are higher than those from the Market or Macro Model, even after accounting for the greater number of explanatory variables (4 *vs.* 2).

This modeling exercise demonstrates that combining input types together has greater explanatory power than restricting the model to only one type of input. Surprisingly, many commonly available models (like those that we survey above and that are detailed in Appendix 3), rely on *either* market *or* macro variables. Moreover, as we show below, including multiple sources of information in a single model is particularly valuable when the model inputs are sending conflicting signals.

Both financial market and macroeconomic inputs contribute to the estimated probability of recession and fit the data better when combined than when used separately.

Figure 2: US Recession Probability Models: Coefficient Estimates and Goodness of Fit

(Coefficient Estimates Expressed as Marginal Effect of Explanatory Variable on Probability of Recession)

	Probability of Current Recession			Probability of Future Recession		
	(1) Combined	(2) Market	(3) Macro	(4) Combined	(5) Market	(6) Macro
SP500	**-0.26*** **	**-0.53*** **		**-0.90*** **	**-1.15*** **	
YC	**-1.49*** **	**-1.67*** **		**-25.84*** **	**-19.92*** **	
IP	**-0.53*** **		**-2.69*** **	-0.10		**-4.57*** **
PAY	-0.37		1.80**	**-7.52*** **		7.28***
Adjusted R^2	0.58	0.42	0.27	0.50	0.41	0.01

Note: Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. Marginal effects of an explanatory variable on the probability of recession are evaluated at mean values of explanatory variables. *** / ** / * indicates significance at the 1% / 5% / 10% level, respectively; bold font signifies significance with the expected sign. Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

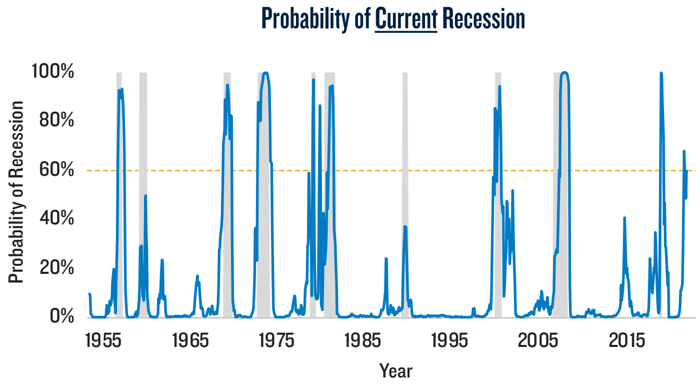
Evaluating Recession Signal Strength: Market and Macro Data Should be Viewed Together

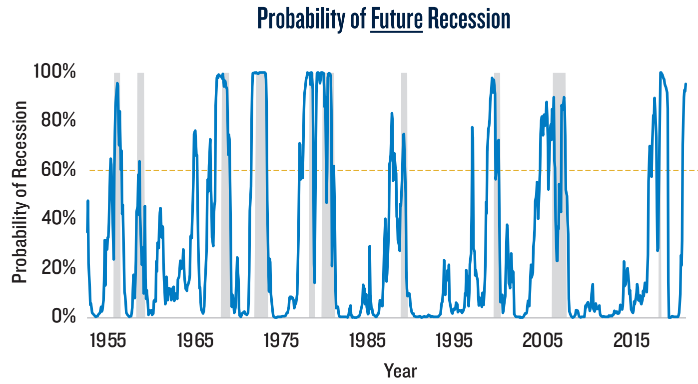
To the eye, estimated monthly recession probabilities seem like reliable recession indicators (Figure 3). As we detail below, probability readings of 60% or higher coincide with realized recessions more often than not. To be sure, there are spikes that do not coincide with a recession (a false warning signal), and instances where the probability remains low despite a looming recession (a false all-clear signal). Similarly, Figure 4 shows recession probabilities (both current and future) based on market variables *alone* and macro variables *alone*. Market-based probabilities tend to experience higher and more frequent spikes, occasionally sounding a false alarm, while macro-based recession probabilities seem to spike less often, occasionally sending an all-clear signal that misses a realized recession.

Elevated recession probability readings are a reliable signal of both current and future US recessions. Probability readings above 60% tend to be associated with recessions, but false signals do occur.

Figure 3: Estimated Probability of Current & Future US Recession: Market & Macro Variables Combined

(1954-2023)

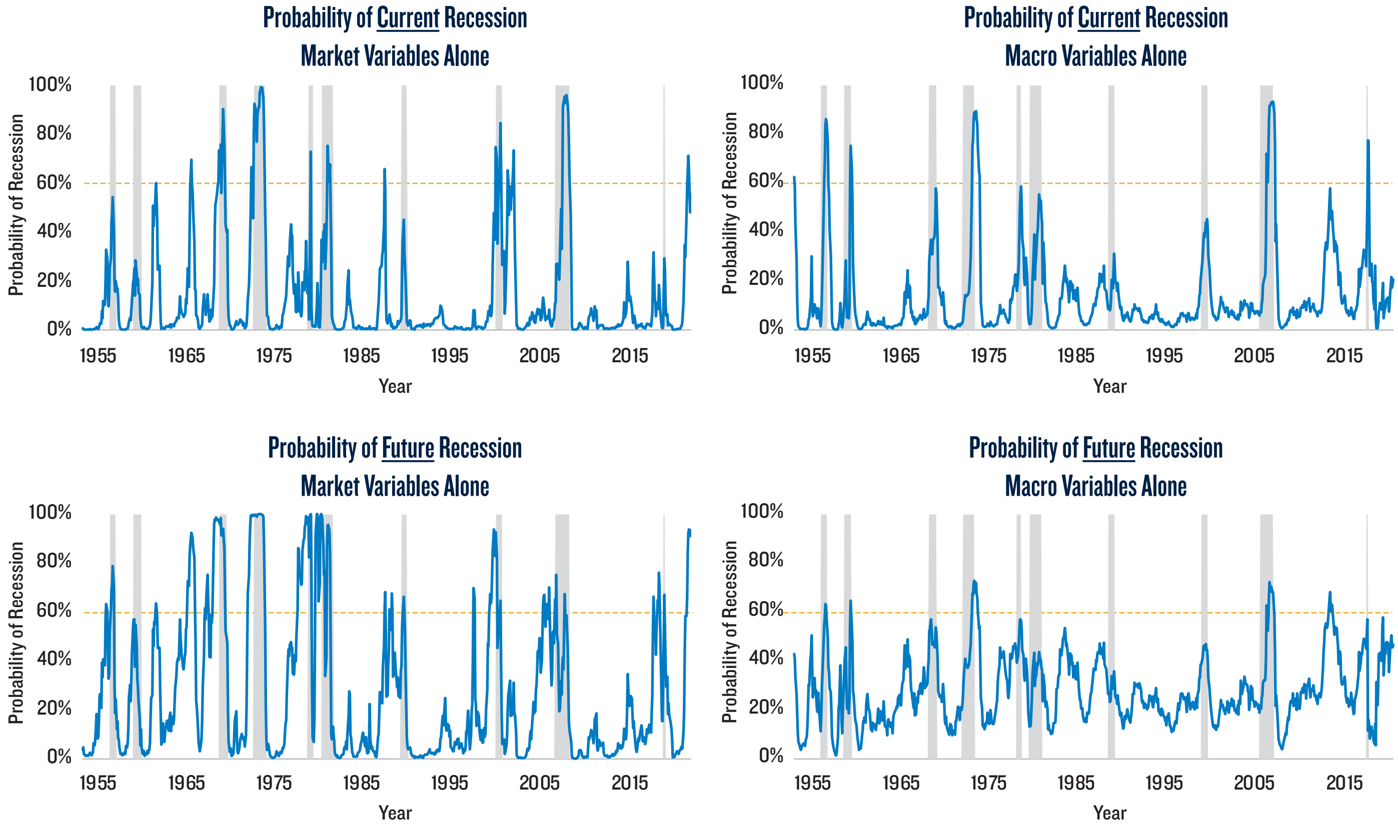




Note: Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. Grey shading indicates NBER recession months. Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Figure 4: Estimated Probability of Current & Future US Recession: Market or Macro Variables Alone

(1954-2023)



Note: Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. Grey shading indicates NBER recession months. Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

These estimated recession probabilities have an intuitive interpretation (*e.g.,* a 90% probability of recession feels "high," and a 10% probability feels "low"). However, a probability **threshold signal** (*i.e.,* when to trigger a recession warning) can be potentially misleading by either failing to provide a warning of a recession or by providing a warning and no recession occurs. Given that recessions are infrequent, how should investors react when the probability threshold has been crossed and a recession probability signal flashes red?

