INSTITUTIONAL ADVISORY & SOLUTIONS

WHAT CAN THE MARKETS TELL US ABOUT FUTURE ECONOMIC GROWTH?

Historical Predictive Power of the Bond, Stock and Real Estate Markets

September 2018

AUTHORS

Sujian Zhi
Associate

Harsh Parikh, PhD
Principal
harsh.parikh@pgim.com
+1 973 802 3088

The PGIM Institutional Advisory & Solutions group advises institutional clients on a variety of asset allocation, portfolio construction, and risk management topics.

Do bond, stock and real estate markets provide useful signals for forecasting future GDP? Using market data since 1970, we examine several market signals and find that, in general, they have not been very helpful in predicting next year's GDP, or the change in next year's GDP versus last year.

If we fit the market signals to the full data period, the signals explained 48% of the variation in next year's GDP and 44% of the variation in the change of next year's GDP. However, what matters more to investors is the predictive power of market signals. In terms of prediction, where only contemporaneous market signals are used to form forecasts, the predictive power of market signals has been poor.

Relative to other market signals, the Treasury yield curve slope, stock market returns and the change in CAPE have exhibited better predictive power. However, even their absolute predictive power has been relatively low, and this power has fluctuated over time.

To improve the predictive power of market signals, we explore combining many signals, and selecting them dynamically. Nevertheless, the average prediction error (RMSE) for next year's annual GDP was 2.05 (in annual GDP percentage points), and 2.45 for the GDP change.

Introduction[1]

Investors often use their views of future GDP as an input when forecasting stock and bond market returns. It seems reasonable to turn this relationship around and argue that the bond, stock and real estate markets, which quickly incorporate investors' current expectations about the future, might contain useful signals regarding the economy's direction. In fact, the Conference Board's Leading Economic Index contains both a stock market and a bond market signal as leading indicators.

1 Many thanks to Junying Shen for her research assistance on this project.

PGIM

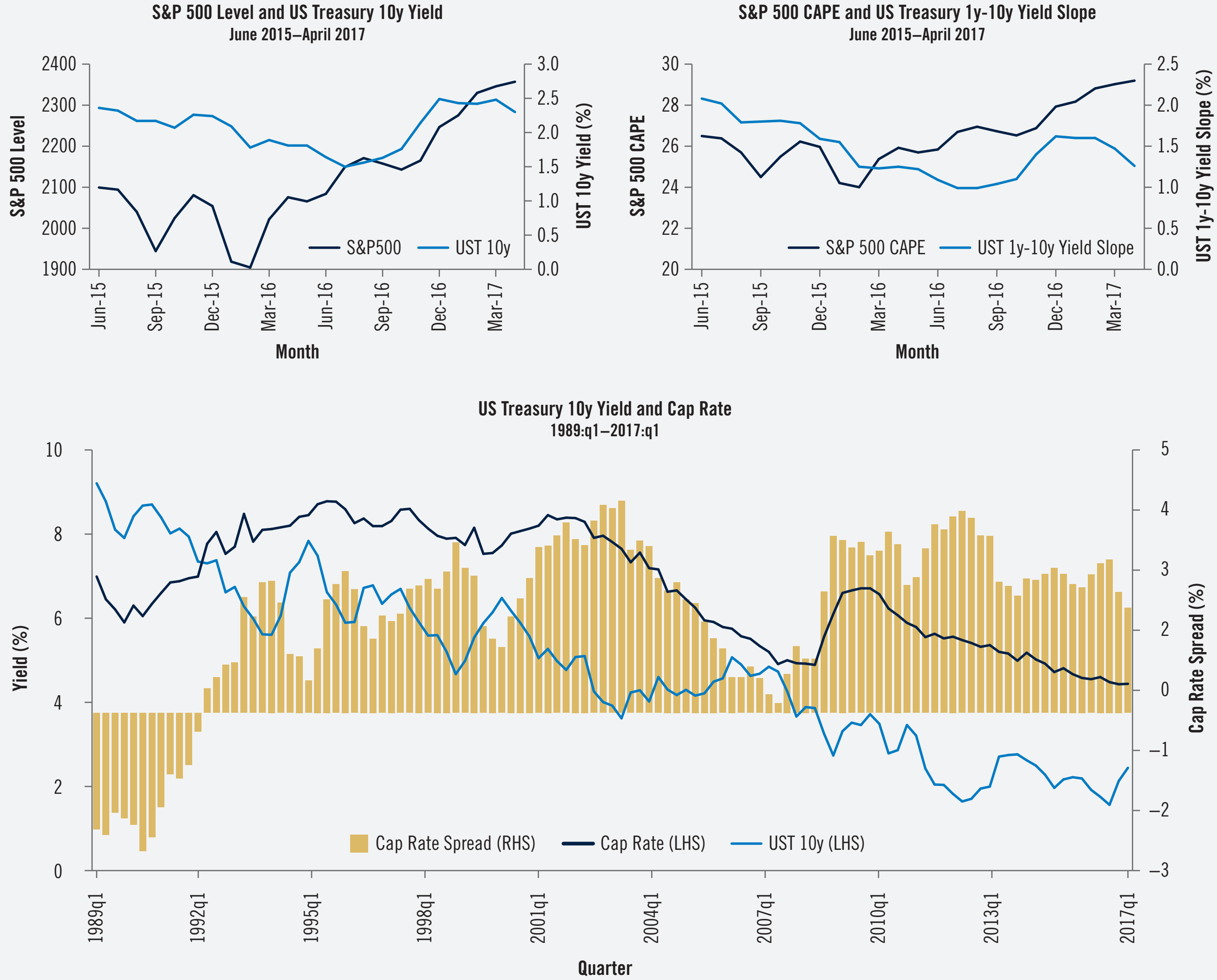
What are the bond and stock markets telling us about future economic growth? From Figure 1 we see that from October 2016 to April 2017, the stock market rose almost 10% to a record level (S&P 500 = 2,346). Also, a measure of equity market valuation, S&P 500 (SPX) CAPE, continued to rise reaching 29.2 in early April from 26.5 in October 2016. The equity market seemed to be sending a bullish signal on the economy.

In addition, 10y Treasury yields increased from an average of 1.76% in October to 2.48% in March 2017, suggesting faster growth ahead. However, yields subsequently fell back in April 2017, averaging 2.30%. Also, while the 1y-10y Treasury yield slope steepened from an average of 110bp in October 2016 to 147bp in March, which is a traditional bullish economic signal, the curve flattened back to 126bp in April 2017. The bond market seemed to be sending a tepid economic growth signal.

Real estate capitalization ("cap") rates for 2017 Q1 were 4.4%, lower than the pre-crisis low of 4.8% in 2008:q3. Low cap rates reflect investor willingness to pay higher property prices for a given level of property income. This suggested a bullish economic outlook. However, the spread between the cap rate and 10y Treasury yield, indicating the relative value of real estate income versus Treasury income, was still above its historical average suggesting a more muted economic outlook. The real estate market seemed to be sending a mixed signal.

In this report, we examine the historical record to see which market, if any, has provided a reliable signal for future economic activity.

