INSTITUTIONAL ADVISORY & SOLUTIONS

US STOCK–BOND CORRELATION

What Are the Macroeconomic Drivers?

May 2021

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US stock-bond correlation, which plays an important role in institutional portfolio construction, has been persistently negative for the last 20y. This negative correlation allows stocks and bonds to serve as a hedge for each other, enabling CIOs to increase stock allocations while still satisfying a portfolio risk budget. However, stock-bond correlation is not immutable. In fact, it was consistently positive for more than 30y prior to 2000. A return to positively correlated stock and bond returns may require CIOs to rethink their asset allocation.

To help CIOs evaluate the potential for a change in US stock-bond correlation, we identify the underlying macroeconomic components of the correlation and show how changes in these components have been linked to changes in monetary and fiscal policy over the last 70y. While neither theory nor history point to a single factor that determines the correlation regime, a CIO should be attuned to macroeconomic policy shifts that may signal a change.

Although the current negative stock-bond correlation regime has coincided with persistently falling and low interest rates, continued low rates alone may not be enough to support a negative correlation. Depending on the macroeconomic policy environment, it is possible to envisage low interest rate scenarios with positive stock-bond correlation.

CIOs with strong macroeconomic policy views might wish to use our findings to translate those views into an expectation for stock-bond correlation. For CIOs without strong views, we advocate a zero correlation expectation as we believe this will produce a prudent risk assessment.

For much of the last 20y, despite episodes of economic, political and market turmoil, the relative performance of major public asset classes has been remarkably stable. Both stock (S&P 500) and bond (10y Treasury) prices have trended higher (Figure 1), pushing yields to all-time lows and equity valuations to near-record highs. Yet, since 2000, a common measure of the correlation between stock and bond returns has been *negative* (Figure 2), meaning that when stocks have performed poorly, bonds have tended to do well, and *vice versa.*[1]

Stock-bond correlation plays an important role in institutional portfolio construction. A negative correlation means that stock and bond returns are natural hedges for each other, affecting overall portfolio risk measurement. Additionally, some investors may rely on negative correlation to boost stock allocations with leveraged allocations to bonds, allowing them to move out along the capital market line.

Positive stock-bond correlation, and the loss of hedging benefits, may require CIOs to rethink how to allocate across asset classes and manage portfolio risk. Investors may be less willing to pay top-dollar for correlated portfolio inputs, reducing valuations as investors demand higher expected forward returns to compensate for bearing greater cross-asset risk. Such a paradigm shift would affect asset allocation decisions and long-term capital market assumptions.

Figure 1: S&P 500 & 10y US Treasury Bonds (Cumulative Total Returns, 1950-2020; 1950 = 100)

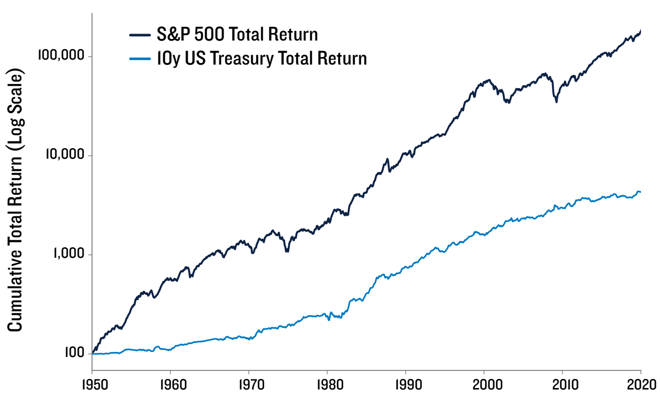
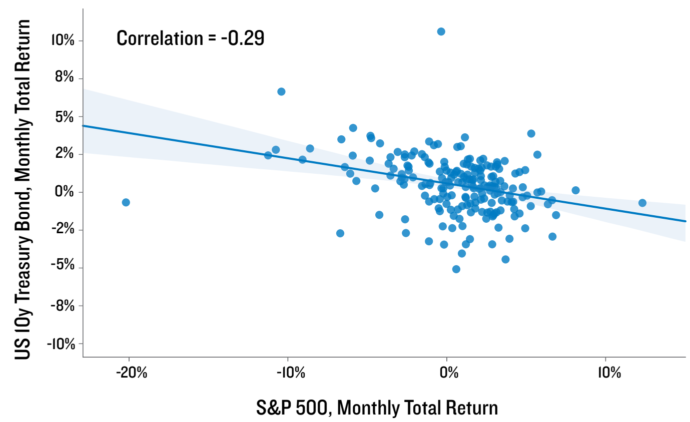


Figure 2: S&P 500 vs. 10y US Treasury Bond Returns (Monthly Total Returns, 2000-2020)



Source: Federal Reserve Board, FRED, Haver Analytics, NBER, Standard & Poor's, Robert J. Shiller, online data and PGIM IAS. For illustrative purposes only.

We estimate stock (S&P 500) – bond (10y Treasury) correlation using monthly total returns over a centered, rolling 5y window from 1950 to 2020 (Figure 3). While the investment horizons of most CIOs exceed 1m, the correlation of monthly returns resembles the correlation using longer-term returns. Additionally, using monthly returns over a 5y window should allow for sufficient sample sizes to reliably estimate time-varying correlation.[2]

Although stock-bond correlation has been persistently negative since 2000, the correlation was persistently *positive* from the late 1960s until the late 1990s, after having been *negative* in the decade-and-a-half before that. Recognizing that the stock-bond correlation regime can change, we offer four broad messages to CIOs.

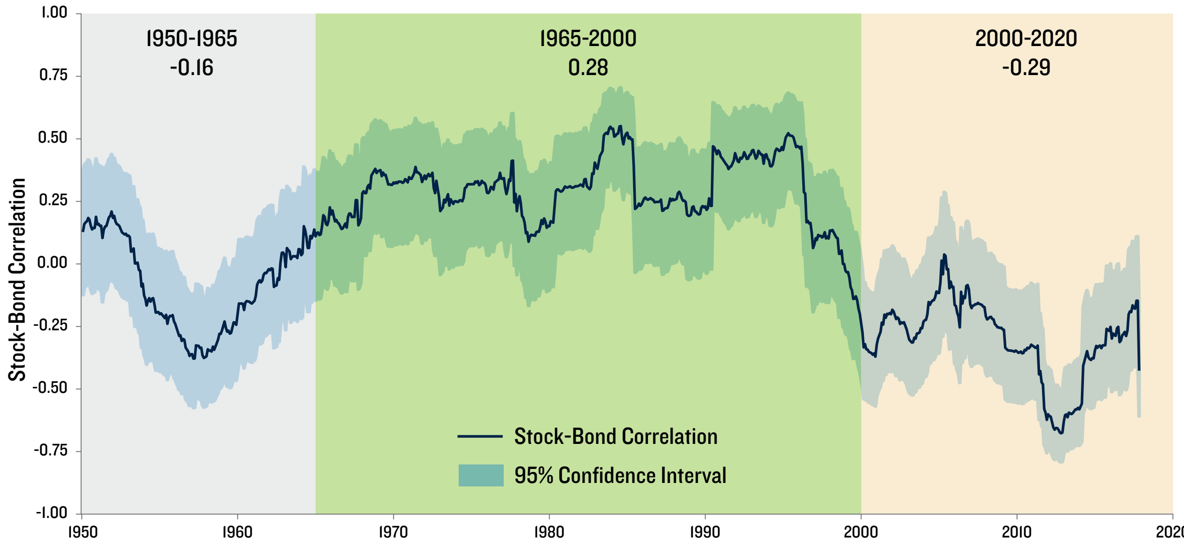
(1) **Stock-bond correlation is affected by macroeconomic drivers.** Stock-bond correlation exhibits stable regimes – extended periods when stock-bond correlation is persistently negative or positive. A regime change is driven, in part, by changes in the macroeconomic and policy backdrop. To show this, we first break down stock-bond correlation into three components: **(i) the level and stability of interest rates; (ii) the perceived riskiness of stocks and bonds; and (iii) the co-movement of interest rates and economic growth.** Then, we show that changes in these components, and, hence, the stock-bond correlation regime, have been driven by the fiscal and monetary policy environment. Specifically, **sustainable fiscal policy, independent and rules-based monetary policy, and demand-side shifts tend to support negative stock-bond correlation, while unsustainable fiscal policy, discretionary monetary policy, monetary-fiscal policy coordination, and supply shifts tend to support positive correlation.**

1 How can stocks and bonds be both positively and negatively correlated? As explained in the Appendix, two assets can have a wide range of correlation values depending on the frequency (*i.e.*, daily, monthly, yearly) of the returns used to compute the correlation. The relevant correlation measure for portfolio managers depends on context and intended use.

2 Stock-bond correlation estimated using *non-overlapping* 1m, 6m, or 12m returns, over a 5y rolling window, are qualitatively similar. Estimating the correlation of non-overlapping long-term returns suffers from small sample sizes which affect the precision of correlation estimates particularly if correlation is assumed to change over time. In some studies, *rolling* longer-term returns are used to increase the sample size, but but we believe such an approach can lead to spurious conclusions. See Appendix for details.

Figure 3: US Stock-Bond Correlation

Correlation of monthly stock and bond returns (5y-centered, rolling window, 1950-2020)



Note: Stock-bond correlation is calculated with 5y rolling window of monthly stock and bond total returns centered at the time of calculation.
Source: DataStream, FRED, NBER, Robert J. Shiller online data and PGIM IAS. For illustrative purposes only.

(2) **What lies ahead for stock-bond correlation?** After nearly 20y of negative stock-bond correlation, prudence dictates being attuned to a potential change in the correlation regime. **As we will show, neither theory nor data point to a single macroeconomic policy that determines the sign of stock-bond correlation. Hence, assessing the risks of a regime change is about accumulating bits and pieces of evidence.**

With the 1965-2000 positive correlation regime as a template, it is hard to resist the conclusion that a high level of interest rates is related to positive stock-bond correlation. As such, the current low level of rates and inflation, buttressed by a Fed committed to keeping rates lower for longer, may provide a sense of comfort about the persistence of negative stock-bond correlation.

However, the level and stability of interest rates alone do not fully determine stock-bond correlation. What also matters is the broader macroeconomic policy backdrop and its implications for all three components of stock-bond correlation: interest rate volatility, the co-movement of bond and equity risk premia, and the co-movement of economic growth and rates. We see three potential future paths for stock-bond correlation:

(A) Continued monetary policy independence; negative stock-bond correlation regime remains intact

If inflation remains dormant, the Fed's current commitment to low policy rates would not jeopardize its inflation fighting credibility. Low rates would be viewed as function of economic slack and not the result of a shift in Fed priorities or an accommodation of expansionary fiscal policy. If so, the future may well look like the recent past. Transparent policymaking keeps: interest rate volatility subdued; economic growth and interest rates positively correlated (*i.e.*, rates rise if and only if growth prospects improve); and risk premia driven by short-term, risk-on/risk-off, market dynamics rather than trending higher in tandem. Along this path, conditions for continued negative stock-bond correlation remain intact.