A good recession warning signal should have two important characteristics:

(1) A high percentage of recessions accurately picked up by a warning signal (True Positive Rate);

(2) A high percentage of true warning signals relative to all warning signals, indicating that there are few false warnings (Positive Predictive Value).

Signal errors are unavoidable and the frequency of signal errors are, in part, a function of the threshold itself. Too low a probability threshold, and the signal flashes "red" too frequently and warns of recessions that do not occur. Too high a threshold, and the signal flashes "green" too often and fails to warn of realized recessions too frequently.[7]

Defining a probability reading greater than 60% as a recession signal, stronger and more reliable signals come from models that combine market and macro variables (Figure 5).[8] For assessing the risk of a current recession, 58% of realized recessions are accurately

7 To better understand the necessity of these two quality measures, consider a simple analogy of a tennis line judge (before the days of electronic line judges) who needs to call shots "in" or "out." The perfect line judge calls "out" only for shots that are actually out (*i.e.*, true positive) and "in" only for shots that are actually in (*i.e.,* true negative). In reality, line judges are imperfect. Consider two extreme examples. First, imagine a line judge who *rarely* calls a shot "out" and then only calls "out" when it is unmistakable. All of these line judge's "out" calls will be accurate (*i.e.,* true positives), but many actual out shots will be missed and many "in" calls will be wrong (*i.e.,* false negatives); therefore, a low percentage of actual out shots are called "out," but all "out" calls are accurate. At the other extreme, imagine a line judge that *always* calls "out." This line judge never misses a shot that is actually out (*i.e.,* true positives), but many "out" calls are inaccurate (*i.e.*, false positives); therefore, a high percentage of all actual out shots are called "out," but the percentage of accurately called "out" shorts relative to all "out" calls is low. Ideally, if a line judge is reliable, the percent of true "out" calls relative to *all actual out shots* and relative to *all "out" calls* will be high.

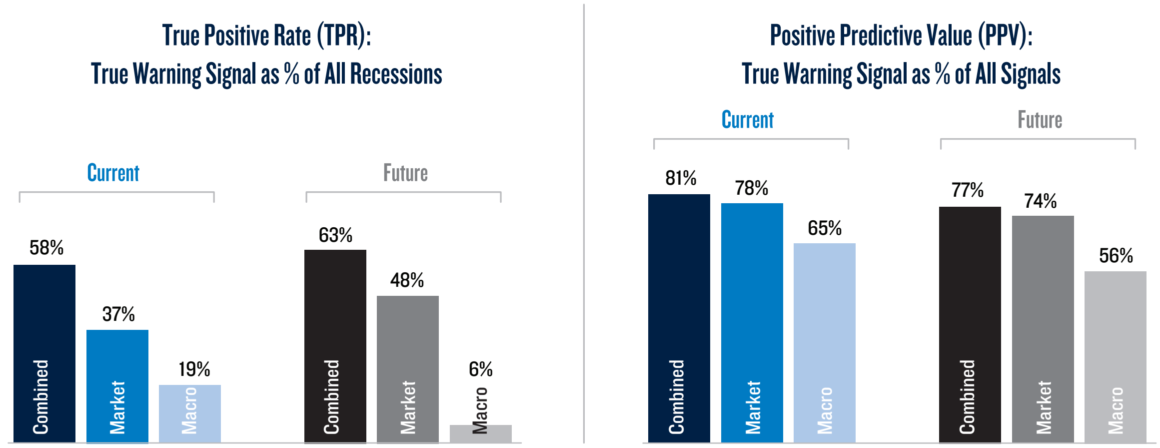
8 In Appendix 2 we evaluate the signal quality of a wider range of probability readings, the quality of a negative ("all-clear") signal and the trade-off between a low signal threshold that may flash red too frequently, and a high signal threshold that may not flash red often enough.

picked up by a warning signal (*i.e.,* True Positive Rate) and 81% of warning signals are accurate (*i.e.,* Positive Predictive Value); the future recession signal has similarly strong metrics (63% and 77%, respectively). However, signals based on market data alone are considerably weaker, and macro-based signals are weaker still.

Combining both market and macro information leads to a stronger and more reliable recession signal, dominating recession signals coming from either market or macro variables separately.

Figure 5: Probability of Recession Warning Signal Quality

(Warning Signal Is a Recession Probability Reading ≥ 60%)



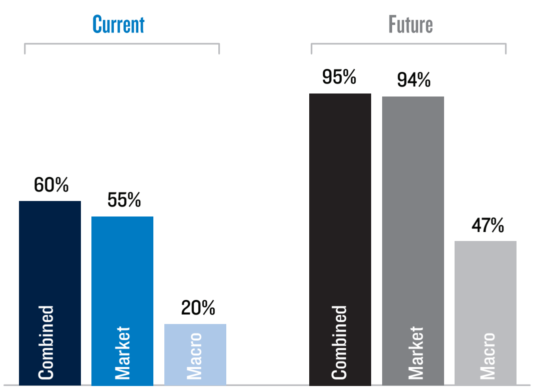
Note: Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. The True Positive Rate is the count of true positive (TP) signals relative to all recessions, true positives plus false negatives (FN): TP⁄(TP+FN). Positive Predictive Value is the count of true positive signals relative to all positive signals, both true and false: TP⁄(TP+FP). Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Parsing Market and Macro Cross Currents

As of March 2023, the estimated probability of a *current* recession, based on combining market and macro variables, is 60%, and the probability of a *future* US recession over the next 1-12m is 95% (Figure 6). Beneath these elevated risk assessments are dramatic crosscurrents, with market variables and macro variables giving conflicting signals. Based on market variables alone, the probability of a current recession is 55% while the probability of a future recession is 94%. In contrast, based on macro variables alone, the probability of a current recession falls to 20% and that of a future recession is 47%. While it is not unusual for market variables alone and macro variables alone to lead to (widely) different recession probabilities, currently the gap between recession probabilities (the "GAP") is near the top of its historical range (Figure 7).