Figure 1: Recent Signals from the Bond, Stock and Real Estate Markets
June 2015–April 2017



Source: Federal Reserve Bank of St. Louis, FRED; NCREIF; Professor Shiller's website (CAPE); and PGIM IAS

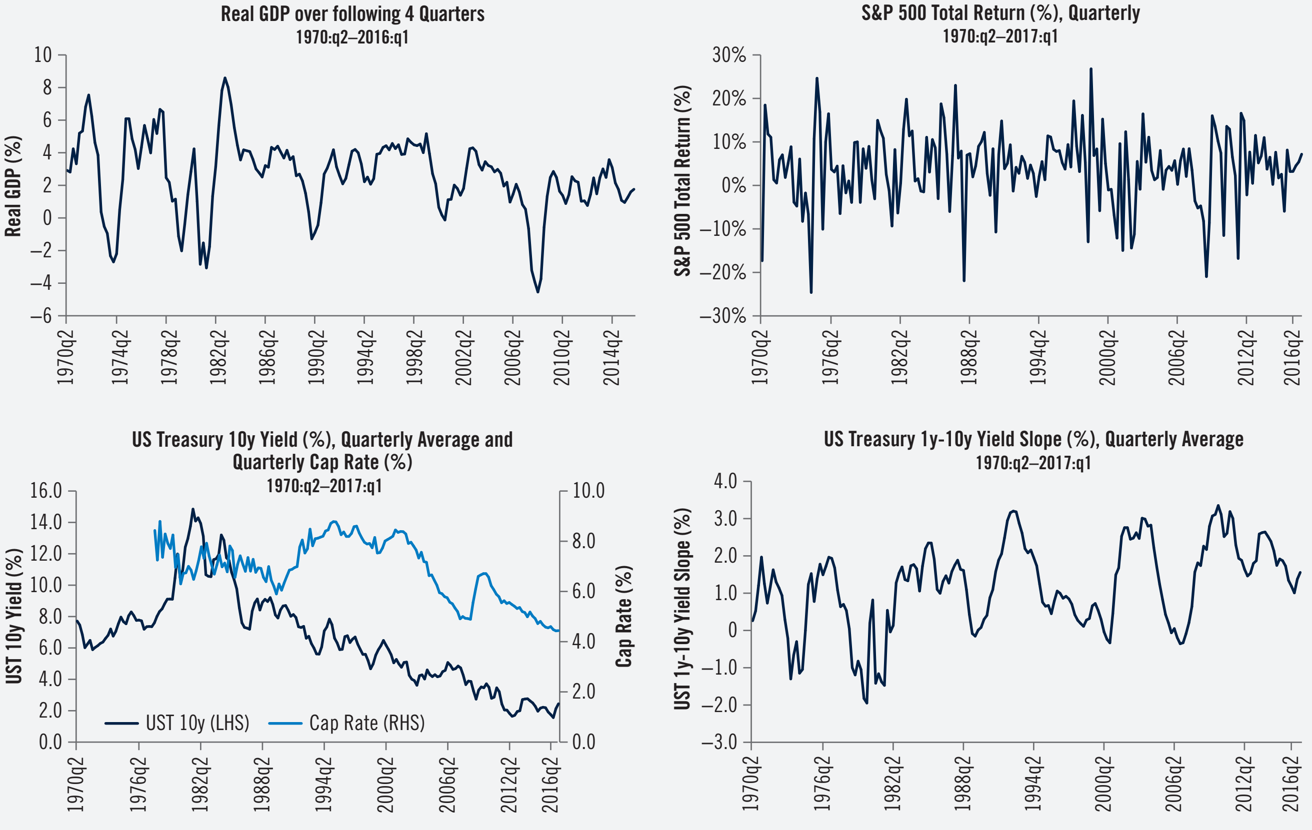
Market Signals and Future GDP

There are reasonable arguments for why the bond, stock and real estate markets might contain useful information about future GDP. If strong GDP is anticipated, the demand today for bonds as an economic hedge might decline, leading to a rise in Treasury yields (*i.e.*, low or negative bond returns). Also, the yield curve might steepen reflecting an expectation of rising yields as the economy grows. For stocks, an anticipation of strong GDP is likely to increase stock prices due to a forecast of rising dividends.[2] Similarly, if a strong economy is expected, then real estate values are likely to appreciate today which will tend to reduce capitalization rates.[3]

Despite these reasonable arguments, the quality of market signals as predictors for future GDP is an empirical issue. Since the 1980s, academic research has highlighted the signal strength of the bond market for future GDP.[4] In particular, the slope of the Treasury yield curve was identified as a useful signal. In contrast, stock market returns were found to be a relatively poor signal. There is less research examining cap rates as a signal for the economy.

Figure 2 provides time series of GDP and various market signals since 1970. (Real estate cap rate data are only available since 1978.) Figure 2 also shows quarterly stock market total returns. We see that stock market returns have been the most volatile time series. Given the smoother GDP series, it is, perhaps, not surprising that the stock market would have difficulty providing a clear signal regarding future GDP. In contrast, bond and real estate signals have a volatility more comparable to that of GDP, which might increase their relative signal power.

Figure 2: GDP, S&P 500 Total Returns, 10y Treasury Yields, 1y-10y Treasury Slope, and Cap Rates (quarterly observations)
1970:q2–2017:q1



Source: Federal Reserve Bank of St. Louis, FRED; NCREIF; Datastream; and PGIM IAS

2 Stock prices reflect discounted future dividends. While future dividends might rise, so might the required discount rate. Consequently, it is not obvious that future GDP growth must be positively correlated with current stock returns.

3 A capitalization rate is the rate of return on a real estate investment property based on the income that the property is expected to generate. It is computed by dividing net operating income (NOI) by the average quarterly investment for the quarter. For this study, cap rate is appraisal cap rate and value weighted by NCREIF Property Index (NPI).

4 Campbell R. Harvey, "The Real Term Structure and Consumption Growth", *Journal of Financial Economics*, December 1988.

Our goal is to evaluate various market signals by measuring their ability to explain, and more importantly, to predict next year's GDP. Of perhaps more interest to investors, we also examine the ability of market signals to predict if GDP is increasing or decreasing versus last year (ΔGDP).[5] To measure whether a signal can "explain" GDP, we use regression to measure the empirical fit between the signal and GDP over a given data period. However, to measure whether a signal can "predict" GDP, we use available market signal data as of a given time, construct a forecast of next year's GDP, and then assess whether the signal did a good job predicting GDP. It is important to differentiate between a signal's explanatory power and its predictive power. It is possible for a signal to explain movements in GDP when looking over the entire period. However, this does not mean that the signal did a good job at predicting GDP because when forming a prediction, one cannot incorporate data unavailable at the time of making the prediction.

We first evaluate each market signal individually by computing its regression coefficient (β) and the R^2 from the following models:[6]

$$\mathbf{GDP}_{t+1\_t+4} = \alpha + \beta \times \textbf{Market Signal}_t + \varepsilon_t$$

$$\mathbf{\Delta GDP}_{t+1\_t+4} = \alpha + \beta \times \textbf{Market Signal}_t + \varepsilon_t$$

The first regression measures the ability of the market signal to explain next year's GDP. The second regression measures the signal's ability to explain the change in GDP versus last year. Time is measured in calendar quarters. The left-hand side variable is one year (four quarters) realized GDP in the year immediately following the current quarter. The right-hand side variable, "Market Signal" is either a bond, stock or real estate market signal, measured monthly, which is then averaged over the quarter just ending.[7] For example, suppose a signal is measured over April, May and June. We then average these monthly signals and measure how well this quarterly-averaged signal forecasts GDP over the ensuing year beginning in July and ending in the following June.

We consider three bond, two stock and two real estate signals, as well as their changes:

Bond Market Signals:	10y Treasury yield (**"level"**); 1y-10y Treasury yield spread (**"slope"**); and Aaa-Baa 10y credit spread difference (**"quality spread"**).
Stock Market Signals:	S&P 500 (SPX) **total returns**; and S&P 500 **CAPE**.
Real Estate Market Signals:	Capitalization rates (**"cap rate"**); and Cap Rate − 10y Treasury yield (**"cap rate spread"**).

For the bond market, in addition to the Treasury market signals, we add the quality spread between 10y Aaa-rated and Baa-rated corporate bonds. A credit spread is the yield difference between 10y corporate bonds of a given rating and the 10y constant maturity Treasury. The quality spread is the difference between Baa spreads and Aaa spreads and is typically positive. An increasing quality spread means that Baa-rated credit spreads are increasing relative to Aaa-rated bonds and may signal worsening future economic growth.