(B) Shifting Fed priorities and expansionary fiscal policy; a shift to positive stock-bond correlation

With fiscal spending needed to support growth, the debt-to-GDP ratio already elevated, and a shift in Fed priorities to a symmetric long-term inflation and employment target, monetary and fiscal policy goals are looking more synchronous. Dormant inflationary pressures may provide some leeway for the Fed to remain accommodative, perhaps helping to subdue rate volatility. However, greater policy coordination could lead to a shift to a negative correlation between economic growth and interest rates as the Fed tries to continually spur growth, not to react to it. Should stock-bond correlation respond and begin to shift toward positive territory, stock and bond risk premia could start to trend higher together, reflecting their diminished mutual hedging properties and muted expectations for forward returns, further reinforcing the shift to positive stock-bond correlation.

(C) Sustainability worries and an accommodative Fed; positive correlation in a challenging environment

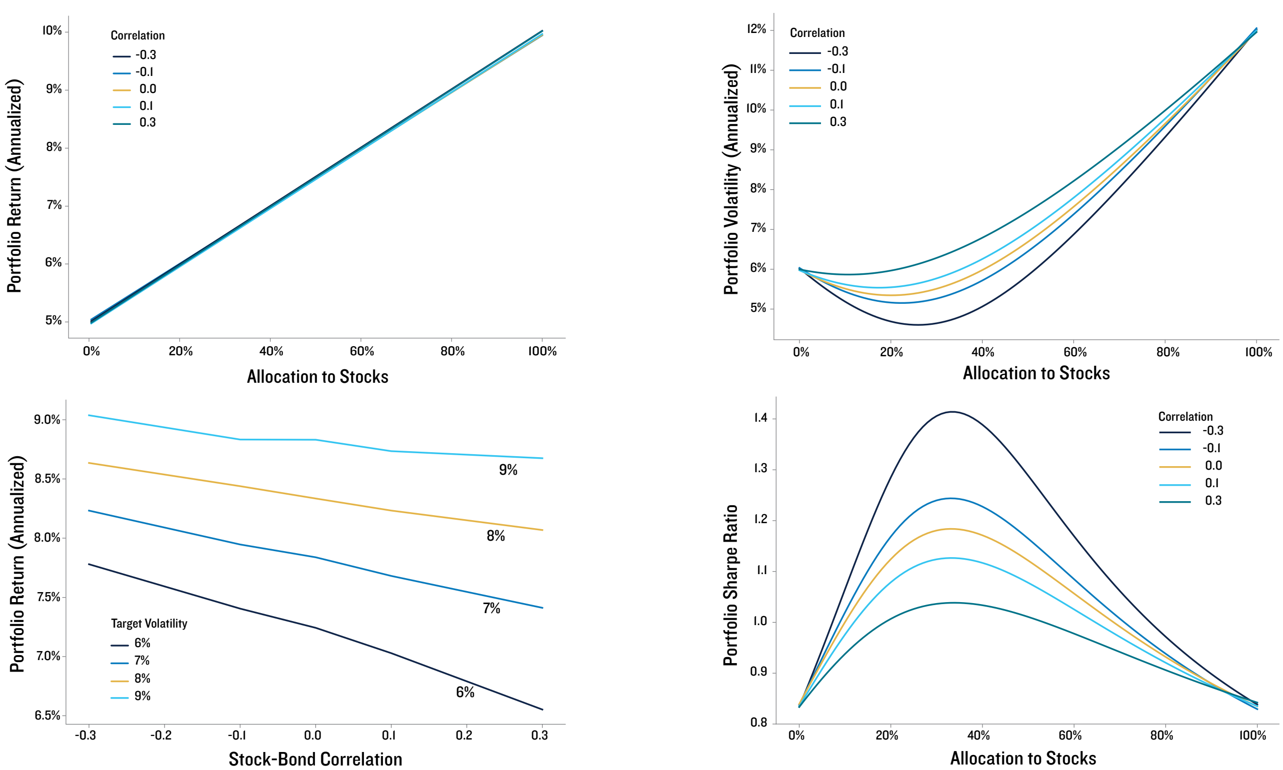
Fueled by intensifying fiscal sustainability worries, monetary policy could try to suppress rates by expanding the Fed's balance sheet further even if inflation begins to develop. A complicit Fed willing to sacrifice its inflation-fighting credibility would likely produce greater interest rate volatility and higher risk premia. These forces would likely lead to positive stock-bond correlation in the context of a much more challenging economic and market backdrop.

(3) A shift in stock-bond correlation may have implications for institutional portfolios. A shift from negative to positive stock-bond correlation means that stocks and bonds no longer hedge each other. Assuming unchanged expected returns, the loss of this hedge would lead to an increase in the volatility and value-at-risk of a balanced portfolio and a decrease in the portfolio's risk-reward profile. **Maintaining current risk levels in the face of a shift to positive correlation would require a significant reduction in the allocation to stocks and would lead to more muted expected portfolio performance.**

To quantify what a change in stock-bond correlation could mean for portfolio performance, assume that stocks have an expected annual return of 10%/y and an annualized volatility of 12%, bonds have a 5%/y expected return with 6% volatility (*i.e.*, *ex-ante* stock and bond Sharpe ratios are equal and constant), and their returns are jointly normally distributed. Under these conditions, we simulate portfolio performance over a range of allocations (rebalanced monthly) and with five different assumptions for stock-bond correlation (-0.3, -0.1, 0, 0.1 and 0.3).

Not surprisingly, portfolio returns vary little as correlation changes (Figure 4 Upper Left). So, for a CIO concerned only with expected returns, a shift in correlation – all else equal – is of little consequence. However, a shift in correlation significantly affects *portfolio* volatility and Sharpe ratio (even with constant asset-specific Sharpe ratios). Starting with a 60/40 portfolio and assuming stock-bond correlation of -0.3 (in line with the prevailing stock-bond correlation of the last 20y), portfolio volatility is about 7% (4 Upper Right). If stock-bond correlation were to rise to zero, portfolio volatility climbs to 7.5%. For a CIO with a portfolio volatility target, maintaining a 7% volatility target would require that stock allocation falls by 8ppt to a bit above 50%, which would consequently reduce expected returns by about 0.4%/y to just below 8%/y (4 Lower Left). If correlation were to rise further and turn positive, say to 0.3 (in line with the prevailing correlation from 1965-2000), maintaining 7% volatility would require an even lower stock allocation to about 40%, reducing expected returns by an additional 50bp/y.[3] Indeed, using the 60/40 portfolio as a benchmark, the *ex-ante* Sharpe ratio that can be achieved when correlation is negative may not be attainable when the correlation is positive (4 Lower Right).

Figure 4: Stock-Bond Portfolio Performance under Different Stock-Bond Correlation Regimes



Note: Portfolio performance based on 1000 simulated monthly returns, with monthly rebalancing. Stock and bond returns are assumed to be jointly normal, with annualized expected returns of 10%/y and 5%/y, and annualized volatilities of 12% and 6%, respectively.
Source: PGIM IAS. For illustrative purposes only.

3 Should an allocator not have the flexibility to shift asset class weights so dramatically, their risk tolerance would instead need to ratchet up.

(4) What is a CIO to do? Linking stock-bond correlation regimes to macroeconomic policy provides investors with a roadmap, but it is no panacea. Anticipating changes in correlation requires knowing how policymakers will behave and how economic data would evolve in response. **Currently, both fiscal and monetary policy settings seem to be in flux and may echo policy regimes of an earlier era less familiar to today's CIO.** It is vital that CIOs remain open-minded to potential shifts in the stock-bond correlation regime.

For CIOs with strong macroeconomic views, we believe our findings can help translate those views into an expectation for stock-bond correlation and optimal portfolio construction. **For CIOs without strong views, we advocate assuming zero correlation as this will produce a more cautious risk assessment.** And, for all CIOs, we would advocate being attentive to key economic and policy developments that could shift stock-bond correlation.

Breaking down stock-bond correlation

Fundamentally, bond and stock prices reflect the discounted value of all future cash flows. Treasury bonds (with maturity T) promise a periodic, fixed nominal coupon payment ($\boldsymbol{CP}$) and a one-time nominal face-value payment ($\boldsymbol{FV}$) at maturity. Stocks are a claim on future nominal dividends ($\boldsymbol{CF_t}$). The discount rate is the sum of a common nominal risk-free rate ($\boldsymbol{i_t}$) and an asset-specific risk premium for bonds and equities ($\boldsymbol{BRP_t}$ and $\boldsymbol{ERP_t}$, respectively) that captures cash-flow uncertainty and investor risk preferences:

$$\textit{Bond Price} = \sum_{t=1}^{T} \frac{CP}{(1 + BRP_t + i_t)^t} + \frac{FV}{(1 + BRP_t + i_t)^t} \quad (1)$$

$$\textit{Stock Price} = \sum_{t=1}^{\cdots} \frac{CF_t}{(1 + ERP_t + i_t)^t}$$

Using some algebra and focusing on the economically meaningful terms, we identify three key components of the covariance of stock and bond returns:[4]

$$cov_t(stock_t, bond_t) \approx \gamma_1 var_t(\Delta i) + \gamma_2 cov_t(\Delta CF, \Delta i) + \gamma_3 cov_t(\Delta ERP, \Delta BRP) + \textit{other cross terms} + error_t . \quad (2)$$

Risk-free rate: A change in the *common* risk-free rate portion of the discount rate contributes to positive co-movement in stock and bond prices. All else equal, when the nominal risk-free rate falls (rises), prices of both assets rise (fall) as the discounted value of cash flows rises (falls). Large changes in interest rates (*i.e.*, high $var_t\ (\Delta i)$) will have a large common influence on stock and bond returns and will support positive correlation.[5] The magnitude of the risk-free rate's positive contribution to stock-bond correlation depends, in part, on the sensitivity of the two assets to changes in the risk-free rate.

Interaction of cash flows and risk-free rates: The interplay between expected equity cash flows and interest rates ($cov_t\ (\Delta CF,\Delta i)$) is critical to understanding stock-bond correlation. Equity cash flows are in the stock price numerator, while interest rates are in the denominator of both stock and bond prices. Therefore, expected equity cash flows (*i.e.*, dividends) moving in the same direction as interest rates ($cov_t(\Delta CF,\Delta i) > 0$) would support negative stock-bond correlation, while equity cash flows and rates moving in the opposite direction ($cov_t(\Delta CF,\Delta i) < 0$) would support positive correlation.[6] Assuming equity cash flows are largely affected by economic growth (*i.e.*, real consumption growth, **c**), if economic growth and rates tend to move together ($cov_t(\Delta c,\Delta i)>0$), then stock-bond correlation will tend to be negative as stock prices *alone* benefit from greater cash flows while *both* stock and bond prices suffer from higher rates. In contrast, if economic growth and rates move in opposite directions, then stock-bond correlation tends to be positive. As we will show, the relationship between economic growth and rates relates to fiscal and monetary policy and shifts in aggregate demand and supply.

Interaction of risk premia: The other portion of an asset's discount rate is its risk premium which captures additional compensation demanded by investors based on their risk tolerance and how expected cash flows change with investor wealth.[7] Equity and bond risk premia vary both over time and relative to one another. For example, when economic conditions are difficult, investors may expect

4 See Appendix for the derivation of the covariance.

5 The risk-free rate includes real and expected inflation components; changes to either, all else equal, tend to lead to positive stock-bond correlation.

6 The relationship between equity cash flows and interest rates depends not only on the macroeconomic regime but also on the type of equity asset. While we assume the equity market is represented by the S&P 500 Index, a "growth stock" index (deferred cash flows) or a "value stock" index (near-term cash flows) may have different sensitivities of their cash flows to changes in interest rates.