Figure 6: Estimated Probability of Current & Future US Recession

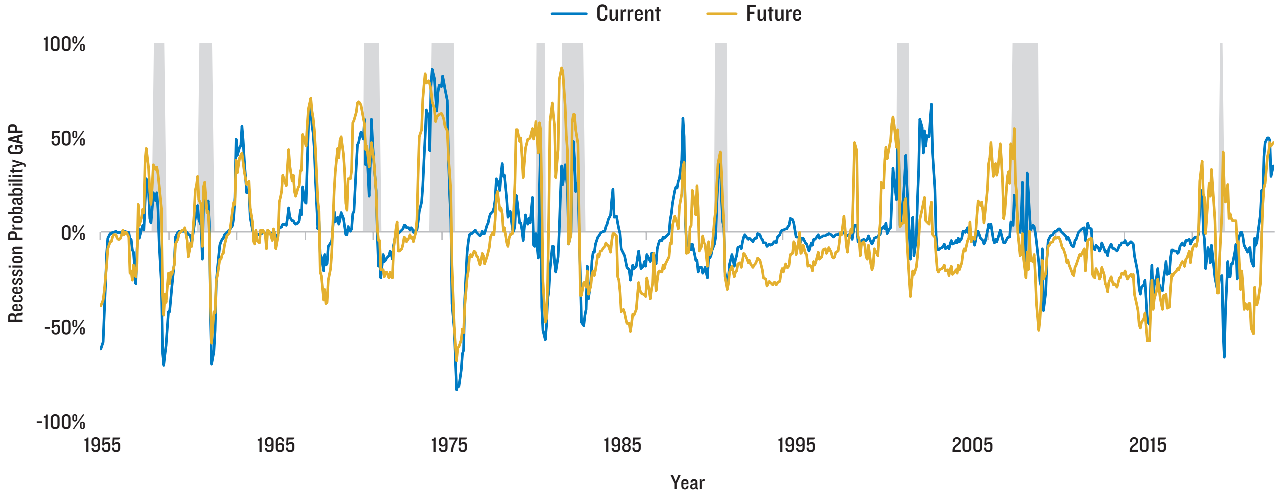
(as of March 2023)



Note: Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Figure 7: Recession Probability GAP: Difference in Market-Driven *vs.* Macro-Driven Recession Probability

(1954-2023)



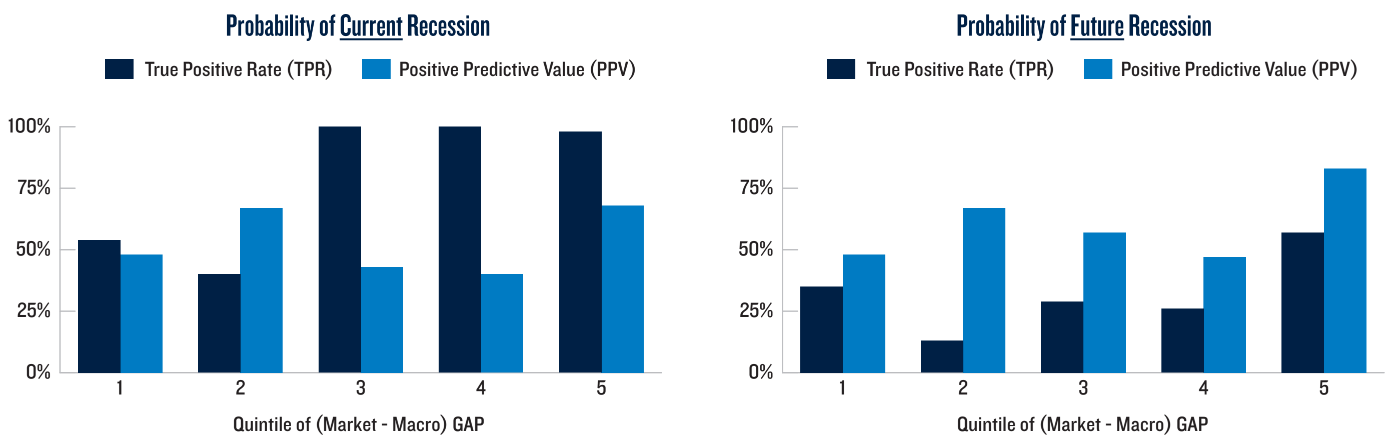
Note: Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. Grey shading indicates NBER recession months. Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Importantly, the signal quality from combining market and macro variables does not deteriorate even when there is a large discrepancy between what market variables and macro variables are saying on their own (Figure 8). In fact, realized recessions coincide more with elevated probability readings when the GAP is widest (in either direction), with quantitative measures of signal strength (*e.g.,* TPR and PPV) as high if not higher when the GAP is widest (*i.e.,* 1st and 5th quintiles). Contradictory indications from market and macro models are not a reason to doubt the clarity and quality of the signal that comes from a combined model.

Reliable recession warning signals can be generated even when market and macro forces are not synchronized, highlighting the advantages of combining different types of inputs. Do not discount any apparent disagreement between market and macro models. In fact, recession signal quality does not deteriorate when market *vs.* macro model disagreement is greatest.

Figure 8: Warning Signal Quality by Market-Macro Probability GAP

(Warning Signal Is a Recession Probability Reading ≥ 60%)



Note: Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. True Positive Rate is the count of true positive signal readings relative to all recessionary periods, true positives plus false negatives: TP/(TP+FN). Positive Predictive Value is the count of true positive readings relative to all positive readings, both true and false: TP/(TP+FP). GAP is the difference between market model and macro model recession probabilities. Quintiles are taken over the full history. Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Market Implications – Changes in Recession Probability (Not Levels) Matter

Figure 9 shows that elevated recession risk tends to be a lagging indicator for the performance of risky assets. By the time probability models signal recession (*e.g.*, a probability reading ≥ 60%), US equities have already declined and are poised to rally, perhaps after a pause. For example, in the 12m before the estimated probability of a *current* recession hits 60%, the S&P 500 has, on average, already declined by 10% (across 9 non-overlapping episodes from 1954 to 2023). During the subsequent 12m, the equity market pauses for about 6m and then rallies 10% over the ensuing 6m. Similarly, when the probability of a *future* recession first hits 60%, equities have already paused for about a year and subsequently rally by about 10% without any further pause. In contrast to stocks, bonds tend to increase steadily.

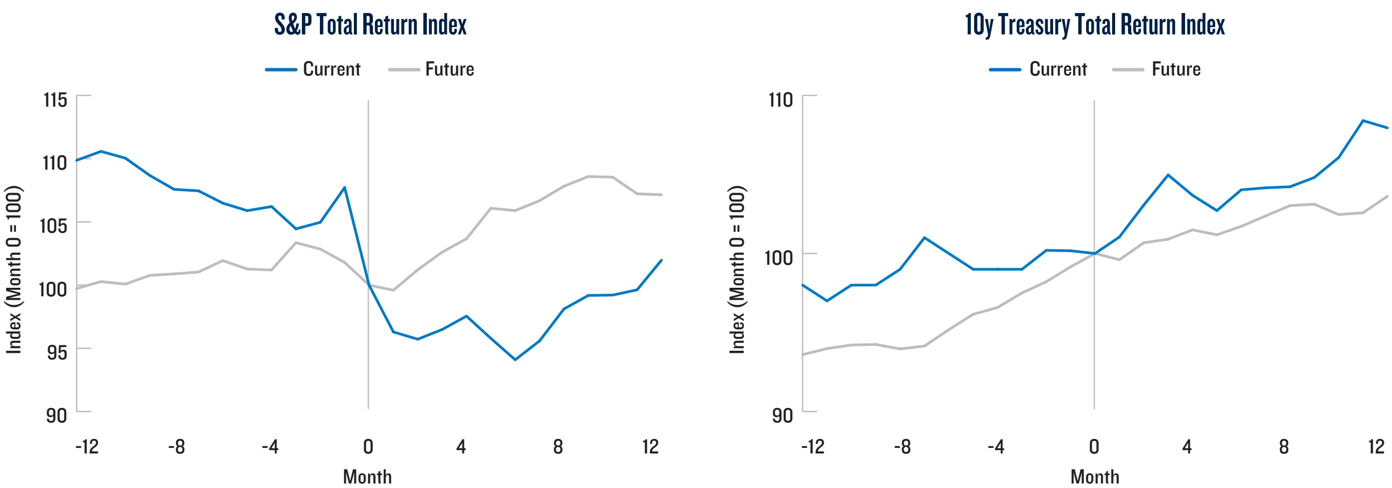
Importantly, the *change* in recession probabilities has far more significant and consistent implications for market performance (Figure 10).