For the stock market, we add CAPE, or cyclically-adjusted price-earnings ratio, as a potential signal. CAPE is an equity valuation measure just as bond yields can be viewed as the value of money. The level of CAPE reflects the "richness" of stocks and the quarterly change in CAPE indicates if stocks are getting "richer" or "cheaper." A high, or rising, CAPE indicates that investors are willing to pay more for a dollar of equity earnings which may signal optimism regarding future GDP.[8]

Explanatory Power of Individual Market Signals: 1970–1989

To begin, we first re-confirm earlier academic research, using just bond and stock market signals, by restricting the data period from 1970:q2 to 1989:q2. We ignore real estate market signals due to lack of data for much of this period. Figure 3 contains the results using a single market signal to explain GDP (later we will consider the value of combining market signals). Figure 3 is divided into "bond signals" (top half) and "stock signals" (bottom half). The left side of the figure shows the ability of the signal to explain next year's GDP, and the right side shows the ability to explain the change in GDP (next year's less last year's).

5 The real GDP measure that we use for our analysis is most recently available, seasonally adjusted, based on constant-dollar weights.
6 Later, we examine the root mean squared error (RMSE) from a predictive regression.
7 We considered measuring the signal using just the last month of the quarter ending. However, these "monthly" signals generally performed worse than the "quarterly" signals used in this study. Please see the Appendix.
8 Since the real earnings in CAPE are an average of last 10 years, the measure may be perceived to capture only price movements. Therefore, we also analyze and report our findings for alternative stock market signals like Forward 12m PE and Forward 18m PE. Overall, we obtain similar results using forward PE measures, although the CAPE measure better explains next year GDP in the full sample.

Figure 3: Ability of Bond and Stock Signals to Explain Next Year's GDP & Change in GDP

1970:q2–1989:q2

	Next year's GDP			GDP Change (Next Yr – Last Yr)		
	intercept	coefficient	R^2	intercept	coefficient	R^2
Bond Signal						
10y Yield*						
Chg 10y Yield	**3.37** (6.48)	**–0.97** (–2.60)	**6%**	**0.14** (0.22)	**–1.50** (–2.13)	**7%**
1y-10y Yield Slope	**2.11** (6.33)	**1.76** (6.68)	**56%**	**–0.75** (–1.11)	**1.22** (2.95)	**14%**
Chg 1y-10y Yield Slope	3.35 (6.10)	0.45 (1.25)	1%	**0.11** (0.19)	**1.80** (2.53)	**10%**
Aaa-Baa Quality Spread*						
Chg Quality Spread	**3.35** (6.50)	**–2.99** (–2.61)	**7%**	0.12 (0.17)	0.52 (0.27)	0%
Stock Signal						
S&P 500 Total Return	**3.07** (5.38)	**8.76** (2.41)	**9%**	**–0.29** (–0.47)	**13.07** (2.57)	**10%**
Chg S&P 500 TR	3.35 (5.96)	1.00 (0.79)	2%	**0.06** (0.09)	**3.90** (1.87)	**2%**
S&P 500 CAPE*						
Chg S&P 500 CAPE	**3.36** (6.83)	**1.07** (2.32)	**14%**	**0.12** (0.19)	**1.37** (2.14)	**7%**

Note: t-statistics (using HAC standard errors with 4 lags) are in parentheses. Rows are are bold if the coefficient on the market signal is significant at 90% confidence interval i.e., when the absolute value of t-statistic is greater than 1.645. An * indicates that both the dependent and independent variables were non-stationary series in the sampling period and no regression results are reported. For such time series, OLS regression may produce a spurious result with biased t-statistics and artificially high R^2s. We check for non-stationarity using an augmented Dickey-Fuller test. A p-value from the ADF test over 5% suggests non-stationarity.
Source: Federal Reserve Bank of St. Louis, FRED; Professor Shiller's website (CAPE); NCREIF; Datastream; and PGIM IAS

The 1y-10y Treasury yield curve slope (measured as the 10y yield minus the 1y yield) for the quarter ending had considerable power explaining next year's GDP. Specifically, the average 1y-10y slope for the past quarter explained 56% of the variation in next year's GDP.[9] The estimated coefficient (1.76) is positive and statistically significant indicating that a steep (flat) yield curve slope is correlated with high (low) future GDP growth. This result is consistent with the popular rule of thumb that an inverted yield curve (*i.e.*, a negative slope) usually precedes recessions (*i.e.*, negative GDP). In addition, as shown in the right-hand side of Figure 3, a steep (or steepening) yield curve was correlated with an increase in GDP next year compared to last year.

Empirical results suggest the Treasury yield curve slope was correlated with future GDP. A flatter slope suggested lower future GDP growth.

Notably, the change in the 10y Treasury yield was not as correlated with GDP (*i.e.*, $R^2 = 6\%$), although the coefficients for GDP and GDP change were negative and significant. An increase in the 10y yield was correlated with lower GDP, but its explanatory power was much weaker than that for the 1y-10y yield slope.

The ability of the change in quality spread during the period to explain future GDP was also relatively low (*i.e.*, $R^2 = 7\%$). The change in the quality spread was negatively correlated (and statistically significant) with next year's GDP, indicating that an increase in the quality spread this quarter versus last quarter was associated with low GDP in the following year.

9 If we extend the regression period from 1953:q3 to 1989:q2 the R^2 for the bond 1y-10y slope signal was 40%.

For stock market signals, positive stock market returns last quarter had a positive and significant coefficient not only for next year's GDP but also for the change in GDP. However, last quarter's S&P 500 total return explained only 9% of the variation in next year's GDP, compared to 56% for the yield curve slope. This poor relative performance result may reflect a disconnect between the stock market and future economic growth perhaps due to psychological factors unrelated to future economic activity driving stock market returns. Or, more rationally, the low correlation may reflect that there are two important components to a common stock valuation model: future expected dividends and how they are discounted. While future GDP growth may increase expected dividends and, hence, stock prices, this growth may also be accompanied by rising discount rates which would tend to decrease stock prices.

For the stock market valuation measure, *i.e.*, CAPE, we find that an increase in CAPE explained both high and increasing GDP next period. Rising equity market valuations tended to correctly reflect positive future growth. However, CAPE's overall explanatory power was not that strong (R^2 = 14% and 7%, respectively, for GDP and GDP change).

Overall, for the 1970:q2–1989:q2 period we see that both the bond and stock market signals had explanatory power for GDP and GDP change. A steeper Treasury curve, higher S&P 500 total returns and a rising CAPE explained both high future GDP growth and a positive GDP change. Of the three signals, the Treasury yield slope had the most explanatory power.

Explanatory Power of Individual Market Signals since 1989

How have the market signals performed more recently?[10] Compared to the earlier period, the results are strikingly different for 1989:q3 to 2016:q1 (Figure 4). The explanatory power of the 1y-10y Treasury slope for next year's GDP, that was so evident in the prior period, disappeared. However, it remained the case that a steep yield curve explained increasing GDP growth next year (R^2 = 14%).

However, the quality spread emerged as a useful signal. A wide (or, widening) quality spread was correlated with low GDP next period. However, the correlation with GDP change was mixed: a high level of the quality spread explained increasing GDP while an increasing quality spread explained a slowing in GDP.

Results for stock market signals were about the same as they were for the earlier 1970:q2–1989:q2 period. The stock market, both the quarter's total return and change in CAPE, continue to have meaningful explanatory power (R^2 of 12% and 19%, respectively) for next year's GDP. However, unlike the earlier period, both signals were not helpful to explain whether GDP would be increasing or decreasing versus last year.

For real estate, the level of the cap rate spread was a significant explanatory factor for next year's GDP. A high cap rate spread (*i.e.*, cap rate less 10y Treasury yield) explained high GDP (R^2 = 9%). However, the cap rate spread was not quite a significant explanatory factor for the change in GDP, although the coefficient was positive.

Overall, while the explanatory ability of bond market signals for either future GDP or GDP change weakened post-1989, we still see some power for the yield slope and quality spread to explain the direction of change in GDP. However, most noteworthy, was that the level of the yield slope lost its explanatory power for next year's GDP. Stock market signals (market returns and the change in CAPE) maintained their explanatory power and were now comparable to bond market signals.