7 Disentangling risk premia from forward discount rates is not straightforward as observed risk-free forward rates themselves have embedded forward term premia. Consequently, two investors with different term structure models could observe current interest rates and arrive at different assessments of term premia. We use two commonly cited measures for equity and bond risk premia.

equity cash flows to fall but bond cash flows to remain steady, increasing the risk premium from stocks relative to bonds. If investors were to become less risk averse, then both risk premia (and the gap between them) would be expected to decline. Risk premia moving together (*i.e.*, $\boldsymbol{cov_t}(\Delta \boldsymbol{ERP}, \Delta \boldsymbol{BRP})>0$) supports positive stock-bond correlation, while a reassessment of relative riskiness leading to risk premia moving in opposite directions (*i.e.*, $\boldsymbol{cov_t}(\Delta \boldsymbol{ERP}, \Delta \boldsymbol{BRP})<0$) supports negative correlation.[8]

The empirical evidence

We now turn to the historical data for evidence that (i) the volatility of rates, (ii) the covariance of growth and rates, and (iii) the covariance of stock and bond risk premia all affect stock-bond correlations as the conceptual framework would predict. To present the empirical evidence, we show how the key components of stock-bond correlation relate individually to the stock-bond correlation regime, and how these components change along with correlation itself.[9]

Rates volatility: 3m yield volatility was two to three times higher during the positive correlation regime of 1965-2000 (Figure 5) than during the two negative correlation regimes. This fits the expected pattern. Also, since rate changes tend to be large and volatile during periods of high rates, these periods tend to be associated with positive stock-bond correlation.[10]

In contrast, since rate changes are small and stable during periods of low rates, other components of stock-bond correlation will tend to have greater overall influence in these periods, producing a more muted, and likely negative, correlation. Indeed, from 1965 to 2000, when stock-bond correlation was positive, 3m yields averaged 6.4%, while during negative correlation regimes 3m yields were much lower (2.3% from 1950 to 1965 and 1.6% from 2000 to 2020).

Figure 5: Economic Conditions During Different Stock-Bond Correlation Regimes (1950-2020)

US Economic Conditions	US Stock-Bond Correlation Regime		
	1950-1965	1965-2000	2000-2020
Stock-Bond Correlation	**-0.16**	**0.28**	**-0.29**
Consumer Price Inflation	1.3%	4.3%	1.8%
US 3m Treasury Yield	2.3%	6.4%	1.6%
US 3m Treasury Yield Volatility	0.9%	2.5%	1.8%
US 10y Treasury Yield	3.3%	7.8%	3.4%
US 10y Treasury Yield Volatility	0.7%	2.4%	1.2%
Correlation of Real Consumption Growth and US 3m Treasury Yield	-0.04	-0.33	0.20
Correlation of Real Consumption Growth and US 10y Treasury Yield	-0.01	-0.22	0.15
Correlation of Bond Risk Premium and Equity Risk Premium	0.45	-0.46	-0.44

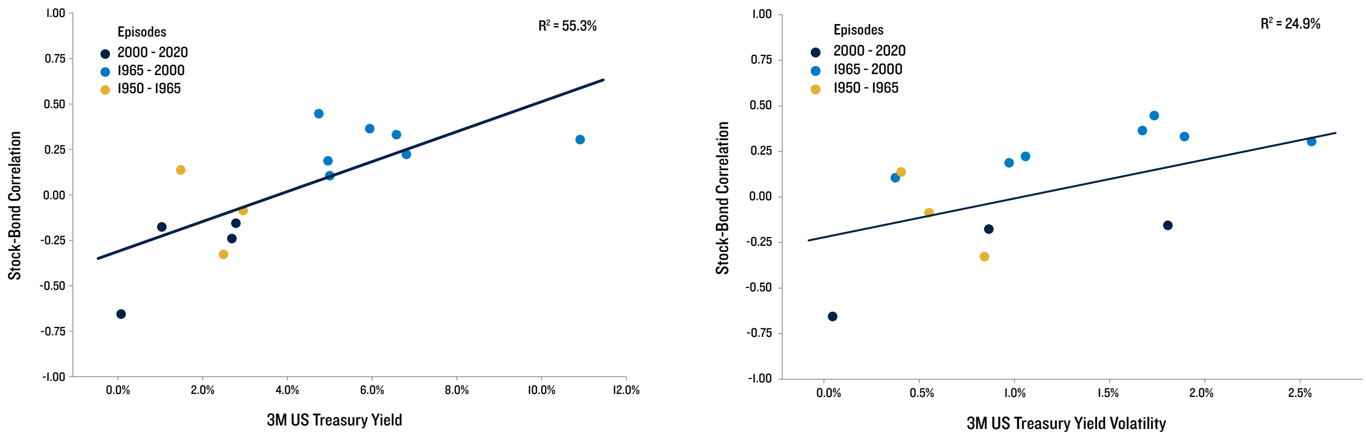
Note: Yields, growth rates, volatilities are all on an annualized basis. Correlations are calculated using monthly data, consistent with stock-bond correlation measures. Bond risk premium (BRP) as measured by ACM term premium is available only from 1961, so, the 1950-1965 BRP average and volatility use 1961-1965 data. Similarly, PCE is available from 1959, and, therefore, the 1950-1965 PCE rate average uses 1959-1965 data.
Source: Bureau of Economic Analysis, Bureau of Labor Statistics, DataStream, Federal Reserve Board, FRED, Haver, NBER, Robert J. Shiller online data, Standard & Poor's and PGIM IAS. For illustrative purposes only.

8 We are ignoring the covariances among growth, BRP/ERP and the components of the discount factor. Also note that, although both stock and bond prices are affected by changes in cash flows (dividends and coupons, respectively), since Treasury cash flows are fixed and certain and, so, are not related to variable equity cash flows, their joint movements do not play a role in stock-bond correlation (*i.e.*, $cov_t(\Delta CF, \Delta CP)=0$).

9 Although our analysis is "univariate," a multivariate approach could be used as well.

10 The price equations suggest that the volatility of rates determines, in part, the covariance between stocks and bonds. The fact that the level of rates varies systematically with stock-bond correlation – a well-documented finding – reflects that rates volatility and rates levels are highly correlated.

Figure 6: Stock-Bond Correlation *vs.* 3m US Treasury Yields and Yield Volatility (Non-Overlapping 5y periods, 1950-2020)



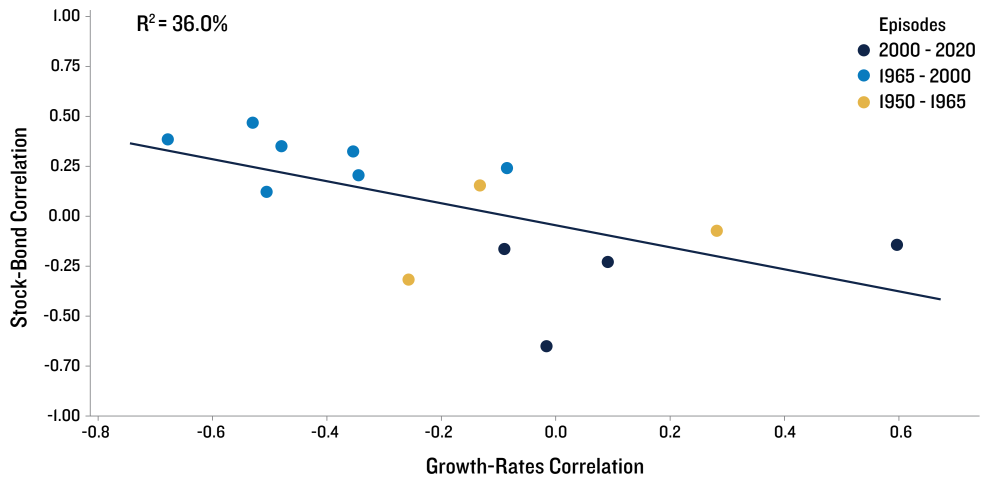
Source: Bureau of Labor Statistics, Federal Reserve Board and PGIM IAS. For illustrative purposes only.

Using non-overlapping 5y periods from 1950 to 2020, we find that higher and more volatile rate periods are associated with positive stock-bond correlation while lower and more stable rate periods are associated with negative correlation. In other words, stock-bond correlation is positively correlated with the level of 3m yields (left panel of Figure 6) and with yield volatility (right panel).[11]

Correlation of economic growth and interest rates: If periods of stronger economic growth (with stronger equity cash flow growth) coincides with periods of higher rates, then stock and bond prices will tend to move in opposite directions, all else equal.

As Figure 5 shows, when stock-bond correlation was positive during the 1965-2000 regime, the correlation of growth and rates was negative (-0.33), and when stock-bond correlation was negative during the 2000-2020 regime, growth-rates correlation was positive (0.2), as expected. However, during the negative 1950-1965 correlation regime, growth-rates correlation was also negative, contrary to our prediction (although at -0.04, growth-rates correlation was essentially zero). That said, Figure 7 shows there is a clear negative relationship between stock-bond correlation and growth-rates correlation when looking at sequential, non-overlapping 5y periods – periods of higher and positive growth-rates correlation correspond to periods of lower and often negative stock-bond correlation, and *vice versa.*[12]

Figure 7: Stock-Bond Correlation *vs.* Growth-Rates Correlation (Non-Overlapping, 5y periods, 1950-2020)



Source: Bureau of Economic Analysis, Federal Reserve Board, Standard & Poor's and PGIM IAS. For illustrative purposes only.

11 Periods of high and volatile inflation also tend to be associated with periods of positive stock-bond correlation. CPI inflation was 4.3%/y from 1965-2000 when stock-bond correlation was positive, compared to 1.3%/y for 1950-1965 and 1.8%/y for 2000-2020 when the correlation was negative. Similarly, inflation volatility was higher during periods of positive stock-bond correlation than during periods of negative stock-bond correlation. Parallel to the evidence with respect to interest rates, when looking at sequential 5y periods the correlation of stock-bond correlation with inflation is 0.69 and with inflation volatility is 0.22.

12 Inflation-growth correlation has a similar impact on stock-bond correlation as does expected inflation-growth correlation.

Correlation of stock and bond risk premia: If stock and bond risk premia move together (*i.e.*, $cov_t(\Delta ERP, \Delta BRP) > 0$) – regardless of direction – then stock-bond correlation tends to be positive, and *vice versa*.[13] For example, if investors become generally more apprehensive about the future (say, worries about slow growth and higher inflation), they may more heavily discount all assets that promise future cash flows and prefer cash, producing positively correlated changes in both bond and stock risk premia. Changes in investor risk tolerance are generally of long duration, causing ERP and BRP to follow a common trend. Figure 8 shows a shared upward trend for BRP and ERP from 1965 to around 1980, followed by a clear shared downward trend to 2000 reflecting either lowered perceived risk, greater risk tolerance, or both.