- **Falling *vs.* Rising:** Regardless of level, annualized forward excess total stock returns are higher when the probability of recession (either current or future) is falling relative to when the probability of recession is rising. For example, the average forward 6m excess return is 1.3%/y when the probability is rising and 4.8%/y when it is falling. In the short-term, say on a forward 1m and 3m basis, when the probability of recession is rising, average excess stock returns (-2.8%/y and 0.1%/y respectively) are below average excess bond returns (2.1%/y and 1.1%/y, respectively), though underperformance relative to bonds is not evident at longer horizons.
- **High & Rising *vs.* High & Falling:** When the probability of recession (either current or future) is high & rising, excess stock returns are the weakest and tend to underperform bonds, while a high & falling environment is best. For example, when the current recession probability is high & rising, the average 3m annualized forward excess stock return is -11.7%/y *vs.* the average bond excess return of 3.1%/y. Similarly, when the future recession probability is high & rising, the average 3m annualized forward excess stock return is -4.2%/y *vs.* the average bond excess return of -2.7%/y. In contrast, the average 3m annualized forward excess stock return is 22.3%/y when the current recession probability is high & falling and 8.8%/y when the probability of a future recession is high & falling. Note that these stark differences all are with reference to high probability readings, which underscores the fact that it is not the level of recession risk, but its direction of change, that is most relevant for forward market returns.

By the time recession probabilities are elevated, the stock market has generally already declined, and, perhaps after a pause, is more likely to rally than sell off further.
A better indicator for forward excess stock returns is the change in recession probability, not the level.
Specifically, excess stock returns are weakest when the probability of a recession is high & rising and are strongest when the probability of a recession is high & falling.

Figure 9: Stock and Bond Total Excess Return Index Performance Before and After 60% Recession Probability Reading

(S&P 500 and 10y Treasury total excess return indices; month 0 = 100; non-overlapping average; 1954-2023)



Note: Month 0 is defined as the month in which the estimated probability of recession hits a specific threshold (60%). Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Figure 10: Forward Stock and Bond Total Excess Returns by Recession Probability Environment[9]

Annualized Average Excess Total Return When the...																	
Asset	Forward Return Window	Probability of Current Recession Is...								Probability of Future Recession Is...							
		High (≥ 60%)	Low (<60%)	Rising	Falling	High & Rising	High & Falling	Low & Rising	Low & Falling	High (≥ 60%)	Low (<60%)	Rising	Falling	High & Rising	High & Falling	Low & Rising	Low & Falling
S&P 500	+1m	-3.0%	3.4%	-2.8%	8.8%	**-27.7%**	**30.6%**	0.3%	6.7%	-1.6%	4.0%	1.1%	4.6%	**-5.0%**	**3.1%**	3.1%	5.0%
	+3m	3.8%	2.9%	0.1%	6.0%	**-11.7%**	**22.3%**	1.5%	4.4%	1.3%	3.5%	1.2%	5.0%	**-4.2%**	**8.8%**	3.0%	4.1%
	+6m	7.9%	2.5%	1.3%	4.8%	**-2.7%**	**19.7%**	1.8%	3.3%	0.8%	3.8%	2.2%	4.0%	**-4.2%**	**7.4%**	4.2%	3.3%
	+12m	9.5%	2.4%	1.7%	4.4%	**5.2%**	**14.3%**	1.3%	3.4%	-1.0%	4.2%	2.4%	3.8%	**-4.9%**	**4.0%**	4.7%	3.8%
10y Treasury	+1m	4.6%	0.5%	2.1%	-0.5%	**12.2%**	**-3.6%**	1.1%	-0.1%	-1.4%	1.5%	2.0%	-0.4%	**-1.8%**	**-0.9%**	3.3%	-0.3%
	+3m	3.1%	0.6%	1.1%	0.6%	**3.1%**	**3.1%**	0.9%	0.4%	-1.6%	1.6%	1.1%	0.6%	**-2.7%**	**-0.1%**	2.4%	0.8%
	+6m	2.0%	0.8%	0.5%	1.3%	**-0.1%**	**4.3%**	0.6%	1.0%	-1.3%	1.5%	0.7%	1.0%	**-2.3%**	**0.0%**	1.7%	1.3%
	+12m	1.7%	0.9%	0.8%	1.1%	**0.1%**	**3.4%**	0.9%	0.9%	-0.5%	1.4%	0.7%	1.2%	**-1.3%**	**0.5%**	1.4%	1.4%

Note: Asset class returns are calculated based on a total return price index. Excess returns are relative to 3m LIBOR. Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Acknowledgments

We wish to thank Dr. Guillermo Felices (PGIM Fixed Income), Sarah Griffin (PGIM), Dr. Taimur Hyat (PGIM), and George Jiranek (PGIM Fixed Income) for their valuable comments and suggestions.

9 See Appendix 4, Figure A9 for Sharpe ratio of forward stock returns by recession probability environment.

Appendix 1: Model Details and Results

We use a logistic model to estimate the probability of a binary event, say, if the US economy will be in recession or not in a given month.

Starting with a binary dependent variable of interest, $\boldsymbol{Y_t}$, assume that the probability that it is equal to 1 has a logistic probability density function and depends on some independent variables, $\boldsymbol{x_{it}}$:

$$P(Y_t = 1|x_t) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + \dots + \varepsilon_t)}} \quad (1)$$

Then the log odds ratio can be written as:

$$ln\left[\frac{P(Y_t = 1|x_t)}{1 - P(Y_t = 1|x_t)}\right] = \beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + \dots + \varepsilon_t \quad (2)$$

In our case, the $\boldsymbol{x}$'s are either market variables <u>and</u> macro variables combined, market variables alone, or macro variables alone. The dependent variable is binary, taking on a value of 1 or 0 depending on if the US is in recession or not. We use two alternative definitions for being in a recession: either if the US is currently in recession at time t or if the US is in recession at any time within the next 1-12m.

$$Y_t = \begin{cases} 1, & month\ t\ is\ in\ a\ reccesion \\ 0, & month\ t\ is\ not\ in\ a\ reccesion \end{cases} \text{ or } Y_t = \begin{cases} 1, & month\ t+1, \dots, \text{or } t+12\ is\ in\ a\ reccesion \\ 0, & month\ t+1, \dots, \text{or } t+12\ is\ not\ in\ a\ reccesion \end{cases} \quad (3)$$

Note $\boldsymbol{\beta_i}$ is the marginal effect that variable $\boldsymbol{x_i}$ has on the *log odds of a recession*, not the marginal effect that variable $\boldsymbol{x_i}$ has on the probability of recession. The transformation of the $\boldsymbol{\beta_i}$'s into marginal changes in the probability of recession is non-linear and needs to be evaluated at specific values of (all) $\boldsymbol{x_i}$'s, which we set to be their (the $\boldsymbol{x_i}$'s) mean values. Also note that because the logit regression model is non-linear, the usual goodness of fit measures are not applicable, instead a "pseudo-R^2" is used as a measure of goodness of fit (defined as 1 – the ratio of the log likelihood function of the assumed model to the log likelihood of the null hypothesis), with many of the same properties and interpretation. (In addition, in the reported results, we adjust the pseudo-R^2 for the number of estimated parameters as if the R^2 was from a linear regression.)

Data construction details:

- Monthly recession dates are based on NBER Business Cycle dating committee classifications
- **SP500** is the monthly contemporaneous trailing 12m return in the S&P 500 total return index
- **YC** is the contemporaneous monthly average difference between the 10y Treasury yield and the effective Fed funds rate
- **IP** is the monthly contemporaneous trailing 12m percent change in US industrial production
- **PAY** is the monthly contemporaneous trailing 12m percent change in US non-farm payrolls

Estimation details:

We use the logit model described in Equation 1 for two different dependent variables and three sets of independent, explanatory variables. To estimate the probability of a *current* recession, $\boldsymbol{p(Y_t = 1|\ x_t)}$, the dependent variable is scored 1 if there is a recession in that month and 0 otherwise. To estimate the probability of a *future* recession, $\boldsymbol{p(Y_{t+1} = 1|\ x_t)}$, the dependent variable is scored 1 if there is a recession anytime in the next 1-12m period. For each of the two dependent variables, there are three sets of explanatory variables (represented by the $\boldsymbol{x}$'s in equation 1): (1) market variables alone, (2) macro variables alone, and (3) market variables and macro variables together – for a total of six smodels. All models are estimated using the monthly data from 1954 to 2019 as described above. Note our estimation period excludes the 2020 recession. Estimation results are in Figure A1.