> Post 1989, stock market signals were on the same footing as bond market signals in explaining next year's GDP.

Perhaps these post-1989 results were driven by the unique economic environment since 2008? As a check we split the period into two sub-periods: 1989:q3 to 2007:q2 (pre-crisis) and 2007:q3 to 2016:q1 (post-crisis). We do see some important differences between the two subperiods.

For the pre-crisis period, the ability of the 1y-10y yield slope to explain next year's GDP (see left side of Figure 5) was poor. After 2007, however, it returned to having meaningful explanatory power with an R^2 of 28%. In both sub-periods, however, the yield slope helped explain the change in GDP: A steeper Treasury market slope suggested increasing GDP growth.

For the pre-crisis period, the change in the quality spread lost much of its ability to explain the direction of change in GDP. Whereas, the coefficient on the change in quality spread to explain the next year GDP was significant the R^2 was only 3%. However, following 2007, the change in the quality spread was a significant explanatory factor for next year's GDP. Overall, following 2007, yield slope and change in quality spread signals return to their pre-1989 historical explanatory power.

10 Our data period ends in 2016:q1 as we need one additional year of GDP data to calculate forward GDP growth which is the right-hand side variable.

Figure 4: Ability of Bond, Stock and Real Estate Signals to Explain Next Year's GDP & Change in GDP
1989:q3–2016:q1

	Next year's GDP			GDP Change (Next Yr – Last Yr)		
	intercept	coefficient	R^2	intercept	coefficient	R^2
Bond Signal						
10y Yield*						
Chg 10y Yield	2.42 (7.48)	0.18 (0.39)	0%	–0.07 (–0.22)	–0.30 (–0.55)	0%
1y-10y Yield Slope	2.14 (3.52)	0.17 (0.72)	1%	**–1.18** (–2.71)	**0.73** (2.93)	**14%**
Chg 1y-10y Yield Slope	2.42 (7.77)	–1.10 (–1.40)	4%	–0.06 (–0.21)	1.00 (1.08)	3%
Aaa-Baa Quality Spread	**4.00** (6.34)	**–1.65** (–2.62)	**14%**	**–1.61** (–2.43)	**1.62** (2.20)	**10%**
Chg Quality Spread	**2.41** (7.68)	**–2.23** (–3.04)	**8%**	**–0.38** (–0.13)	**–2.53** (–1.74)	**7%**
Stock Signal						
S&P 500 Total Return	**2.20** (6.36)	**7.58** (2.44)	**12%**	–0.16 (–0.48)	4.08 (1.51)	2%
Chg S&P 500 TR	2.40 (7.21)	0.86 (0.95)	0%	–0.05 (–0.15)	2.06 (1.20)	1%
S&P 500 CAPE*						
Chg S&P 500 CAPE	**2.36** (8.29)	**0.53** (3.50)	**19%**	–0.07 (–0.21)	0.22 (1.50)	3%
Real Estate Signal						
Cap Rate*						
Chg Cap Rate	2.39 (7.19)	–0.64 (–1.17)	1%	–0.03 (–0.09)	1.19 (1.00)	2%
Cap Rate Spread	**1.73** (3.39)	**0.35** (2.15)	**9%**	–0.80 (–1.17)	0.39 (1.44)	8%
Chg Cap Rate Spread	2.42 (7.47)	–0.35 (–0.93)	1%	–0.08 (–0.26)	0.62 (1.32)	2%

Note: t-statistics (using HAC standard errors with 4 lags) are in parentheses. Rows are bold if the coefficient on the market signal is significant at 90% confidence interval i.e., when the absolute value of t-statistic is greater than 1.645. An * indicates that both the dependent and independent variable were non-stationary series in the sampling period and no regression results are reported. Regression may produce a spurious result with biased t-statistics and artificially high R^2. We check for non-stationarity using an augmented Dickey-Fuller test. A p-value from the ADF test over 5% suggests non-stationarity.
Source: Federal Reserve Bank of St. Louis, FRED; Professor Shiller's website (CAPE); NCREIF; Datastream; and PGIM IAS

For stocks, last quarter's stock returns were positively and significantly correlated with GDP growth next year, but only for the first sub-period. Stock returns explained 8% of the variation in GDP, roughly comparable to the results for the entire 1970:q3–1989:q3 period. For both sub-periods, the change in CAPE continued to be correlated with next year's GDP as it was for the 1970:q2–1989:q3 period. However, the change in CAPE was no longer correlated with the change in GDP.

Figure 5: Ability of Bond, Stock and Real Estate Signals to Explain Next Year's GDP & Change in GDP

1989:q3–2007:q2 and 2007:q3–2016:q1

	1989:q3–2007:q2						2007:q3–2016:q1					
	Next year's GDP			Change GDP			Next year's GDP			Change GDP		
	intc	coeff	R^2	intc	coeff	R^2	intc	coeff	R^2	intc	coeff	R^2
Bond Signal												
10y Yield*												
Chg 10y Yield	2.91	–0.46	2%	**–0.15**	**–1.17**	**7%**	**1.45**	**1.53**	**8%**	**0.18**	**1.91**	**6%**
	(8.92)	(–1.08)		(–0.48)	(–2.57)		(2.84)	(2.14)		(0.27)	(1.66)	
1y-10y Yield Slope	2.49	0.35	7%	**–0.86**	**0.62**	**15%**	**–1.73**	**1.42**	**28%**	**–4.25**	**1.99**	**28%**
	(4.44)	(1.52)		(–1.93)	(2.29)		(–1.28)	(3.18)		(–3.44)	(3.08)	
Chg 1y-10y Yield Slope*							1.38	–1.44	8%	0.00	0.46	0%
							(2.91)	(–1.08)		(0.00)	(0.24)	
Aaa-Baa Quality Spread*												
Chg Quality Spread	**2.93**	**–2.50**	**3%**	–0.08	–1.82	1%	**1.35**	**–2.08**	**15%**	0.06	–2.67	13%
	(9.37)	(–2.05)		(0.25)	(–0.98)		(2.69)	(–4.01)		(0.09)	(–1.59)	
Stock Signal												
S&P 500 Total Return	**2.76**	**5.61**	**8%**	–0.18	3.14	2%						
	(8.68)	(3.30)		(–0.51)	(1.13)							
Chg S&P 500 TR	2.93	0.66	0%	–0.08	1.21	1%	1.32	1.13	1%	0.03	3.66	3%
	(–0.12)	(0.80)		(–0.26)	(1.10)		(2.30)	(0.59)		(0.04)	(0.82)	
S&P 500 CAPE*												
Chg S&P 500 CAPE	**2.87**	**0.40**	**16%**	–0.10	0.13	1%	**1.37**	**0.67**	**27%**	0.05	0.42	6%
	(10.40)	(3.71)		(–0.31)	(0.86)		(3.43)	(3.49)		(0.08)	(1.31)	
Real Estate Signal												
Cap Rate*												
Chg Cap Rate*							1.31	–0.57	0%	**0.13**	**6.08**	**25%**
							(2.29)	(–0.73)		(0.22)	(3.41)	
Cap Rate Spread*							**–2.58**	**1.46**	**47%**	**–4.15**	**1.57**	**28%**
							(–1.73)	(3.06)		(–3.29)	(2.67)	
Chg Cap Rate Spread	2.93	0.11	0%	–0.11	0.76	4%						
	(9.07)	(0.30)		(–0.36)	(1.61)							

Note: t-statistics (using HAC standard errors with 4 lags) are in parentheses. Rows are bold if the coefficient on the market signal is significant at 90% confidence interval i.e., when the absolute value of t-statistic is greater than 1.645. An asterisk indicates that both the dependent and independent variable were non-stationary series in the sampling period and no regression results are reported. Regression may produce a spurious result with biased t-statistics and artificially high R^2. We check for non-stationarity using an augmented Dickey-Fuller test. A p-value from the ADF test over 5% suggests non-stationarity.
Source: Federal Reserve Bank of St. Louis, FRED; Professor Shiller's website (CAPE); NCREIF; Datastream; and PGIM IAS

No real estate signal was a significant explanatory factor in the first sub-period. However, post 2007, we see that the cap rate spread was a significant explanatory factor for both next year's GDP and the change in GDP.