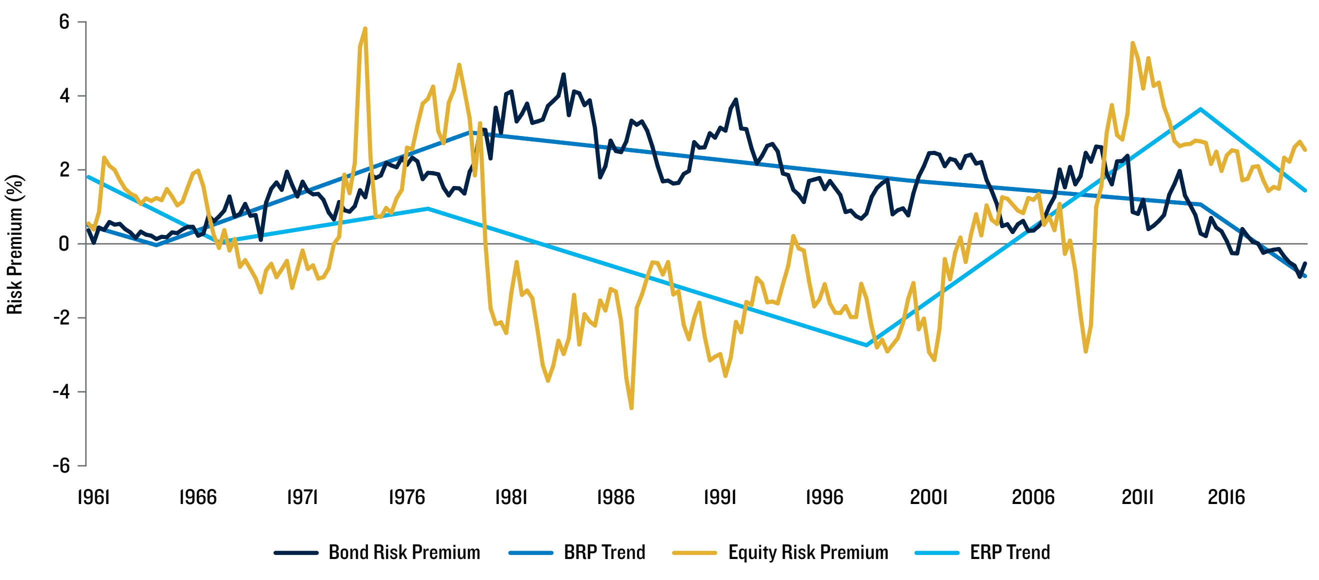
However, depending on the macroeconomic environment, changes in stock and bond risk premia can diverge as well. For example, investors may suddenly view stocks as having high risk and bonds as low risk, causing ERP and BRP to become negatively correlated. These negatively correlated movements, related to mean-reverting "risk-on, risk-off" periods, are familiar to investors (Figure 9) and are generally short-lived, but can be a dominant source of risk premia co-movement. What matters for stock-bond correlation is the relative strength of common versus divergent changes in ERP and BRP.

The presence of a common trend in risk premia (first upward from 1965-1980 and downward until 2000) contributed to the 1965-1980 positive stock-bond correlation regime. However, the short-term "risk-on, risk-off" movements were more dominant, with ERP and BRP negatively correlated as shown in Figure 5. Nevertheless, this component was not sufficient to prevent stock-bond correlation from being positive.

Beginning in 2000, the bond risk premium continued to trend lower, while the equity risk premium began to trend higher for about a decade. This divergent trend movement combined with divergent short-term "risk-on, risk-off" movements have produced a negative ERP-BRP correlation that has, in turn, helped to support the recent prolonged period of negative stock-bond correlation.

More recently, a shared common trend lower in ERP and BRP seems to have emerged, suggesting a weakening of the current negative stock-bond correlation regime. Although speculative, this deserves monitoring. An assessment of a relative repricing of stock and bond risks with a negative pull on stock-bond correlation, or an absolute repricing with a positive sway, can be linked, in part, to macroeconomic policies as we discuss in the next section.

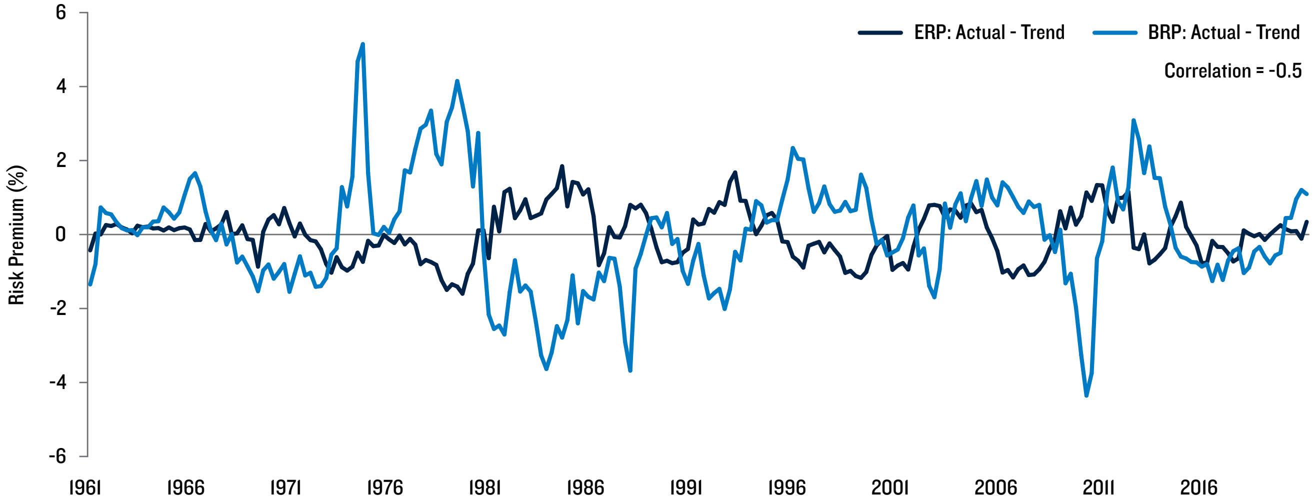
Figure 8: Bond and Equity Risk Premia (1961-2020)



Source: Federal Reserve Bank of New York, Haver Analytics, Standard & Poor's and PGIM IAS. For illustrative purposes only.

13 We define the ERP as the trailing 12m earnings yield minus 10y US Treasury yield. We define the BRP as the difference between the observed 10y Treasury yield and a rolling cumulation of forward short-term rates estimated with a term structure model that uses principal components of Treasury yields as pricing factors (Adrian, Crump and Moench 2013). Defined as such, the BRP was briefly negative for the first time in its history in 2016 and hovered around zero before becoming more persistently negative, perhaps reflecting the valuable hedging properties of bonds, though there are other (not mutually exclusive) explanations. Furthermore, other term structure models that currently assume a flatter forward profile for short-term nominal rates, driven by muted forward growth prospects and inflation risks, may infer a significantly positive BRP.

Figure 9: Bond and Equity Risk Premia: Deviations from Trend (1961-2020)



Source: Federal Reserve Bank of New York, Haver Analytics, Standard & Poor's and PGIM IAS. For illustrative purposes only.

Macroeconomic policy drivers of stock-bond correlation

As suggested by asset price relationships (Equation 1) and validated by the data, stock-bond correlation can be broken down into:

- the volatility (*i.e.*, $\boldsymbol{var_t}$ $(\Delta \boldsymbol{i})$) and level of nominal risk-free rates;
- the correlation of economic growth and interest rates (*i.e.,* $\boldsymbol{cov_t}(\Delta \boldsymbol{c},\Delta \boldsymbol{i})$); and
- the correlation of bond and equity risk premia (*i.e.,* $\boldsymbol{cov_t}(\Delta \boldsymbol{ERP},\Delta \boldsymbol{BRP})$).

We now discuss how these components relate to the broader economic policy backdrop, specifically:

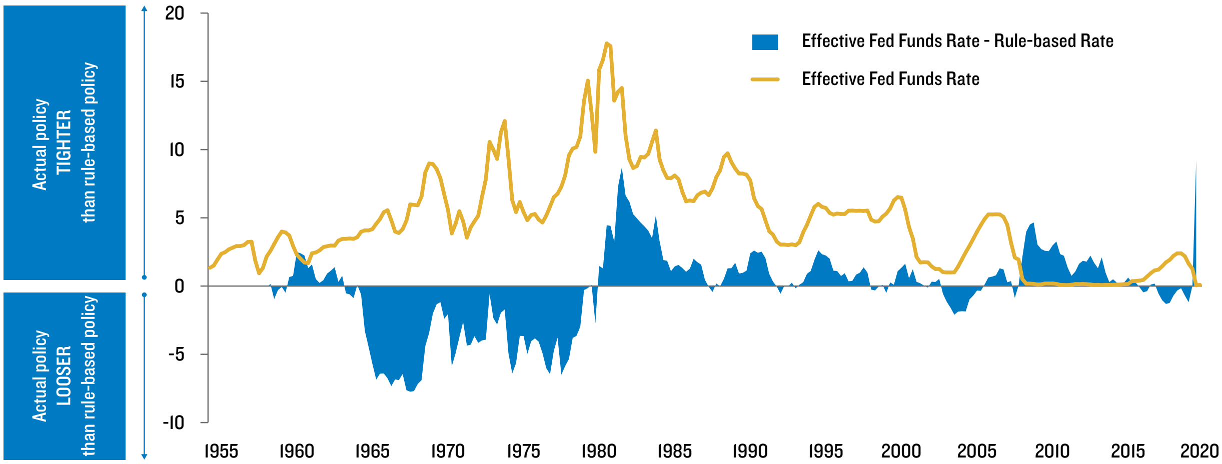
- the degree of monetary policy discretion;
- the sustainability of fiscal policy;
- the degree of fiscal and monetary policy independence; and
- shifts in aggregate supply and demand.

Discretionary versus rules-based monetary policy: Rules-based monetary policy is supportive of negative stock-bond correlation, while discretionary policy is likely associated with positive correlation. When monetary policymakers act in an anticipated *"rules-based"* fashion, changes in the policy rate are dictated by economic conditions. In other words, economic growth and rising policy rates (to combat emerging inflation) move in tandem (*i.e.,* $\boldsymbol{cov_t}(\Delta \boldsymbol{c},\Delta \boldsymbol{i})>0$) which is supportive of *negative* stock-bond correlation. In contrast, *"discretionary"* monetary policy – for example, a large rate hike that slows economic growth to support the dollar – leads to negative correlation between economic growth and rates and *positive* stock-bond correlation.

Fed policy, as reflected by the federal funds rate, can be described as a function of the unemployment rate and inflation, reflecting the Fed's dual mandate to promote price stability and full employment. Such a rule-based policy, often referred to as the "Taylor Rule," is viewed as both descriptive (reflecting the actual history of policy setting) and prescriptive (arising as an optimal policy path for some macroeconomic models).

The Fed publishes a collection of rule-based (counterfactual) policy rates that can be used as a benchmark relative to actual effective Fed funds rates. Comparing the two helps identify periods when the Fed adhered more closely to a rule-based policy and periods when it pursued a more discretionary policy (Figure 10).

Figure 10: The Effective Fed Funds Rate and Deviations from the Taylor Rule (1955-2020)



Source: Federal Reserve Board, Haver Analytics and PGIM IAS. For illustrative purposes only.

Following the Treasury-Fed Accord of 1951, as the Fed's mission pivoted from suppressing federal debt expense toward maintaining price stability and full employment, the fed funds rate was, on average, quite close to the rules-based rate. Until the mid-1960s the Fed adhered to a rules-based policy path that resulted in low and stable interest rates (and inflation) supporting negative stock-bond correlation.