Figure A1: Recession Probability Models: Estimated Coefficients, Marginal Effects and Goodness of Fit

	Probability of Current Recession: $p(Y_t = 1 \mid x_t)$					
	Coefficient Estimates			Marginal Effects (Evaluated at the Means)		
	(1) Combined	(2) Market	(3) Macro	(4) Combined	(5) Market	(6) Macro
SP500	**-12.74*****	**-13.62*****		**-0.26*****	**-0.53*****	
YC	**-74.17*****	**-42.82*****		**-1.49*****	**-1.67*****	
IP	**-26.15*****		**-37.47*****	**-0.53*****		**-2.69*****
PAY	-18.50		25.02**	-0.37		1.80**
Adjusted R^2	0.58	0.42	0.27	0.58	0.42	0.27

	Probability of Future Recession: $p(Y_{t+1} = 1 \mid x_t)$					
	Coefficient Estimates			Marginal Effects (Evaluated at the Means)		
	(1) Combined	(2) Market	(3) Macro	(4) Combined	(5) Market	(6) Macro
SP500	**-6.83*****	**-7.84*****		**-0.90*****	**-1.15*****	
YC	**-196.40*****	**-135.28*****		**-25.84*****	**-19.92*****	
IP	-0.75		**-23.92*****	-0.10		**-4.57*****
PAY	**-57.14*****		38.13***	**-7.52*****		7.28***
Adjusted R^2	0.50	0.41	0.01	0.50	0.41	0.01

Note: Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime over the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. *** / ** / * indicates significance at the 1% / 5% / 10% level, respectively; bold font signifies significance and correct sign. Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Appendix 2: Signal Strength

Model signals typically are evaluated based on four metrics (Figure A2):

(1) **True Positive Rate (TPR):** The ratio of true positives to all realized recessions (true positives + false negatives), capturing how often a realized recession coincides with a positive signal (***TP/(TP+FN)***).

(2) **Positive Predictive Value (PPV):** The ratio of true positives to all positives, both true and false, capturing how often a positive signal coincides with a realized recession (***TP/(TP+FP)***).

(3) **True Negative Rate (TNR):** The ratio of true negatives to all realized non-recessions (true negatives + false positives), capturing how often a non-recessionary period coincides with a negative signal (***TN/(TN+FP)***).

(4) **Negative Predictive Value (NPV):** The ratio of true negatives to all negatives, both true and false, capturing how often a negative signal coincides with a realized non-recessionary period (***TN/(TN+FN)***).

All four signal quality metrics for all six of our estimated recession probability models and for a range of signal threshold values (50%, 60%, 70% and 80%) are presented in Figure A3.

Figure A5 illustrates the tradeoff inherent in choosing a signal threshold by plotting the True Positive Rate and the Positive Predictive Value across the entire range of possible warning signals (0% to 100% probability of recession). The top panel shows that the percent of recessions accurately picked up by the warning signal *falls* as the signal rises; the bottom panel shows that the percent of warning signals that are accurate *rises* as the level of the signal rises. At very low signal readings, every recession is captured, but the percent of true warnings is low, and the percent of false warnings is high. As the signal threshold gets higher, the percent of recessions that get picked up falls, but the percent of true warning signals rises.

Figure A2: Metrics for Assessing Signal Strength

	Predicted Recession		Predicted No Recession		Sum	Ratio
Realized Recession	TP	+	FN	=	Realized Positive (RP)	TPR = TP/RP
	+		+			
Realized No Recession	FP	+	TN	=	Realized Negative (RN)	TNR = TN/RN
	=		=			
Sum	Predicted Positive (PP)		Predicted Negative (PN)		Total = RP + RN = PP + PN	
Ratio	PPV = TP/PP		NPV = TN/PN			

Source: PGIM IAS. For illustrative purposes only.

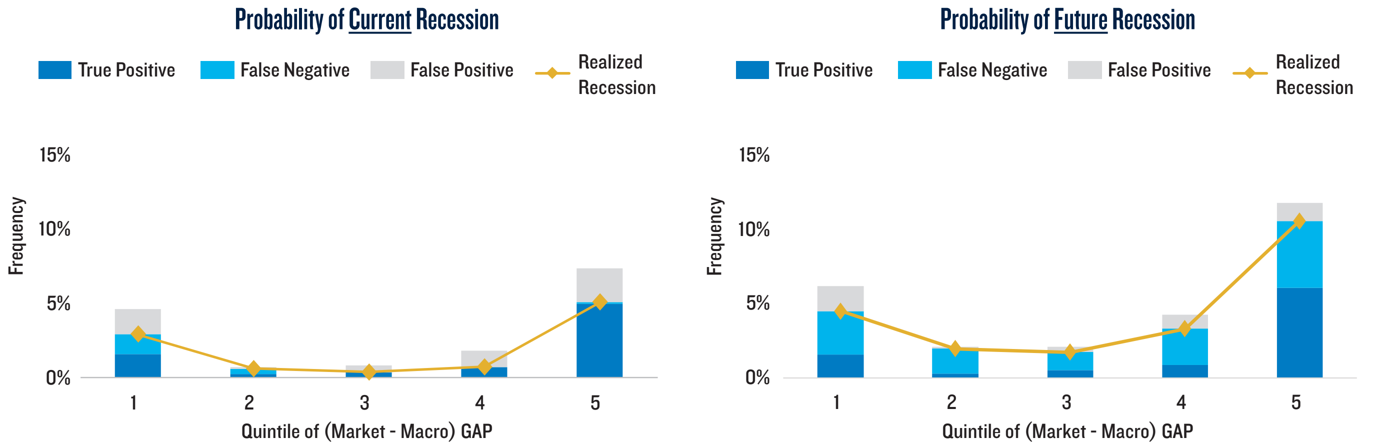
Figure A3: Assessing Recession Probability Model Signal Strength

Signal (≥)	Frequency	True Positive Rate	Positive Predictive Value	True Negative Rate	Negative Predictive Value
Probability of Current Recession – Market and Macro Variables Combined					
50%	11%	62%	75%	97%	94%
60%	10%	58%	81%	98%	94%
70%	9%	55%	86%	99%	93%
80%	7%	46%	88%	99%	92%
Probability of Current Recession – Market Variables Alone					
50%	9%	42%	60%	96%	91%
60%	7%	37%	78%	98%	91%
70%	4%	30%	94%	100%	90%
80%	3%	22%	100%	100%	89%
Probability of Current Recession – Macro Variables Alone					
50%	6%	28%	63%	97%	90%
60%	4%	19%	65%	98%	88%
70%	3%	16%	67%	99%	88%
80%	2%	11%	71%	99%	88%
Probability of Future Recession – Market and Macro Variables Combined					
50%	25%	70%	75%	92%	89%
60%	22%	63%	77%	93%	87%
70%	19%	54%	78%	95%	85%
80%	15%	45%	83%	97%	83%
Probability of Future Recession – Market Variables Alone					
50%	24%	62%	71%	91%	87%
60%	17%	48%	74%	94%	83%
70%	12%	37%	82%	97%	81%
80%	10%	31%	83%	98%	79%
Probability of Future Recession – Macro Variables Alone					
50%	8%	13%	45%	94%	74%
60%	3%	6%	56%	98%	74%
70%	1%	2%	67%	100%	73%
80%	0%	0%	N/A	100%	73%

Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

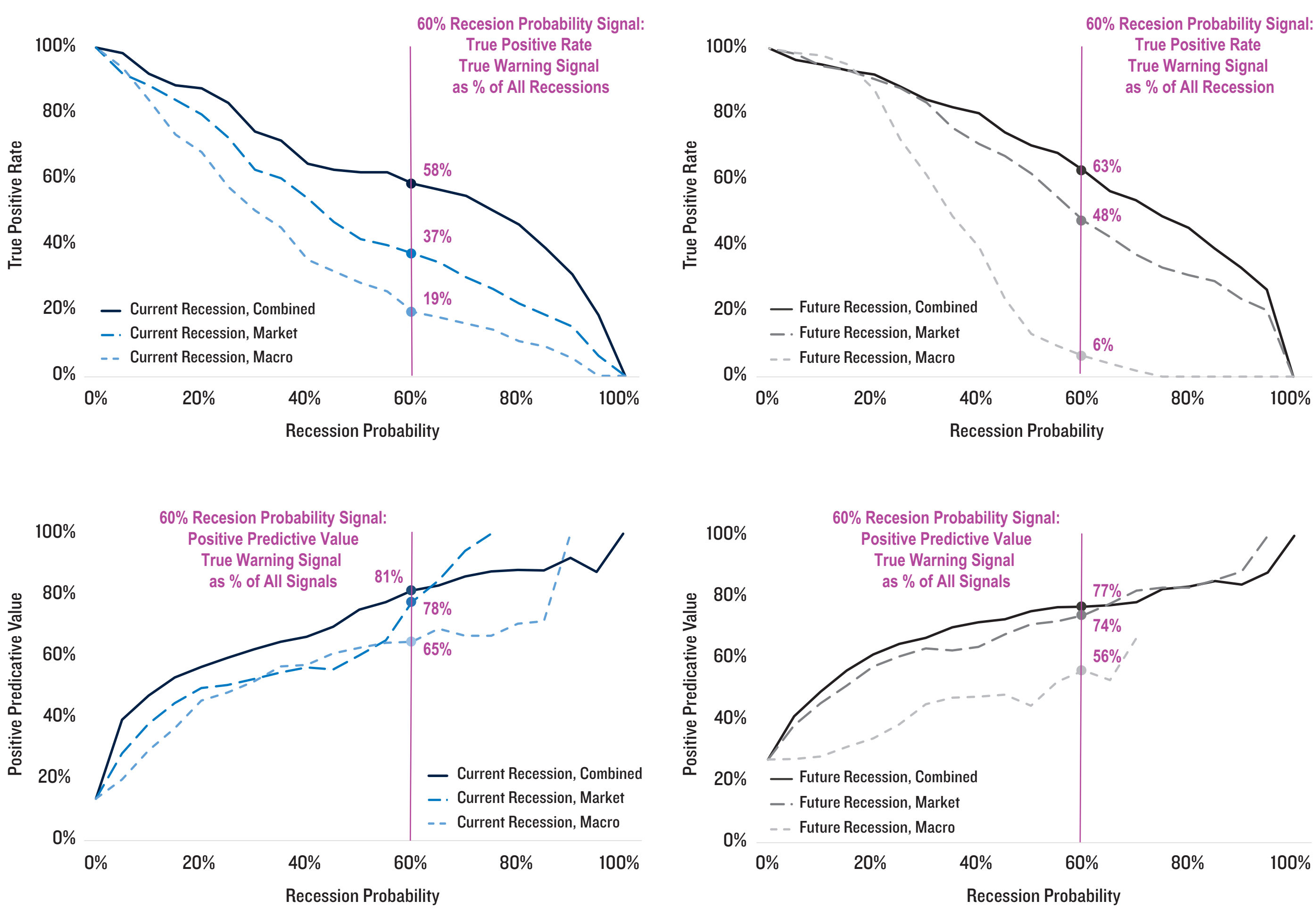
Figure A4: Warning Signal Quality by Probability GAP Quintile

(GAP is the Difference between Market and Macro Recession Probabilities, Warning Signal Is a Recession Probability Reading ≥ 60%)



Note: Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. True Positive Rate is the count of true positive signal readings relative to all recessionary periods, true positives plus false negatives: TP/(TP+FN). True Negative Rate is the count of true negative signals to all non-recessionary periods: TN/(TN+FP). Positive (Negative) Predictive Value is the count of true positive (negative) readings relative to all positive (negative) readings, both true and false: TP/(TP+FP) and TN/(TN+FN). GAP is the difference between market model and macro model recession probabilities. Quintiles are taken over the full history. Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Figure A5: Estimated Recession Probability Signal Quality



Note: Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. True Positive Rate is the count of true positive signals relative to all recessions, true positives plus false negatives: TP/(TP+FN). Positive Predictive Value is the count of true positive signals relative to all positive signals, both true and false: TP/(TP+FP). Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Appendix 3: Alternative Recession Probability Models

In our study of recession probability models, we devote little time to explanatory variable selection or functional form specification of the estimated probability model. There is a rich literature on these issues. But to benchmark the performance of our parsimonious model, we present several other (mostly publicly available) models here:[10]

(1) **Federal Reserve Board Research Excess Bond Premium Implied Recession Risk Over the Next 12m (Fed Board Research):** "The Excess Bond Premium, as introduced by Gilchrist and Zakrajsek (2012), is a *corporate bond credit spread net of expected defaults* that is intended to measure corporate bond risk appetite and act as a *leading indicator* of economic downturns."*

(2) **Federal Reserve Bank of New York Probability of Recession 12m Ahead (NY Fed):** "This model uses the difference between *10-year and 3m Treasury rates* to estimate the probability of a recession in the United States *12m ahead*. End of period is calculated by Haver Analytics based upon coefficients estimated by the Federal Reserve Bank of New York."*

(3) **Haver Analytics Probability of US Recession 12m Ahead (Haver):** "The monthly probability of a U.S. recession predicted by near-term Treasury spread is calculated by Haver Analytics based on the methodology outlined in the Federal Reserve Board's Finance and Economics Discussion Series (FEDS) Note entitled "(Don't Fear) The Yield Curve" and elaborated on in a working paper titled "The Near-Term Forward Yield Spread as a Leading Indicator: A Less Distorted Mirror" by Eric C. Engstrom and Steven A. Sharpe. The model uses the *difference between the 3m forward Treasury rate beginning 18m ahead and the 3m Treasury bill* to estimate the probability of a *recession in the United States 12m ahead*. Average is based on the probability derived from the average monthly interest rate spread."*

(4) **Federal Reserve Bank of St. Louis Smoothed Recession Probability (St. Louis Fed: Smoothed):** "Data are calculated by Jeremy Piger at the University of Oregon using a dynamic-factor Markov-switching (DFMS) model applied to four variables: *nonfarm payroll employment, industrial production index, real personal income excluding transfer payments, and real manufacturing and trade sales.* These probabilities use the DFMS model with Bayesian estimation techniques developed in Kim and Nelson (1998, Review of Economics and Statistics). The DFMS model was originally developed by Marcelle Chauvet in "An Econometric Characterization of Business Cycle Dynamics with Factor Structure and Regime Switches," International Economic Review, 1998. Smoothed recession probabilities calculated from the original DFMS model using maximum likelihood estimation techniques are produced monthly by Marcelle Chauvet. *Three months of probabilities above 80% have been a historical indicator of the start of a recession.* Three months below 20% have generally signaled the start of an expansion. The series is generally updated on or just before the first of each month with a two-month lag, which is due to the lag in release of the real manufacturing and trade sales variable by the U.S. Census Bureau."*

(5) **Federal Reserve Bank of St. Louis GDP-Based Recession Probability (St. Louis Fed: GDP-Based):** "This index measures *the probability that the U.S. economy was in a recession during the indicated quarter*. It is based on a mathematical description of the way that recessions differ from expansions. The index corresponds to the probability (measured in percent) that the underlying true economic regime is one of recession based on the available data. Whereas the NBER business cycle dates are based on a subjective assessment of a variety of indicators that may not be released until several years after the event, this index is entirely mechanical, is *based solely on currently available GDP data* and is reported every quarter. Due to the possibility of data revisions and the challenges in accurately identifying the business cycle phase, the index is calculated for the quarter just preceding the *most recently available GDP numbers*. Once the index is calculated for that quarter, it is never subsequently revised. The value at every date was inferred using only data that were available one quarter after that date and as those data were reported at the time."*

Currently, recession estimates are quite widespread, ranging from 1% to 95% (see Figure 1 above, which includes the PGIM IAS recession probability models for comparison). Looking back over their entire histories, these recession probability estimates are not particularly correlated with one another (Figure A6). Signal quality metrics for these models are presented in Figure A7, with historical recession probability time series plotted in Figure A8.