Figure 6 provides a summary of the significant findings. Overall, we find that the 1y-10y yield slope was positively correlated with either next year's GDP or the change in GDP versus last year. In contrast, the quarterly change in the quality spread was negatively correlated with either next year's GDP or the change in GDP. As far as stock market signals are concerned, last quarter's S&P 500 total return and the quarterly change in CAPE was positively correlated with either next year's GDP or the change in GDP.

Post 2007, we see that the real estate cap rate spread was a significant explanatory factor for both next year's GDP and the change in GDP.

Figure 6: Ability of Bond, Stock and Real Estate Signals to Explain Next Year's GDP & Change in GDP
Summary: R^2 and Sign of Significant Regression Coefficient

	Next year's GDP				GDP Change (Next Yr – Last Yr)			
R^2 and (coeff sign)	1970:q2–1989:q2	1989:q3–2016:q1	1989:q3–2007:q2	2007:q3–2016:q1	1970:q2–1989:q2	1989:q3–2016:q1	1989:q3–2007:q2	2007:q3–2016:q1
Bond Signal								
10y Yield								
Chg 10y Yield	6% (neg)			8% (pos)	7% (neg)		7% (neg)	6% (pos)
1y-10y Yield Slope	56% (pos)			28% (pos)	14% (pos)	14% (pos)	15% (pos)	28% (pos)
Chg 1y-10y Yield Slope					10% (pos)			
Aaa-Baa Quality Spread		14% (neg)				10% (pos)		
Chg Quality Spread	7% (neg)	8% (neg)	3% (neg)	15% (neg)		7% (neg)		
Stock Signals								
S&P 500 Total Return	9% (pos)	12% (pos)	8% (pos)		10% (pos)			
Chg S&P 500 TR					2% (pos)			
S&P 500 CAPE								
Chg S&P 500 CAPE	14% (pos)	19% (pos)	16% (pos)	27% (pos)	7% (pos)			
Real Estate Signals								
Cap Rate								
Chg Cap Rate								25% (pos)
Cap Rate Spread		9% (pos)		47% (pos)				28% (pos)
Chg Cap Rate Spread								

Note: Table shows regression results that are significant and non-spurious. A market signal is considered significant if its regression coefficient has a t-statistic value greater than 1.645 or lower than –1.645 based on two-tailed test of regression coefficient being statistically different from zero at a 90% confidence level.
Source: Federal Reserve Bank of St. Louis, FRED; Professor Shiller's website; NCREIF; Datastream; and PGIM IAS

Prediction Power of Individual Market Signals: 1970–2016

So far, our analysis has evaluated the historical correlation between market signals and GDP entirely "in-sample". In other words, we have used available history to measure the relationship. However, for investment purposes investors may rightly consider "out-of-sample" performance to be a better way to evaluate the quality of market signals. In other words, suppose we use some initial data to estimate the relationship between the signal and future GDP, and then rely on that estimated relationship to predict next year's GDP. The difference between the signal's prediction and actual future GDP is the signal's prediction error. Next quarter, we re-estimate the relationship (say, using a rolling 10 years regression window) and measure the prediction error the following quarter, and so on. In other words, out-of-sample performance evaluation more closely follows what an investor is forced to do – use only the history that is contemporaneously available to extract a signal, then see how well the signal predicts the future. To measure prediction performance, we calculate the root mean squared error (RMSE) in prediction, and then rank the signals in terms of their predictive power over the entire period.

Figure 7: Prediction Power of Bond, Stock and Real Estate Signals for Next Year's GDP and GDP Change

1978:q2–2016:q1

	RMSE (in units of GDP %)	
	Next year's GDP	GDP Change (Next Yr – Last Yr)
Bond Signal		
10y Yield*		
Chg 10y Yield	1.75	2.09
1y-10y Yield Slope	1.84	1.96
Chg 1y-10y Yield Slope	1.79	2.10
Aaa-Baa Quality Spread	1.80	2.10
Chg Quality Spread	1.84	2.18
Stock Signal		
S&P 500 Total Return	1.68	2.10
Chg S&P 500 TR	1.77	2.11
S&P 500 CAPE*		
Chg S&P 500 CAPE	1.62	2.09
Real Estate Signal		
Cap Rate*		
Chg Cap Rate	1.75	2.09
Cap Rate Spread*		
Chg Cap Rate Spread	1.75	2.11

Note: Predictive power is measured using RMSE. The lower the RMSE, the better is the signal's predictive ability. Out-of-sample rolling regressions are formed with 10 years of quarterly data, and we predict one period ahead for next year's GDP or GDP Change. The asterisk indicates a non-stationary time series in the sampling period which can result in a spurious regression. If the p-value of the ADF test is over 5%, then the time series is considered non-stationary.
Source: Federal Reserve Bank of St. Louis, FRED; Professor Shiller's website; NCREIF; Datastream; and PGIM IAS

Figure 7 contains the out-of-sample prediction results for the full period from 1978:q2 to 2016:q1. The figure reports root mean squared errors (RMSE). The RMSE measures the average prediction error in annual units of GDP. So, a RMSE = 1.75 indicates that the signal produced an average error of approximately 1.75 GDP percentage points for next year's GDP (or change in GDP). Considering that average annual GDP was approximately 2.4%, the out-of-sample results show that while some signals clearly perform better than others, all signals produced relatively high prediction errors. Stock markets signals did best to predict next year's GDP. Both the S&P 500 total return and the Chg S&P 500 CAPE produced the lowest prediction error compared to all other signals. Notably, the 1y-10y Treasury slope signal was among the least predictive signals. The two real estate signals, and the Chg 10y Yield, were average performing signals.

Stock market signals did the best to predict next year's GDP. To predict GDP change, 1y-10y Treasury yield slope was the best.

To predict the GDP change, none of the signals were particularly strong. However, the 1y-10y Treasury yield slope was relatively the best.

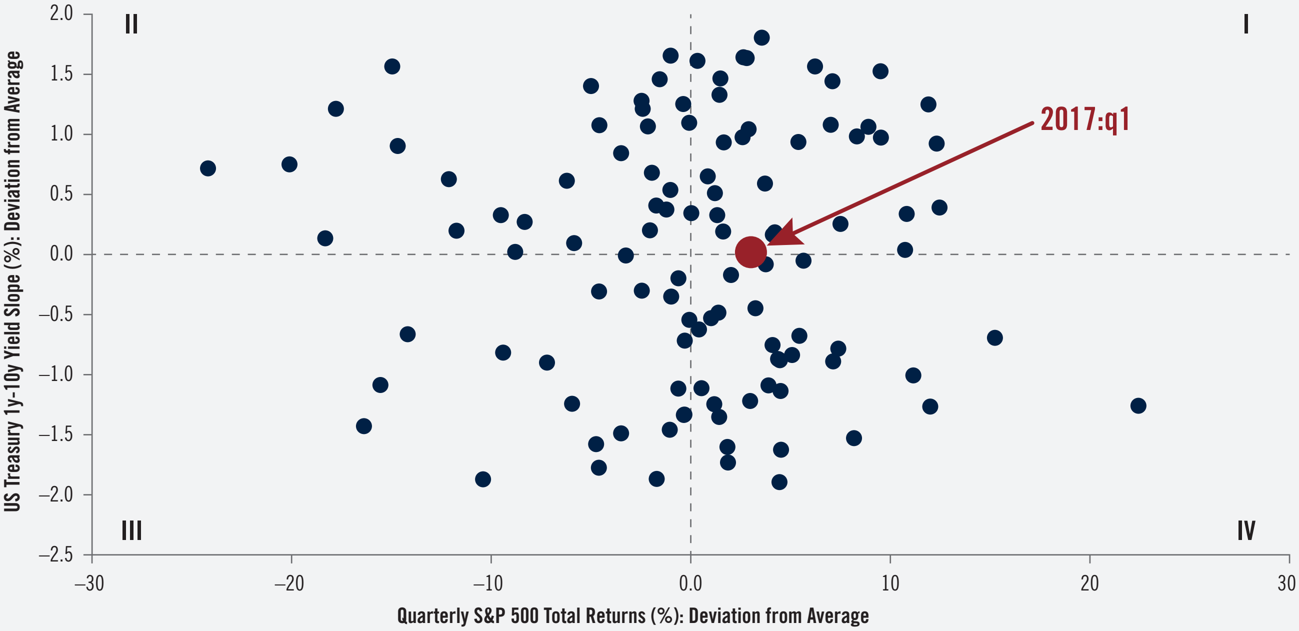
The quality spread signals were relatively poor predictors for either GDP or GDP change.