However, starting in the late 1960s Fed policy became more discretionary. The effective funds rate ran below the rules-based rate for the next 15y, conducive to *negative* correlation between economic growth and rates and supportive of *positive* stock-bond correlation. Systematically loose policy led to entrenched inflation expectations with high and variable interest rates, providing further support for positive stock-bond correlation.

In 1979, Chairman Volcker ushered in a new monetary policy era, yet monetary policy *continued to operate in a discretionary manner* for the next decade (setting rates *higher* than rules-based policy rates). Although rates were falling, they remained volatile. Hence, monetary policy continued to support negative correlation between economic growth and rates which, in turn, was supportive of positive stock-bond correlation.

From the late 1980s, and extending well into the 1990s, the Fed hewed to a rules-based monetary policy producing a positive growth-rates correlation which was less supportive for positive stock-bond correlation. However, we will show that other policy and economic considerations supported a positive correlation during the period.

Turning to the current negative stock-bond correlation regime that began in 2000, monetary policy was *initially* rules-based and supportive of negative stock-bond correlation. However, in the wake of the 2008 Financial Crisis, a rule-based Fed policy would have suggested negative policy rates. With the effective policy rate bounded by zero, Fed policy *appears* to have been discretionary (and too tight versus a rule-based policy), running a more discretionary (and *tighter*!) policy. However, to circumvent the lower bound on policy rates, the Fed deployed other policy tools to further ease financial conditions.[14] Importantly, the Fed re-doubled efforts to make policy-making transparent (*e.g.,* post-FOMC meeting press conferences, publishing economic projections and, for a time, targeting the unemployment rate), minimizing the discretionary nature of monetary policy. While not strictly rules-based, this commitment to transparency contributes to negative stock-bond correlation.

Fiscal sustainability: Expansionary fiscal policy can reduce net savings, push up interest rates, and crowd out private investment, thereby restricting the capital stock and limiting long-term growth. Rising debt-to-GDP levels can lead to upward pressure on rates and downward pressure on growth ($\boldsymbol{cov_t}(\Delta \boldsymbol{c},\Delta \boldsymbol{i})<0$), supportive of positive stock-bond correlation. In fact, it is possible to envisage a vicious cycle where an increase in debt leads to higher interest rates (***r***) and lower growth (***g***) worsening the debt burden and widening the ***r-g*** gap.[15]

14 For a view of how well these rules capture actual Fed decision making see Chairman Bernanke's comments (https://www.brookings.edu/blog/ben-bernanke/2015/04/28/the-taylor-rule-a-benchmark-for-monetary-policy/) and (Haakio and Kahn, 2014).

15 Some economists have argued that, given some starting level of debt and assuming balanced budgets into the future, if the real growth rate exceeds the interest rate on the debt, then over time the debt-to-GDP ratio will decline. Others argue that the set of preconditions needed for this result, while possible in theory, are difficult to envisage, particularly with respect to today's US economic situation.

Figure 11: US Public Debt-to-GDP Ratio (1930-2020)

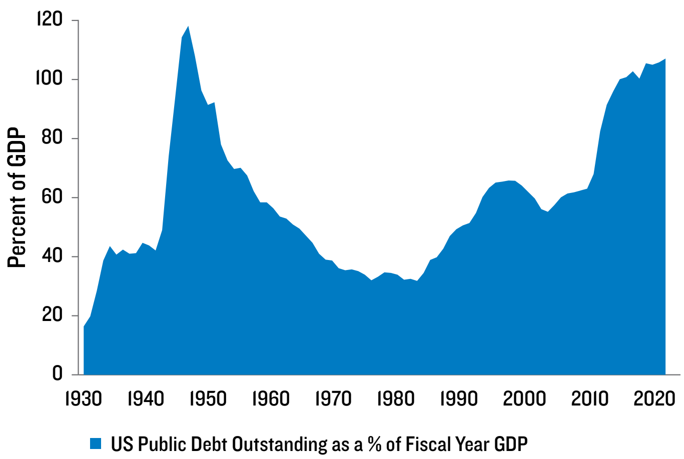
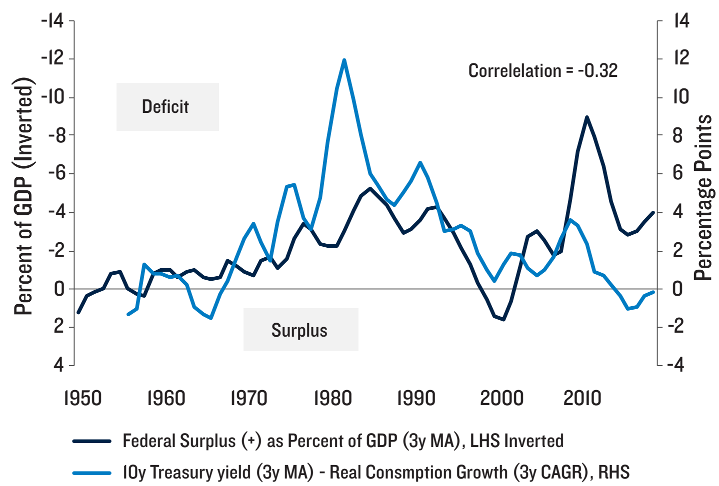


Figure 12: US Federal Budget Balance and r-g Gap (1950-2020)



Note: GDP = Gross Domestic Product; MA = Moving Average; CAGR = Compound Annual Growth Rate; LHS = left hand side; RHS = right hand side.
Source: Bureau of Economic Analysis, Federal Reserve Board, Haver Analytics, Office of Management and Budget, U.S. Treasury and PGIM IAS. For illustrative purposes only.

During the 1950s, fiscal restraint and strong and stable growth helped halve the debt-to-GDP ratio (Figure 11). However, fiscal deficits then became the norm in the late 1960s and the ***r-g*** gap turned positive, intensifying fiscal sustainability concerns (Figure 12). This shift in fiscal paradigm and the negative growth-rates correlation contributed to a positive stock-bond correlation. More recently, the late-1990s to early-2000s period was characterized by a stable debt-to-GDP ratio, and a stable ***r-g*** gap, both reminiscent of the 1950s.

Today, conflicting signals are emerging. Increases in the debt-to-GDP ratio harken back to the late 1960s and 1970s, which would tilt the balance of risks toward higher interest rates, lower growth, and positive stock-bond correlation. However, the ***r-g*** gap is *negative*, as low interest rates offset tepid growth, helping sustain the high debt load.[16]

Independence vs. inter-dependence of monetary and fiscal policy: Although monetary and fiscal policy are typically independent, incentives to coordinate can arise, particularly if either monetary or fiscal policy is constrained.[17] If monetary policy cannot lower interest rates to boost growth, then fiscal policy becomes necessary. Alternatively, if fiscal policy is constrained by the inability to issue or the cost of issuing debt, *monetary* financing (which requires a complicit central bank) is an alternative.

In theory, monetary-fiscal policy coordination helps buoy positive stock-bond correlation as growth rises and interest rates fall ($cov_t(\Delta c,\Delta i)<0$, much like discretionary monetary policy) which, in turn, supports both bond and equity risk premia. A short-lived bout of inflation may be expected, but if policy coordination is considered temporary then long-term expectations should remain anchored. However, if policy coordination is viewed as permanent, then inflation and inflationary expectations may become unanchored, producing volatile and higher rates, lower growth, and rising risk premia. Such an environment would support positive stock-bond correlation, though in a far less benign way, owing to elevated $var(\Delta i)$ and negative $cov(\Delta c,\Delta i)$.

Independence has been a pillar of monetary policy since the Treasury-Fed Accord, and the use of fiscal policy as a stabilization tool was ushered out in the Reagan era.[18] However, with interest rates hovering close to zero, the Fed signaling no intention of raising rates for several years, and the debt-to-GDP ratio climbing, the preconditions for policy coordination are clearly visible. Yet, so far, inflationary expectations remain well-anchored and economic volatility is muted, with stock-bond correlation still negative.

Aggregate supply vs. aggregate demand shifts: Shifts in aggregate demand and supply have very different macroeconomic consequences that, in turn, are conducive to different stock-bond correlation regimes. A shift in aggregate demand – say, outward – pushes output and prices higher together, leading to an uptick in economic growth and inflation. As growth and inflation rise, so do nominal interest rates. The positive co-movement of economic growth and rates is associated with negative stock-bond correlation. In contrast, a shift in aggregate supply – say, outward – would push output higher but prices lower, leading to an uptick in economic growth and lower interest rates and inflation. This negative co-movement between growth and rates is associated with positive stock-bond correlation.

16 The case for the sustainability of current debt levels, given the prevailing r-g gap, can be found in Blanchard (2019).
17 For a discussion of the linkages between monetary and fiscal policy see Taylor (1995), Leeper (1991), and Leeper (2010).
18 See Romer and Romer (2002) for a history of post-WWII US monetary and fiscal policy.

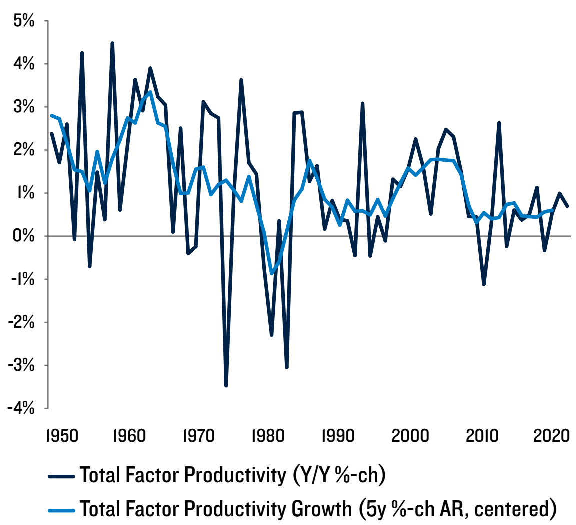
In practice, it is difficult to isolate shifts in aggregate supply and demand precisely. Moreover, one-off supply and demand "shocks" are typically not persistent enough to define a (decades-long) stock-bond correlation regime. Nevertheless, two measures of supply and demand shifts seem to be associated with correlation regimes.

Total factor productivity (TFP), which contributes to economic growth after accounting for any change in production inputs, is one way to measure a persistent supply curve shift. Changes in oil prices can also be viewed as discrete shifts in aggregate supply as higher oil prices – a key cost of production – tend to slow economic growth, feed into higher prices levels, and raise interest rates (*i.e.,* "stagflation").

Indeed, throughout the 1970s, such supply shifts, from both slowing TFP (Figure 13) and rising oil prices (Figure 14), slowed growth, raised inflation, and increased equity and bond risk premia, supporting positive stock-bond correlation. In contrast, an unexpected acceleration in TFP in the late 1990s helped to boost growth while keeping inflation subdued, decreasing interest rates, and moderating both stock and bond risk premia. Aggregate supply shifts – either up or down – support positive stock-bond correlation.