10 * Descriptions for models (1)-(4) are taken directly from Haver Analytics' US Recession Probability module, with emphases ours. Description for model (5) is from *FRED*, Federal Reserve Bank of St. Louis in reference to GDP-Based Recession Indicator Index [JHGDPBRINDX]. NY Fed recession probability estimates are not official forecasts of the Federal Reserve Bank of New York, its president, the Federal Reserve System, or the Federal Open Market Committee. Source: Bureau of Labor Statistics, Chauvet, Marcelle and Piger, Jeremy Max, Smoothed U.S. Recession Probabilities [RECPROUSM156N], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/RECPROUSM156N, April 26, 2023., Favara, Giovanni, Simon Gilchrist, Kurt F. Lewis, Egon Zakrajšek (2016). "Updating the Recession Risk and the Excess Bond Premium," FEDS Notes. Washington: Board of Governors of the Federal Reserve System, October 6, 2016, https://doi.org/10.17016/2380-7172.1836, Federal Reserve Bank of New York, "The Yield Curve as a Leading Indicator," https://www.newyorkfed.org/research/capital_markets/ycfaq.html, and Haver Analytics.

Figure A6: Correlation of Estimated Recession Probabilities

Correlation	IAS: Current, Combined	IAS: Current, Market	IAS: Current, Macro	IAS: Future, Combined	IAS: Future, Market	IAS: Future, Macro	Fed Board Research	NY Fed	St. Louis Fed: Smoothed	St. Louis Fed: GDP-Based	Haver	Average
IAS: Current, Combined		0.8	0.7	0.7	0.5	0.5	0.6	0.3	0.7	0.7	0.2	0.6
IAS: Current, Market	0.8		0.4	0.6	0.7	0.4	0.6	0.3	0.6	0.6	0.2	0.5
IAS: Current, Macro	0.7	0.4		0.3	0.1	0.8	0.5	-0.1	0.6	0.4	-0.1	0.4
IAS: Future, Combined	0.7	0.6	0.3		0.9	0.3	0.4	0.7	0.5	0.6	0.7	0.6
IAS: Future, Market	0.5	0.7	0.1	0.9		0.3	0.3	0.8	0.4	0.6	0.7	0.5
IAS: Future, Macro	0.5	0.4	0.8	0.3	0.3		0.4	0.1	0.4	0.4	0.1	0.4
Fed Board Research	0.6	0.6	0.5	0.4	0.3	0.4		0.0	0.6	0.5	0.0	0.4
NY Fed	0.3	0.3	-0.1	0.7	0.8	0.1	0.0		0.1	0.4	0.9	0.3
St. Louis Fed: Smoothed	0.7	0.6	0.6	0.5	0.4	0.4	0.6	0.1		0.7	0.0	0.5
St. Louis Fed: GDP-Based	0.7	0.6	0.4	0.6	0.6	0.4	0.5	0.4	0.7		0.3	0.5
Haver	0.2	0.2	-0.1	0.7	0.7	0.1	0.0	0.9	0.0	0.3		0.3

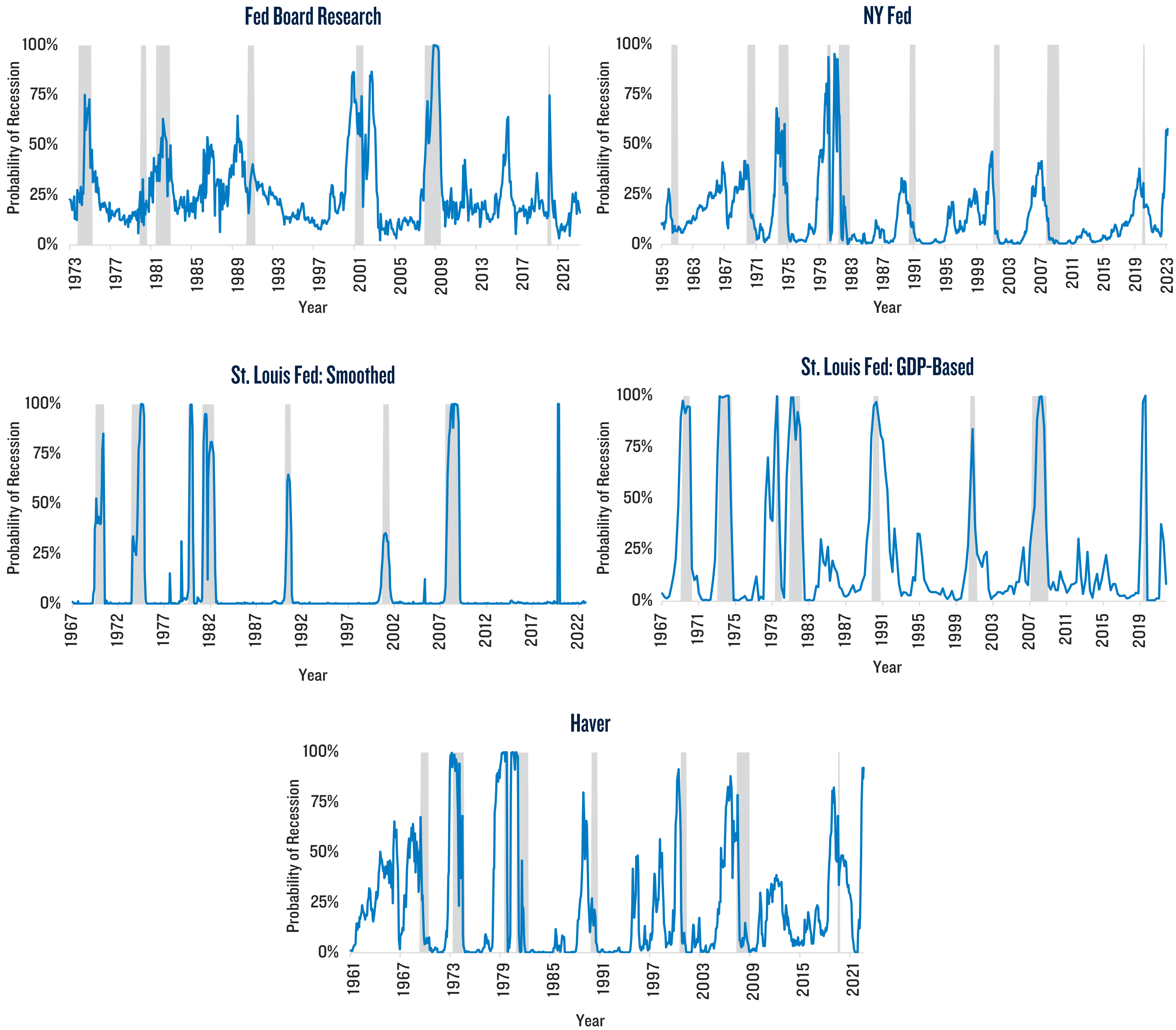
Source: Bureau of Labor Statistics, Federal Reserve Bank of New York, Federal Reserve Bank of St. Louis, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Figure A7: Assessing Recession Probability Model Signal Strength
(Warning Signal Is a Recession Probability Reading ≥ 60%)