So far, we have only considered using a single signal. Can we improve market signals' predictive power by combining them? In addition, the results above were for the entire 28-year period. As shown in Figure 5, some signals had better explanatory power in some periods than in others. We can consider dynamically selecting the set of market signals.

Is There Value in Combining Market Signals?

Can we do better by combining signals? To investigate this possibility, we first consider the explanatory power of combining two of the better performing individual signals: the 1y-10y Treasury yield slope and S&P 500 total returns. Both signals have tended to be positively correlated with GDP and GDP change and have had some relative predictive success.

Figure 8: Quarterly Average 1y-10y Treasury Yield Slope vs. Quarterly S&P 500 Total Returns (deviations from average signal value)
1989:q3–2016:q1



Source: Federal Reserve Bank of St. Louis, FRED; Professor Shiller's website; NCREIF; Datastream; and PGIM IAS

We define a positive bond signal whenever the slope is above the average for the period, and similarly for the stock signal. Figure 8 below plots the deviations of the two signals.

The first and third quadrants represent quarters when both signals concur. The second and fourth quadrants are quarters of disagreement. We observe that it is not uncommon for the signals to conflict. For the 1989:q3–2016:q1 period, the correlation coefficient between the two market signals was −0.3%.

The red dot represents the bond and stock market signal (in deviations) as of the end of the first quarter 2017. The signal from both markets is relatively close to their average signal value.

Figure 9 shows the interaction of the two market signals. For example, when both signals were positive, average GDP in the following year was 2.7%, with a range of 1.2% to 4.4%. The average GDP for all 107 quarters in the period was 2.4%. In addition, the average GDP change was a significant 1.1% with a range of −1.9% to 6.7%.

In contrast, when both signals were negative, average GDP in the following year was 1.7%, well below the average 2.4%. The range was −2.8% to 5.0%, so the two negative signals clearly gave a false reading at times. In terms of GDP change, when both signals were negative, GDP was lower by 1.4 percentage points in the following year, well below the average GDP change of 0.0%. The range was from −4.6% to 1.4% indicating that having two simultaneous negative signals was also not completely reliable as an indicator that growth would be slowing.

When the signals conflicted, Figure 9 shows that the stock signal seemed to carry more weight. For example, a positive bond and a negative stock signal produced only 1.9% GDP in the following year, well below average, and a small decrease in GDP growth versus the prior year. In contrast, a negative bond signal and a positive stock signal produced a robust 3.1% GDP in the following year, but, notably, there was a decrease in GDP (−0.3%) versus the prior year – so GDP remained above average but was slowing.

> When signals conflicted, the stock signal carried more weight to explain GDP in the following year.

In terms of GDP change, we see that two positive signals suggested that the GDP change will likely be positive while any combination that includes a negative signal suggested a decrease in GDP.

Figure 9: Relationship between the Interaction of Bond and Stock Signals and Next Year's GDP and GDP Changes
1989:q3–2016:q1

			Next Year's GDP (%)			GDP Change (Next Yr – Last Yr) (%)		
Bond Signal	**Stock Signal**	**# quarters**	**average**	**min**	**max**	**average**	**min**	**max**
positive	positive	31	2.7	1.2	4.4	1.1	–1.9	6.7
positive	negative	28	1.9	–4.0	4.4	–0.1	–4.9	5.0
negative	positive	27	3.1	–0.6	5.3	–0.3	–3.0	2.2
negative	negative	21	1.7	–2.8	5.0	–1.4	–4.6	1.4
all periods		**107**	**2.4**	**–4.0**	**5.3**	**0.0**	**–4.9**	**6.7**

Note: The bond signal is the 1y-10y Treasury yield slope, and the stock signal is the S&P 500 total returns.
Source: Federal Reserve Bank of St. Louis, FRED; and PGIM IAS

Figure 10: Explanatory Power of Bond and Stock Signals Together for GDP and GDP Change
1989:q3–2016:q1

	intercept	Bond Signal	Stock Signal	R^2
Next Year's GDP	**1.9** (3.3)	0.2 (0.9)	**7.7** (2.4)	13%
GDP Change (Next Yr – Last Yr)	**–1.3** (–3.1)	**0.7** (3.1)	**4.4** (1.8)	17%

Source: Federal Reserve Bank of St. Louis, FRED; and PGIM IAS

To more precisely measure the explanatory power of using both signals we regress GDP and GDP change on the two signals. Figure 10 shows that using both signals improves explanatory power, but only modestly. For example, using the signals together explains 13% of the variation in next year's GDP and 17% of the change in GDP versus the prior year, which is only a slight improvement compared to when the signals were used individually (Figure 4).

In addition, we generally see that the stock signal is stronger than the bond signal for explaining GDP next year, but the bond signal is stronger at explaining the GDP change.

> We generally see that the stock signal was stronger than the bond signal for explaining the level of GDP next year, but the bond signal was stronger at explaining the GDP change.

Prediction Power of Multiple Market Signals

Although a combination of the one stock and one bond signal did little to improve explanatory power, we can consider using many market signals together, not just two. However, using many signals runs the risk of "overfitting the data". In other words, we might find that the regression results show that using multiple market signals will greatly improve explanatory power (*i.e.*, have a very high R^2). However, if we use this model for prediction purposes, we may find that its ability to predict future GDP may still be very poor.

For the full model, we consider a total of 10 (stationary) signals from the three markets.[11] However, since we have many potential predictors and a relatively smooth GDP time series, to avoid overfitting the data we use a variable selection technique, called "stepwise regression", that dynamically selects a subset of the signals each quarter. Using a rolling regression window (10 years), stepwise regression only includes a signal if there is a significant increase in explanatory power when the signal is added.

11 The 10 signals are: Chg 10y Yield, 1y-10y Yield Slope, Chg 1y-10y Yield Slope, S&P 500 Total Return, Chg S&P 500 TR, Chg S&P 500 CAPE, Aaa-Baa Quality Spread, Chg Quality Spread, Chg Cap Rate, and Chg Cap Rate Spread.