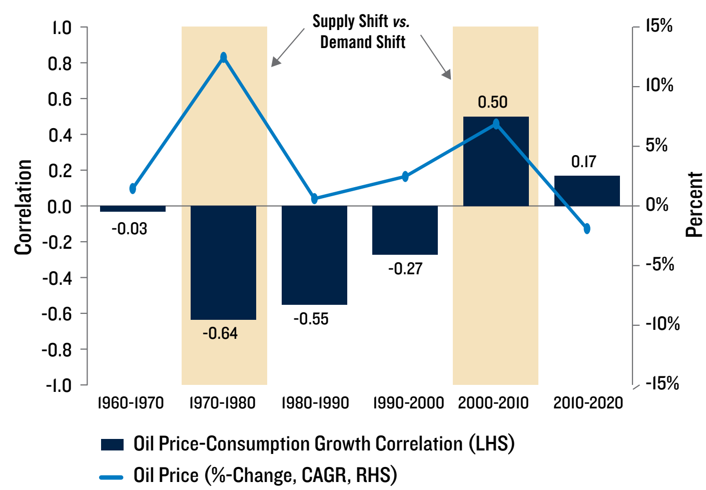
Interestingly, with the increase in domestic oil production since 2000, a rise in oil prices has shifted from being a measure of supply-side pressure to a sign of global demand strength. Consequently, the correlation between oil prices and US economic growth is positive, supporting the current *negative* stock-bond correlation.

Figure 13: US Total Factor Productivity Growth (1950-2020)



Source: Bureau of Labor Statistics, Haver Analytics and PGIM IAS.
For illustrative purposes only.

Figure 14: US Consumption Growth and Oil Price Changes (1960-2020)



The compound annual growth rate (CAGR) is the annualized average rate of revenue growth between two given years, assuming growth takes place at an exponentially compounded rate.

Source: Bureau of Economic Analysis, Bureau of Labor Statistics, Haver Analytics and PGIM IAS. For illustrative purposes only.

A summing up

Figure 15 summarizes the macroeconomic conditions and economic policy settings that affect stock-bond correlation. Stock-bond correlation is in our view, reliably associated with interest rate volatility, the co-movement of economic growth and interest rates, and the co-movement of equity and bond risk premia, both in theory and in the data. These economic conditions themselves are best thought of as "symptoms" of the underlying macroeconomic environment, which ultimately relates to monetary and fiscal policy and broad economic shifts.

Linking stock-bond correlation regimes to economic conditions and policy provides investors with a roadmap but is no panacea. Anticipating changes in correlation is an exercise in foreseeing how policy makers will likely behave and how economic data respond. Although the current negative stock-bond correlation regime has coincided with persistently falling and low interest rates, continued low interest rates alone are not enough to support a negative correlation. Focus ought to be on the broader policy backdrop and its implications for: interest rate volatility, the co-movement of bond and equity risk premia, and the co-movement of economic growth and interest rates. As such, we advocate that CIOs vigilantly monitor the key economic and policy developments that could lead to a shift in stock-bond correlation.

Figure 15: Stock-Bond Correlation, Macroeconomic Conditions and Economic Policy Drivers

POSITIVE
Stock-Bond Correlation Regime

MACROECONOMIC CONDITIONS
- High and variable risk-free rates
- High and variable inflation
- Negative growth-rates correlation
- Equity risk premium and bond risk premium move together

ECONOMIC AND POLICY DRIVERS
- Monetary surprises
- Unsustainable fiscal policy
- Interdependent fiscal and monetary policy
- Supply shocks

PAST REGIMES
- 1965-2000

NEGATIVE
Stock-Bond Correlation Regime

MACROECONOMIC CONDITIONS
- Low and stable risk-free rates
- Low and stable inflation
- Positive growth-rates correlation
- Equity risk premium and bond risk premium move apart

ECONOMIC AND POLICY DRIVERS
- Rules-based monetary policy
- Sustainable fiscal policy
- Independent fiscal and monetary policy
- Demand shocks

PAST REGIMES
- 1950-1965 & 2000-present

Source: PGIM IAS. For illustrative purposes only.

Acknowledgments

We wish to thank Dr. Taimur Hyat for his valuable comments and suggestions.

APPENDIX

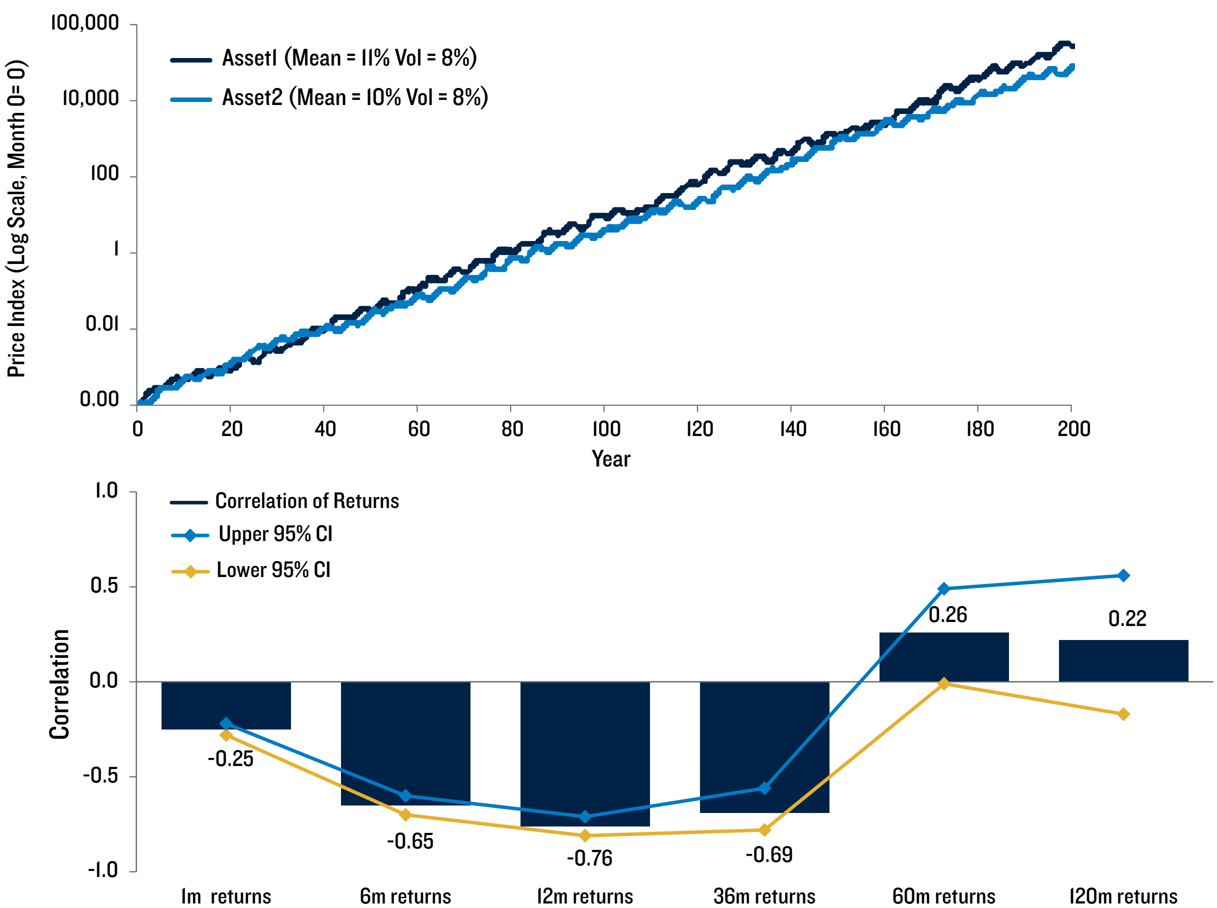
A1: Estimating the correlation coefficient

Correlation is a common gauge of co-movement, but its measurement can be problematic and occasionally misleading. To illustrate, consider two assets with (log) prices that trend higher over time with similar average returns and volatilities. However, the returns of one asset are "pro-cyclical" while the other asset has "counter-cyclical" returns (Figure A1, top panel). In other words, despite a common upward trend and equal volatility, at a business cycle frequency when one asset experiences above-average returns the other tends to have below-average returns, and *vice versa*.

Simulating 200y of monthly returns for these two assets, we find that the correlation of monthly returns is *close to zero* (-0.25) as short-term volatility dominates the common trend. However, the correlation of 12m returns – which is the frequency of the cycle in this constructed example – is *strongly negative* (-0.65), while the correlation of long-term returns, say 5y returns, is *positively* correlated (+0.26) as the common trend in prices eventually squelches both short-term volatility and cyclical fluctuations (Figure A1, bottom panel).

This illustration highlights the pitfalls of blanket statements about "the" correlation: two assets could be correctly characterized as uncorrelated, negatively correlated *and* positively correlated. The relevant correlation measure depends on context and intended use. An investor with a long-term investment horizon but who also manages portfolio allocation on a short-term basis needs to consider both short-term (say, monthly) and long-term (say, 1y or longer) market scenarios. Consequently, both correlation calculations may matter.

Figure A1: 200y of Simulated Asset Prices & Correlation of Returns (Sampled monthly)



Note: CI = Confidence Interval.

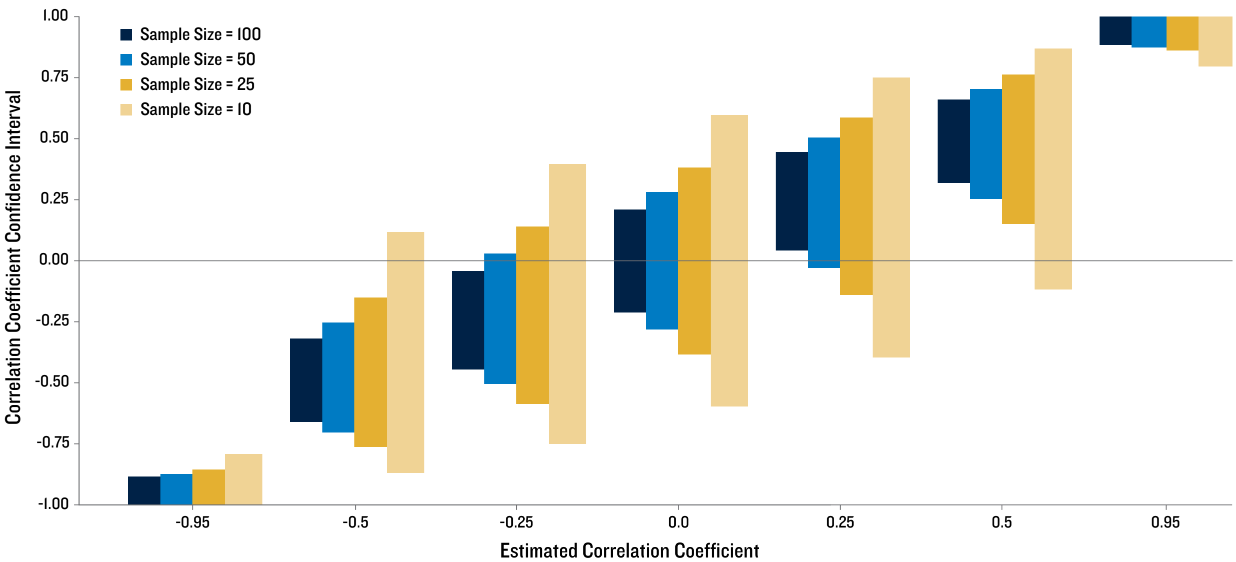
Source: PGIM IAS. For illustrative purposes only.