Model	Input Type	Recession Lookahead	Signal Strength of Predicting Recession	
			True Positive Rate	Positive Predictive Value
Fed Board Research	Market Variables Alone	Future 12m	32%	60%
NY Fed	Market Variables Alone	Future 12m	7%	37%
St. Louis Fed: Smoothed	Macro Variables Alone	Current Month	53%	100%
St. Louis Fed: GDP-Based	Macro Variables Alone	Current Quarter	77%	69%
Haver	Market Variables Alone	Future 12m	22%	23%
IAS: Current, Combined	Combined	Current Month	58%	81%
IAS: Current, Market	Market Variables Alone	Current Month	37%	78%
IAS: Current, Macro	Macro Variables Alone	Current Month	19%	65%
IAS: Future, Combined	Combined	Future 1-12m	63%	77%
IAS: Future, Market	Market Variables Alone	Future 1-12m	48%	74%
IAS: Future, Macro	Macro Variables Alone	Future 1-12m	6%	56%

Source: Bureau of Labor Statistics, Federal Reserve Bank of New York, Federal Reserve Bank of St. Louis, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Figure A8: Estimated Probability of Recession, Various Models (1954-2023)*



* Time period depends on model-specific data availability. Source: Bureau of Labor Statistics, Federal Reserve Bank of New York, Federal Reserve Bank of St. Louis, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Appendix 4: Risk-Adjusted Returns by Recession Probability Environment: Market and Macro Variables Combined

Figure A9: Forward Return Sharpe Ratios by Recession Probability Environment

Forward Return Sharpe Ratios When the...		Probability of Current Recession Is...								Probability of Future Recession Is...							
Asset	Forward Return Window	High (≥60%)	Low (<60%)	Rising	Falling	High & Rising	High & Falling	Low & Rising	Low & Falling	High (≥60%)	Low (<60%)	Rising	Falling	High & Rising	High & Falling	Low & Rising	Low & Falling
S&P 500	+1m	-0.16	0.30	-0.21	0.79	**-1.36**	**2.22**	0.02	0.63	-0.11	0.35	0.09	0.38	**-0.39**	**0.19**	0.26	0.46
	+3m	0.17	0.23	0.01	0.45	**-0.49**	**1.29**	0.12	0.35	0.08	0.27	0.09	0.36	**-0.26**	**0.53**	0.23	0.32
	+6m	0.33	0.19	0.09	0.33	**-0.11**	**0.96**	0.13	0.24	0.04	0.28	0.15	0.26	**-0.24**	**0.36**	0.32	0.24
	+12m	0.44	0.16	0.11	0.29	**0.22**	**0.73**	0.09	0.24	-0.05	0.32	0.15	0.24	**-0.24**	**0.17**	0.35	0.28
10y Treasury	+1m	0.44	0.07	0.27	-0.06	**1.04**	**-0.45**	0.15	-0.02	-0.15	0.21	0.27	-0.05	**-0.21**	**-0.09**	0.47	-0.04
	+3m	0.28	0.08	0.14	0.07	**0.26**	**0.30**	0.12	0.04	-0.16	0.20	0.14	0.07	**-0.32**	**-0.01**	0.31	0.11
	+6m	0.17	0.09	0.06	0.15	**-0.01**	**0.35**	0.07	0.12	-0.13	0.19	0.09	0.12	**-0.26**	**0.00**	0.21	0.18
	+12m	0.15	0.10	0.09	0.13	**0.01**	**0.37**	0.10	0.10	-0.05	0.16	0.08	0.13	**-0.14**	**0.05**	0.16	0.16

Note: Asset class returns are calculated based on a total return price index. Excess returns are relative to 3m LIBOR. Estimated probability of a current (future) recession is based on logit regression; dependent variable equals 1 when the current month (anytime within the next 1-12m) is in recession (NBER defined) and 0 otherwise; regressors are contemporaneous values of SP500, YC, IP and PAY; models are estimated using monthly data from 1954-2019. Source: Bureau of Labor Statistics, Federal Reserve Board, Haver Analytics, NBER, Standard & Poor's and PGIM IAS. For illustrative purposes only.

More Publications from PGIM IAS

Publications

- Private *vs*. Public Investment Strategies – Reported and Real-World Performance *(May 2023)*
- Is There a Need for a Chief Liquidity Officer? *(January 2023)*
- Building Portfolios with Infrastructure: Performance, Cash Flows & Portfolio Allocation *(November 2022)*
- Portfolio Implications of a Positive Stock-Bond Correlation World *(November 2022)*
- Measuring the Value of a Portfolio Liquidity Line (*September 2022)*
- Stock-Bond Correlation: A Global Perspective (*June 2022*)
- Super Funds & Master Trusts in a World of Member Switching, Early Release Schemes & Climate Calamities *(March 2022)*
- The Rebalancing Conundrum: Private Equity Valuations and Market Dislocations *(December 2021)*
- A Rising Private Asset Class: Core+ Real Estate Debt *(July 2021)*
- Harnessing the Potential of Private Assets: A Framework For Institutional Portfolio Construction *(June 2021)*
- US Stock–Bond Correlation: What Are the Macroeconomic Drivers? (*May 2021*)
- Equity Portfolio Manager Active Risk and Information Ratio: How Does the Reward Vary with Active Risk? *(November 2020)*
- Building and Maintaining a Desired Exposure to Private Markets – Commitment Pacing, Cash Flow Modeling, and Beyond *(November 2020)*
- Next-Generation Commodity Benchmarks: RASA Benchmarks Designed to Align with CIO Investment Objectives *(November 2020)*
- Modeling Private Investment Cash Flows with Market-Sensitive Periodic Growth *(October 2020)*
- Riders in the Storm: How Volatility Events Affect Private Asset Class Performance *(June 2020)*
- The Probability of Recession: A Critique of a New Forecasting Technique *(June 2020)*
- What's in Your Real Asset Portfolio? *(May 2020)*
- Measuring the Value of LP Fund-Selection Skill *(April 2020)*
- Building a Better Portfolio: Balancing Performance and Liquidity *(joint with GIC Singapore - April 2020)*
- What is the Optimal Number of Equity Managers? A CIO Toolkit for Manager Allocation *(February 2020)*
- Institutional Gold! *(November 2019)*
- A Fair Comparison Framework: Risk and Return in Private & Public Investments *(October 2019)*
- Asset Allocation for "End-State" Portfolios *(September 2019)*
- The Diversity of Real Assets: Portfolio Construction for Institutional Investors *(April 2019)*
- The Tradeoff Between Liquidity and Performance: Private Assets in Institutional Portfolios *(January 2019)*
- Emerging Market Equity Benchmarks for Japanese Investors: Countries, Sectors or Styles? *(October 2018)*
- Forecasting Long-Term Equity Returns: A Comparison of Popular Methodologies *(September 2018)*
- What Can the Markets Tell Us about Future Economic Growth? *(September 2018)*
- How to Measure the Value of Adding a Cross-Sector Manager *(September 2018)*
- Anchor to Windward: Aligning Absolute Return Objectives *(May 2018)*
- When the Dust Flies: How Volatility Events Affect Asset Class Performance *(April 2018)*
- Asset Allocation with Illiquid Private Assets (*February 2018*)
- The Impact of Market Conditions on Active Equity Management *(March 2017)*

Bespoke Client Projects

- How to design a commodity benchmark aligned with a DB plan's objectives?
- Will my equity managers perform as expected in the next downturn?
- How should we allocate capital across our equity managers?

Case Studies

- Cenland Corporation (I) —The CIO and the Closing of the DB Plan *(December 2019)*
- Cenland Corporation (II) — The CIO and the Freezing of the DB Plan *(December 2020)*
- Cenland Corporation (III) – The CIO and the Transition to DC *(December 2021)*

The Differential

- Read our latest quarterly magazine, *The Differential* and past issues at *pgim.com/IAS/differential-newsletter*.

THE PURSUIT OF OUTPERFORMANCE