Figure 11: Average In-Sample R^2 and Prediction RMSE for Full Regression and Stepwise Regression

1978:q2–2016:q1

	Full Regression		Stepwise Regression	
	Next year's GDP	GDP Change (Next Yr – Last Yr)	Next year's GDP	GDP Change (Next Yr – Last Yr)
avg in-sample (R^2)	0.83	0.38	0.48	0.44
out-of-sample (RMSE, %)	2.18	2.52	2.05	2.45

Note: Rolling regression uses rolling 10-year of market signal data to fit model and predict next year's GDP and GDP changes. Avg in-sample R^2 is the average of R^2 for all iterations of rolling regressions performed. Out-of-sample RMSE compares the rolling regression prediction versus actual GDP and GDP Change.
Source: Federal Reserve Bank of St. Louis, FRED; Professor Shiller's website; NCREIF; Datastream; and PGIM IAS

Figure 12: Predictive Model for Market Signals as of 2017:q1

(Stepwise Regression Model)

	coefficient	
	Next year's GDP	GDP Change (Next Yr – Last Yr)
In-sample R^2	0.45	0.58
Intercept	0.84	–2.43
Bond Signal		
10y Yield*		
Chg 10y Yield	1.58 (1.41)	1.45 (1.54)
1y-10y Yield Slope	**0.40** **(2.29)**	**0.55** **(2.07)**
Chg 1y-10y Yield Slope	**–2.48** **(–4.27)**	**–1.68** **(–1.84)**
Aaa-Baa Quality Spread		**1.43** **(2.50)**
Chg Quality Spread		**–3.00** **(–4.09)**
Stock Signal		
S&P 500 Total Return		
Chg S&P 500 TR		
S&P 500 CAPE*		
Chg S&P 500 CAPE	**0.44** **(1.90)**	
Real Estate Signal		
Cap Rate*		
Chg Cap Rate	1.36 (1.42)	**4.59** **(2.47)**
Cap Rate Spread*		
Chg Cap Rate Spread		

Note: Values are bold if the coefficient on the market signal is significant at a 90% confidence level i.e., when the absolute value of t-statistic is greater than 1.645.
An asterisk indicates a non-stationary time series in the sampling period which may produce a spurious regression. A spurious regression has an artificially high R^2.
If the p-value of the ADF test is over 5%, then the time series is considered non-stationary.
Source: Federal Reserve Bank of St. Louis, FRED; Professor Shiller's website; NCREIF; Datastream; and PGIM IAS

Figure 13: Model Prediction for Next Year's GDP and GDP change
2017:q2–2018:q1

	Forecast of GDP and GDP Change	
	GDP (%)	GDP Change (%)
Full Regression	1.62	0.91
Stepwise Regression	2.14	0.00
Professional Forecast	2.32	0.67

Note: Professional forecast is based on 37 forecasters surveyed by Federal Reserve Bank of Philadelphia published in Second Quarter 2017 Survey of Professional Forecasters.
Source: Federal Reserve Bank of St. Louis, FRED; Federal Reserve Bank of Philadelphia; Professor Shiller's website; NCREIF; Datastream; and PGIM IAS

Consequently, stepwise regression will typically produce a model with fewer signals than the 10 signals available.[12] The hope is that by not overfitting the data, the stepwise regression model will do a better job predicting GDP. For comparison purposes, we show the results for the "full" regression model that always uses all 10 signals.

As shown in Figure 11, for both GDP and GDP Change prediction, stepwise regression gives better (*i.e.*, lower) out-of-sample RMSE relative to the full regression.[13] However, despite efforts to avoid overfitting the data, stepwise regression produces only a modest improvement in predictive ability compared to using the "full" model.

Surprisingly, in terms of prediction, both the full and stepwise regression approaches produced higher RMSE, relative to the single market signal prediction RMSEs in Figure 7. This indicates that combining traditional market signals did not improve their ability to predict the economy's future direction.

Figure 12 presents our latest stepwise regression model (as of 2017:q1) for GDP and GDP Change. Based on the market signals as of 2017 Q1, the stepwise regression model predicts next year's GDP (*i.e.*, 2017:q2–2018:q1) to be 2.14% (Figure 13). Incidentally, this forecast is reasonably close to the professional forecast of 2.32% from the Federal Reserve Bank of Philadelphia. In addition, the stepwise regression predicts no GDP change from last year which is quite different from market consensus that economic growth is going to accelerate.

Conclusion

The slope of the Treasury yield curve, the change in the Aaa-Baa quality corporate spread, the change in stock market valuation (CAPE) and real estate cap rate spread, carry some information about future GDP growth, both in level and change. While all these signals have respectable explanatory (*i.e.*, in-sample) power, their predictive (*i.e.*, out-of-sample) power is relatively weak. Combining signals, and altering the signal combination dynamically did little to improve their predictive power. Overall, market signals are too volatile to provide much help to reliably predict future GDP.

References

Harvey, Campbell R. "The Real Term Structure and Consumption Growth." *Journal of Financial Economics*. December 1988.

12 On average, the stepwise model selects 5 out of 10 signals and the 5 most frequent ones are: 1y-10y Treasury Yield Slope, 1y-10y Treasury Yield Slope Change, S&P 500 CAPE Change, Aaa-Baa Quality Spread, and Aaa-Baa Quality Spread Change. Frequency of each market signal in the predictive stepwise regression model is in the Appendix.

13 The RMSE measures the average estimation error in annual units of GDP. So, a RMSE = 2.05 indicates that the signal produced an average error of approximately 2.05 GDP percentage points.

APPENDIX

Quarterly data versus Monthly data:

Given the different frequency of GDP data and market signal data, the most recent monthly market signal at quarter-end might be better to explain next year's GDP. However, results in the above table comparing regression using quarterly and monthly market signal data show that R^2 is generally lower using monthly data.

	1970:q3–1989:q2 Next year's GDP					
	Quarterly Data			Monthly Data		
	intercept	coefficient	R^2	intercept	coefficient	R^2
Bond Signal						
10y Yield	5.49 (2.42)	–0.24 (–0.94)	4%	5.51 (2.47)	–0.24 (–0.96)	4%
Chg 10y Yield	**3.37** (6.48)	**–0.97** (–2.60)	**6%**	**3.35** (6.14)	**–0.46** (–2.05)	**2%**
1y-10y Yield Slope	**2.11** (6.33)	**1.76** (6.68)	**56%**	**2.28** 5.94	**1.59** (5.48)	**49%**
Chg 1y-10y Yield Slope	3.35 (6.10)	0.45 (1.25)	1%	3.35 (5.98)	0.09 (0.39)	0%
Stock Signal						
S&P 500 Total Return	**3.07** (5.38)	**8.76** (2.41)	**9%**	3.35 (5.97)	0.00 (0.42)	0%
Chg S&P 500 TR	3.35 5.96	1.00 0.79	2%	3.35 (5.98)	0.00 (–0.15)	0%
S&P 500 CAPE	2.28 (1.10)	0.09 (0.57)	1%	1.93 (0.98)	0.12 (0.82)	2%
Chg S&P 500 CAPE	**3.36** (6.83)	**1.07** (2.32)	**14%**	**3.32** (6.46)	**0.87** (2.30)	**11%**

Note: Monthly data is based on last month of each quarter, e.g., March, June, September and December.
Source: Federal Reserve Bank of St. Louis, FRED; Professor Shiller's website; Datastream; and PGIM IAS

Stationarity tests

Regression models using non-stationary variables are prone to produce spurious results. The figure below shows the p-value from a stationarity test. If the ADF test p-value is larger than 5%, the variable is considered non-stationary. Non-stationary variables are not included in the regression model.

p-value of ADF Test (If p-value>5%, time series is non-stationary)					
Time Period	1970:q3–2016:q1	1970:q3–1989:q2	1989:q3–2016:q1	1989:q3–2007:q2	2007:q3–2016:q1
GDP	1%	11%	34%	27%	0%
10y Yield	85%	42%	55%	22%	44%
Chg 10y Yield	0%	0%	0%	0%	0%
1y-10y Yield Slope	1%	3%	0%	0%	6%
Chg 1y-10y Yield Slope	0%	1%	0%	19%	1%
S&P 500 Total Return	0%	0%	0%	0%	26%
Chg S&P 500 TR	0%	0%	0%	0%	1%
S&P 500 CAPE	55%	57%	31%	28%	47%
Chg S&P 500 CAPE	0%	0%	0%	0%	1%
Aaa-Baa Quality Spread	0%	20%	0%	18%	6%
Chg Quality Spread	0%	0%	0%	0%	0%
Cap Rate	76%	0%	82%	79%	93%
Chg Cap Rate	3%	0%	0%	12%	2%
Cap Rate Spread	60%	47%	4%	9%	2%
Chg Cap Rate Spread	0%	0%	0%	0%	59%

Source: Federal Reserve Bank of St. Louis, FRED; Professor Shiller's website; NCREIF; Datastream; and PGIM IAS

Forward P/E ratios

Forward price-to-earnings is a measure of the price-to-earnings ratio using forecasted earnings for the P/E calculation. Since CAPE is a slow-moving, backward-looking, long-term P/E measure (where the "E" is the market's last 10 years of inflation-adjusted earnings), it is possible that a nearer-term P/E (price to forward X months earnings) measure has more explanatory power.