A2: Sample size, inference, autocorrelation and overlapping returns

With about 70y of US data, estimating the correlation of long-term returns is hampered by insufficiently large sample sizes. Analyzing returns at the 1y, 3y or 5y frequency offers only 14 to at most 70 independent (*i.e.*, non-overlapping) data points from which to estimate correlations. Such small sample sizes generally produce large confidence intervals (Figure A2). For example, with 25 data points (the equivalent of looking at 3y returns and estimating a single correlation parameter over the 1950 to 2020 period) the 95% confidence interval for an estimated correlation coefficient of 0.5 is [0.2, 0.72], while the interval for an estimated coefficient of 0.25 (or smaller) includes zero. Allowing for the possibility that correlation varies over time effectively shrinks estimation power of the available data further, making statistical inference even more difficult.

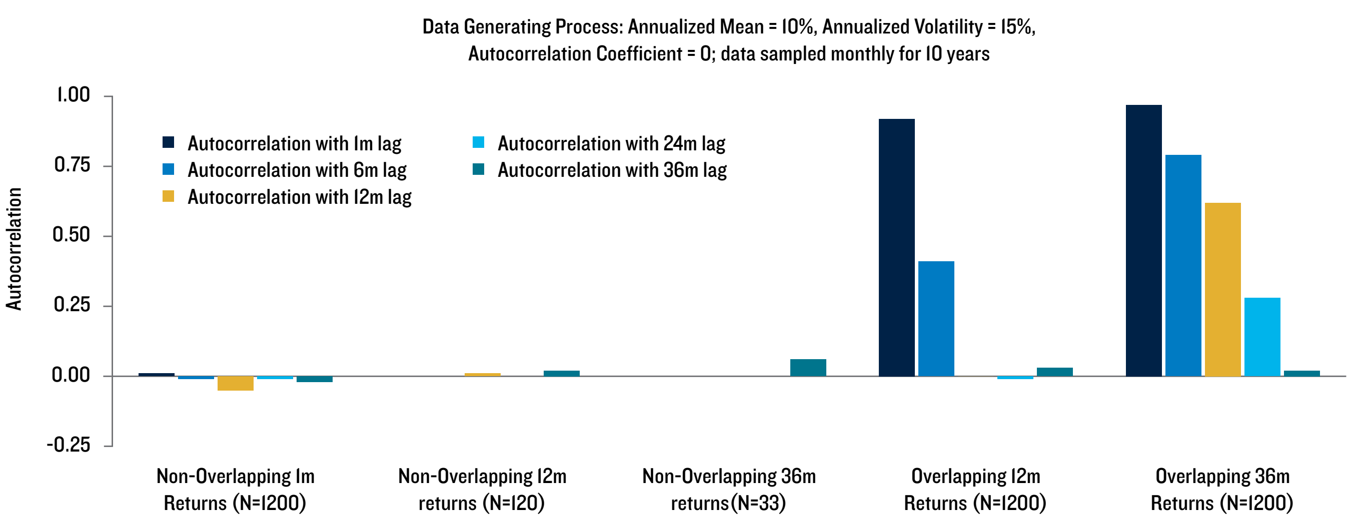
The use of overlapping returns – linking monthly returns together to generate a rolling annual return each month – is a tempting workaround; 120m of data generate 108 overlapping 1y returns. But the increase in sample size is illusory as adjacent annual returns add little new information (*e.g.*, the January-to-January return is mostly the same as the adjacent December-to-December return). The problem is that overlapping long-term returns can have significant autocorrelation even when the actual data-generating process for higher-frequency returns does not (see Figure A3).

Figure A2: Sample Size and Confidence Intervals for Various Correlation Estimates



Source: PGIM IAS. For illustrative purposes only.

Figure A3: Autocorrelation – Overlapping and Non-Overlapping Returns

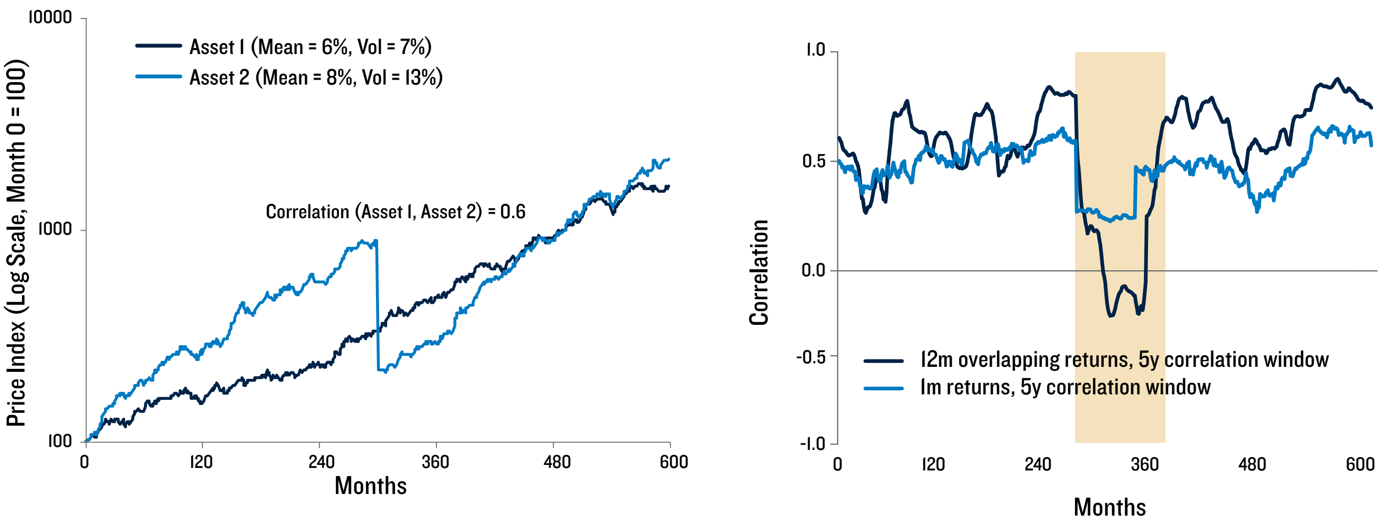


Source: PGIM IAS. For illustrative purposes only.

Moreover, the persistence of overlapping returns can cause short-term price shocks to have a large and persistent impact on correlation. For example, suppose two assets move together with a correlation 0.6 (assuming equal volatilities, *ex-ante*, and assuming "asset 2" has a beta of 0.6 to "asset 1"). A sharp "risk-off" decline in the price of asset 2 and a concomitant rally in asset 1 will sharply lower the correlation of high-frequency returns (and raise the *ex post* volatility of the risk-off asset). But if the price of asset 2 subsequently returns to its upward trend, even if its price level remains below previous highs for some time, the correlation of short-term returns will turn positive again. In contrast, the correlation of overlapping long-term returns will absorb and amplify (*i.e.,* by increasing the number of observations where the two asset returns are of opposite sign) the one-off disconnect and will remain negative for a protracted period (Figure A4).

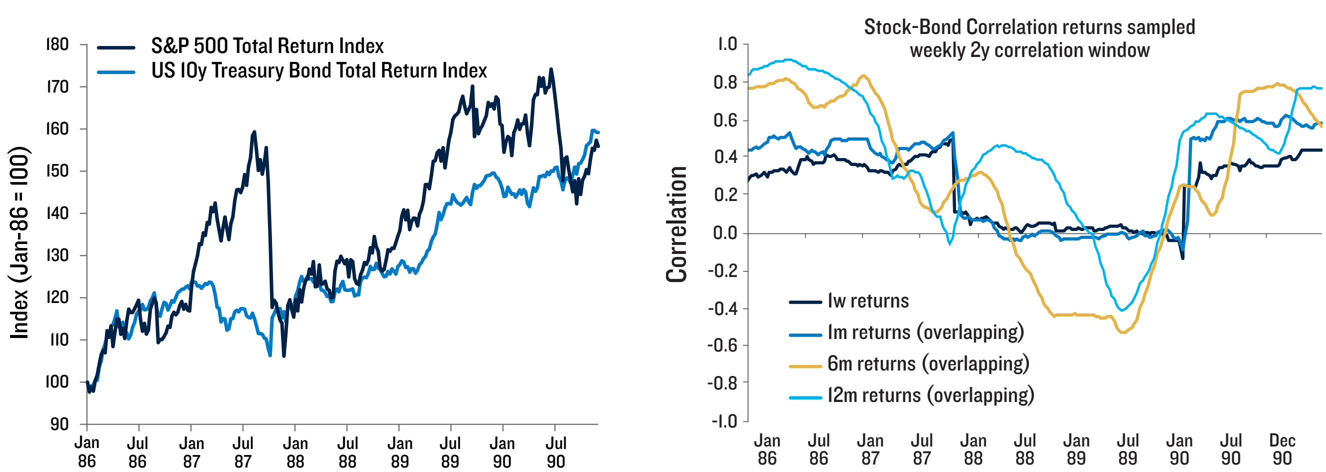
This is not just a theoretical curiosity visible in (highly engineered) simulated data. The sharp 1987 stock market sell-off and subsequent return to trend looks very much like the generated data. The one-off stock price decline pushed the correlation of short-term (1-week) stock and bond returns lower, with an equally sharp rebound, while the correlation of longer-term overlapping returns (6m and 12m) turned deeply negative (Figure A5).[19]

Figure A4: Impact of a One-Time Price Dislocation on Correlation (Overlapping *vs.* Non-overlapping returns)



Source: PGIM IAS. For illustrative purposes only.

Figure A5: S&P 500 & 10y US Treasury Index Total Returns (1986-1990)



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

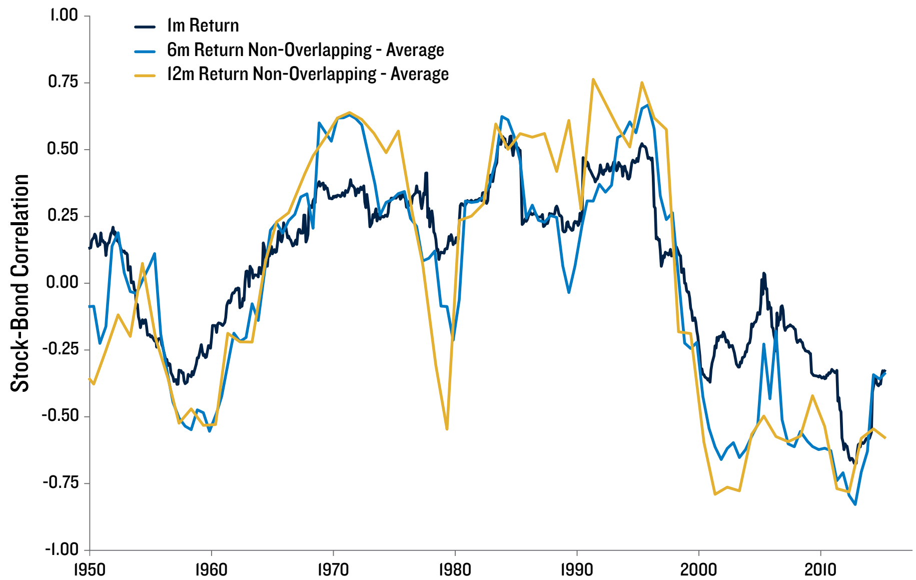
19 For a discussion of investment horizon, correlation and asset allocation, see Parikh (PGIM IAS, 2019).

A3: Stock-bond correlation – short-run *vs.* long-run returns

For investors intending long holding periods, the correlation of long-term returns is likely most relevant for allocation decisions. Yet, rebalancing and risk considerations require a higher-frequency look at the data. Fortunately, for stock-bond return correlations, there seems to be some agreement between correlations using short-run (say, 1m) and longer-term (say, 12m) returns.