Test of stationarity:

p-value of ADF Test (If p-value>5%, time series is non-stationary)					
Time Period	1970:q3–2016:q1	1970:q3–1989:q2	1989:q3–2016:q1	1989:q3–2007:q2	2007:q3–2016:q1
Forward 12M PE*	25%	0%	37%	49%	64%
Chg Forward 12M PE	0%	96%	0%	0%	0%
Forward 18M PE*	29%	96%	49%	57%	70%
Chg Forward 18M PE	0%	96%	0%	0%	0%

Note: Forward PE data started in 1985:q1.
Source: Datastream; IBES; and PGIM IAS

Regression Results

Stock Signal	Next year's GDP intercept	Next year's GDP coefficient	Next year's GDP R^2	GDP Change (Next Yr – Last Yr) intercept	GDP Change (Next Yr – Last Yr) coefficient	GDP Change (Next Yr – Last Yr) R^2
1989:q3–2016:q1						
Forward 12M PE*						
Chg Forward 12M PE	**2.38** (7.45)	**0.57** (2.48)	**7%**	**–0.08** –(0.25)	**0.59** (1.88)	**6%**
Forward 18M PE*						
Chg Forward 18M PE	**2.38** (7.54)	**0.57** (2.48)	**8%**	**–0.07** –(0.23)	**0.49** (1.80)	**4%**
1989:q3–2007:q2						
Forward 12M PE*						
Chg Forward 12M PE	**2.90** (9.64)	**0.45** (2.69)	**7%**	–0.11 –(0.33)	0.38 (1.29)	3%
Forward 18M PE*						
Chg Forward 18M PE	**2.91** (9.75)	**0.39** (3.19)	**6%**	–0.10 –(0.31)	0.26 (1.33)	2%
2007:q3–2016:q1						
Forward 12M PE*						
Chg Forward 12M PE	**1.31** (2.50)	**0.77** (2.04)	**12%**	**0.00** (0.00)	**1.05** (1.72)	**11%**
Forward 18M PE*						
Chg Forward 18M PE	**1.31** (2.65)	**1.03** (1.99)	**16%**	**0.01** (0.01)	**1.25** (1.70)	**13%**

Note: * is non-stationary time series in the sampling period which results in a spurious regression. If p-value of the ADF test is over 5%, time series is non-stationary.
Source: Federal Reserve Bank of St. Louis, FRED; Datastream; IBES; and PGIM IAS

Comparing these results with Figure 4 indicate that the S&P 500 total return and CAPE change explained next year's GDP better than the forward PE change, but forward PE change generally did better explaining the change in GDP.

Stepwise Regression – factor selection

1y-10y yield slope and change of 1y-10y yield slope are the most frequently selected factors (77% and 72% of the time, respectively) in stepwise regression for the period 1988:q2–2016:q1, while quality spread and change of quality spread are selected less frequently (61% and 50%, respectively).

Percentage of Time Market Signal in Rolling Stepwise Regression			
Time Period	1988:q2–2007:q2	2007:q3_2016:q1	1988:q2–2016:q1
Chg 10y Yield	14%	63%	29%
1y-10y Yield Slope	66%	100%	77%
Chg 1y-10y Yield Slope	62%	94%	72%
S&P 500 Total Return	23%	49%	31%
Chg S&P 500 TR	25%	14%	21%
Chg S&P 500 CAPE	62%	63%	63%
Aaa-Baa Quality Spread	75%	29%	61%
Chg Quality Spread	66%	14%	50%
Chg Cap Rate	48%	23%	40%
Chg Cap Rate Spread	13%	6%	11%

Source: Federal Reserve Bank of St. Louis, FRED; Professor Shiller's website; NCREIF; Datastream; and PGIM IAS

IMPORTANT INFORMATION

Past performance is no guarantee or reliable indicator of future results. All investments involve risk, including the possible loss of capital. Equities may decline in value due to both real and perceived general market, economic and industry conditions.

All charts contained herein were created as of the date of this presentation, unless otherwise noted. Performance results for certain charts and graphs may be limited by date ranges, as stated on the charts and graphs. Different time periods may produce different results. Charts are provided for illustrative purposes and are not an indication of past or future performance of any PGIM product. These materials may contain hypothetical and simulated examples, which are provided for illustrative purposes only. Simulated examples have certain inherent limitations and are generally prepared through the retroactive application of a model designed with the benefit of hindsight. There are frequently sharp differences between simulated results and actual results. PGIM routinely reviews, modifies, and adds risk factors to its proprietary models. There is no guarantee, and no representation is made, that an investor will achieve results similar to those shown.

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, and are subject to change without notice. Certain information contained herein has been obtained from sources that PGIM believes to be reliable; however, PGIM 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 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. Any forecasts, estimates and certain information contained herein are based upon proprietary research and should not be considered as investment advice or a recommendation of any particular security, strategy or investment product. 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 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 and its affiliates may make investment decisions that are inconsistent with the recommendations or views expressed herein, including for proprietary accounts of PGIM or its affiliates. These materials are for informational or educational purposes only. In providing these materials, PGIM is not acting as your fiduciary. 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.

The information contained herein is provided by **PGIM, Inc.**, the principal asset management business of Prudential Financial, Inc. (PFI), and an investment adviser registered with the US Securities and Exchange Commission. PFI is not affiliated in any manner with Prudential plc, a company incorporated in the United Kingdom. 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 (Firm Reference 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) Pte. Ltd.**, a Singapore investment manager registered with and licensed by the Monetary Authority of Singapore. In Japan, information is presented by **PGIM Japan Co. Ltd.**, 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. In Australia, this information is presented by **PGIM (Australia) Pty Ltd**. ("PGIM Australia") for the general information of its "wholesale" customers (as defined in the Corporations Act 2001). PGIM Australia is a representative of PGIM Limited, which is exempt from the requirement to hold an Australian Financial Services License under the Australian Corporations Act 2001 in respect of financial services. PGIM Limited is exempt by virtue of its regulation by the Financial Conduct Authority (Reg: 193418) under the laws of the United Kingdom and the application of ASIC Class Order 03/1099. The laws of the United Kingdom differ from Australian laws. Pursuant to the international adviser registration exemption in National Instrument 31-103, PGIM, Inc. is informing you of that: (1) **PGIM, Inc.** is not registered in Canada and relies upon an exemption from the adviser registration requirement under National Instrument 31-103; (2) PGIM, Inc.'s jurisdiction of residence is New Jersey, U.S.A.; (3) there may be difficulty enforcing legal rights against PGIM, Inc. because it is resident outside of Canada and all or substantially all of its assets may be situated outside of Canada; and (4) the name and address of the agent for service of process of PGIM, Inc. in the applicable Provinces of Canada are as follows: in **Québec:** Borden Ladner Gervais LLP, 1000 de La Gauchetière Street West, Suite 900 Montréal, QC H3B 5H4; in **British Columbia:** Borden Ladner Gervais LLP, 1200 Waterfront Centre, 200 Burrard Street, Vancouver, BC V7X 1T2; in **Ontario:** Borden Ladner Gervais LLP, Scotia Plaza, 40 King Street West, Toronto, ON M5H 3Y4; in **Nova Scotia:** Cox & Palmer, Q.C., 1100 Purdy's Wharf Tower One, 1959 Upper Water Street, P.O. Box 2380 - Stn Central RPO, Halifax, NS B3J 3E5; in **Alberta:** Borden Ladner Gervais LLP, 1000 Canterra Tower, 400 Third Avenue S.W., Calgary, AB T2P 4H2.

0810-300

PGIM