- **Short-term and long-term correlations are correlated.** The rolling 1m-return correlation is highly correlated with non-overlapping 6m-return and 12m-return correlations. The "correlation of correlations" is high (Figure A6).
- **Short-term return and long-term return regimes are consistent.** Focusing on correlation regimes, when the correlation of non-overlapping 12m returns is positive (negative), the nested 1m-return correlation is positive (negative) more than 91% (69%) of the time (Figure A7). This suggests that the higher-frequency correlation signal is highly consistent with what a lower frequency correlation will eventually reveal.
- **Negative correlation regimes are not just due to "risk-off" dynamics.** A common view is that stocks and bonds are fundamentally positively correlated, with prices trending together driven by their reliance on a common discount rate (Equation 1, above). Consequently, any observed negative correlation is a result of short-lived periods of market stress (*i.e.,* a "risk-off" selling of stocks and buying of bonds) or of higher short-term volatility and a bad "draw" of data. However, when removing periods around volatility spikes and the subsequent volatility moderation – arguably capturing both "risk-off" and subsequent "risk-on" driven negative stock-bond correlation – the resulting (5y rolling) correlation of 1m stock and bond returns looks remarkably like the full sample estimate (Figure A8). Even without risk-on/risk-off episodes, stock-bond correlation has been reliably negative over the last 20 years, though perhaps a bit more volatile and more deeply negative back in the 1950-1965 period as well.

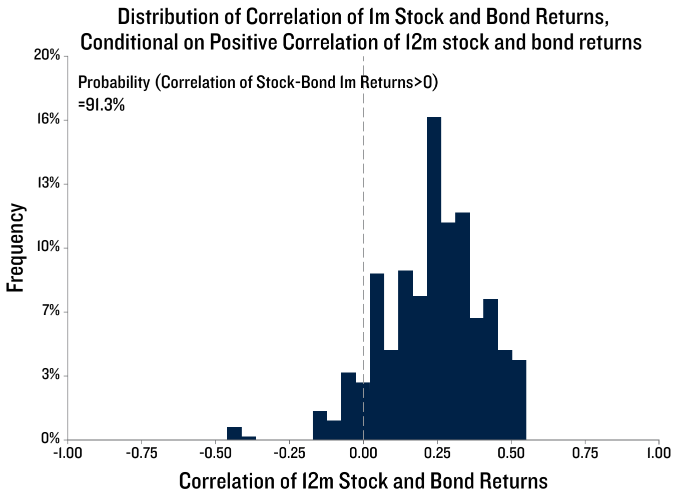
Figure A6: Stock-Bond Correlation
(1m, 6m, and 12m non-overlapping returns, 5y-centered, rolling window 1950-2020)

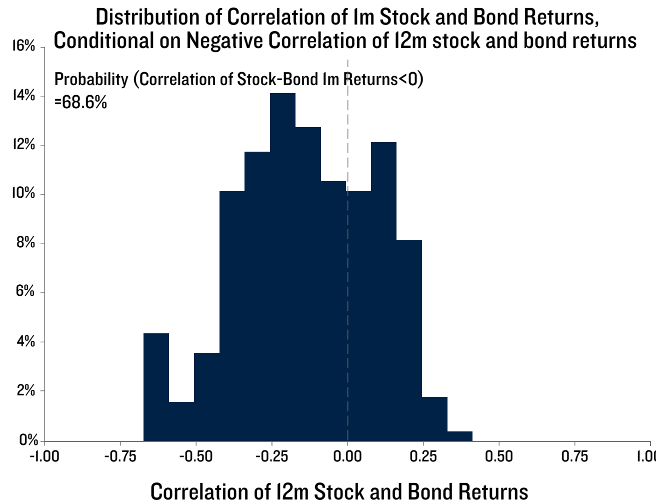


Correlation of Correlations			
	1m Returns	6m Returns, Non-overlapping – Average	12m Returns, Non-overlapping – Average
1m Returns	1.00	0.89	0.82
6m Returns, Non-overlapping – Average	0.89	1.00	0.91
12m Returns, Non-overlapping – Average	0.82	0.91	1.00

Note: 6m (12m) Returns, Non-overlapping – Average measures the average of 6m (12m) correlations sampled at different periods within the 5y rolling window. For example, for the 5y rolling correlation of 6m non-overlapping returns, we can generate six different correlation time series depending on which 6m return we start with. Therefore, 6m Returns, Non-overlapping – Average is the time series of the average of the six correlations.
Source: DataStream, FRED, NBER, Robert J. Shiller online data and PGIM IAS. For illustrative purposes only.

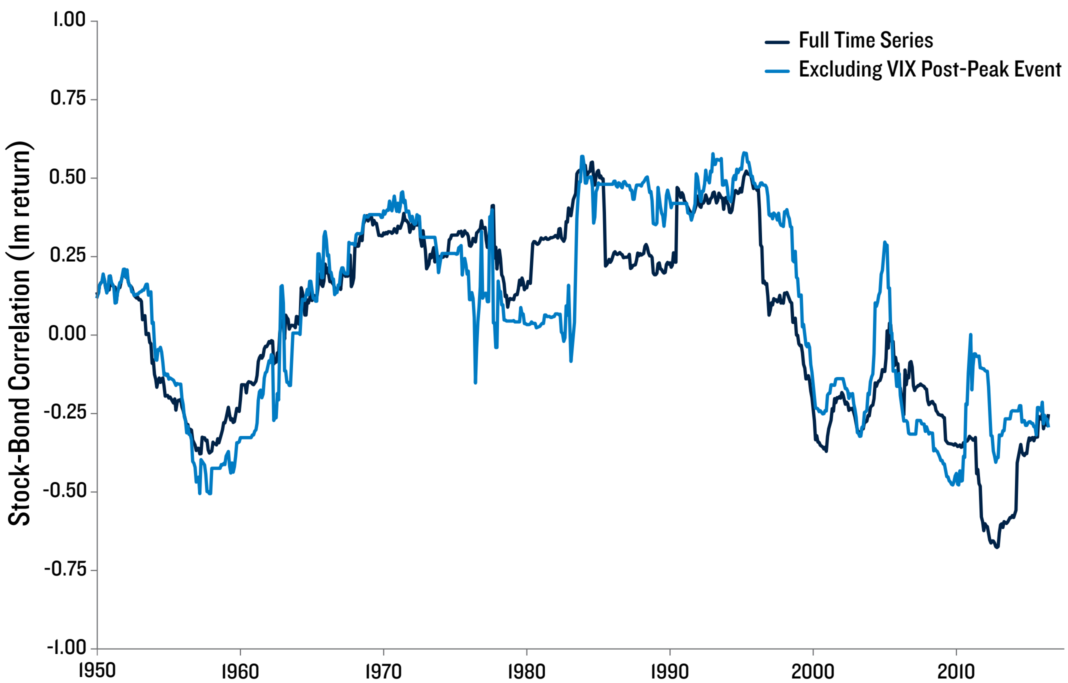
Figure A7: Sign of Stock-Bond Correlation: 1m *vs.* 12m returns (Non-overlapping returns, 5y-centered, rolling window, 1950-2020)





Source: DataStream, FRED, NBER, Robert J. Shiller online data and PGIM IAS. For illustrative purposes only.

Figure A8: Stock-Bond Correlation Excluding Volatility Spike Periods (1950-2020)



Note: A VIX post peak event occurs when, after a period of several months, the VIX has fallen significantly from its recent peak toward pre-peak levels. If the VIX in month t_{0+9} falls to less than 2/3 the value in month t_0, we call month t_0 a VIX peak month. The post-peak event period includes the two months leading into the peak month (*i.e.*, month t_{0-1} and month t_0) and the nine months following the peak month (*i.e.*, month t_{0+1} through month t_{0+9}). Consequently, we assume a post-peak event has a duration of 11 months.[20]
Source: DataStream, FRED, NBER, Robert J. Shiller online data and PGIM IAS. For illustrative purposes only.

20 For greater detail on the use of equity volatility to define risk-off/risk-on periods of asset performance in that context, see Xie, "When the Dust Flies - How Volatility Events Affect Asset Class Performance," PGIM IAS, April 2018.

A4: Deriving stock/bond covariance from the log-linearized present discounted value of cash flows

To derive the covariance of stock and bond returns, we begin by writing the price of a zero-coupon bond (a simplification) as the bond's face value (***FV***) discounted by the risk-free rate (***i***) and a bond risk premium (***BRP***).

$$\textit{Bond Price}_t = \frac{FV}{(1 + BRP_t + i_t)^t} \tag{A1}$$

Taking the natural log of the bond price and approximating gives the following expression:

$$ln(\textit{Bond Price})_t = ln\,(FV) - t \times ln\,(1 + BRP_t + i_t) \approx ln\,(FV) - t \times (BRP_t + i_t) + \varepsilon_B \tag{A2}$$

Taking the first difference of the log price, bond returns are a linear function of the risk-free rate and the bond risk premium, along with an approximation error:

$$r_B = -\Delta BRP - \Delta i + \Delta \varepsilon_B \tag{A3}$$

Similarly, the stock price can be written as an infinite stream of cashflows (***CF***) discounted by the risk-free rate and the equity risk premium (***ERP+i***) less the steady state growth rate of cash flows (***g***).

$$\textit{Stock Price}_t = \frac{CF_{t+1}}{ERP_t + i_t - g_t} \tag{A4}$$

Taking natural logs of the stock price and then differencing, stock returns are:

$$ln(\textit{Stock Price})_t = ln\,(CF_{t+1}) - ln\,(ERP_t + i_t - g_t) \tag{A5}$$

$$r_S = ln\left(\frac{CF_{t+2}}{CF_{t+1}}\right) - ln\left(\frac{ERP_{t+1} + i_{t+1} - g_{t+1}}{ERP_t + i_t - g_t}\right) = \Delta ln(CF) - ln\,(1 + \frac{\Delta ERP + \Delta i - \Delta g}{ERP_t + i_t - g_t}) \tag{A6}$$

For $\Delta ERP + \Delta i - \Delta g$ close to 0, (A6) becomes:

$$r_S \approx \Delta ln(CF) - k_t\,(\Delta ERP + \Delta i - \Delta g) + \varepsilon_S \tag{A7}$$

$$\textit{wkere } k_t = \frac{1}{ERP_t + i_t - g_t}$$

Using (A7) and (A3), the covariance of stock and bond returns can be expressed as follows:

$$cov_{S,B}(r_B, r_S) = cov_{S,B}(\,(-\Delta BRP - \Delta i + \Delta\varepsilon_B), (\Delta ln(CF) - k\Delta ERP - k\Delta i + k\Delta g + \varepsilon_S)\,) \tag{A8}$$

Focusing on the terms of interest, the covariance of stock and bond returns can be decomposed as:

$$cov_{S,B}(r_B, r_S) = \gamma_1 var\ (\Delta i) - \gamma_2 cov\ (\Delta CF, \Delta i) + \gamma_3 cov\ (\Delta ERP, \Delta BRP) + \textit{cross terms and error terms} \tag{A9}$$
$$\gamma_1, \gamma_2, \gamma_3 > 0$$

Interpreting this decomposition of stock-bond covariance is intuitive. Changes in the risk-free rate affect both stock and bond prices in the same direction, hence rate volatility contributes positively to the covariance of stock-bond returns. The equity risk premia and bond risk premia are also both elements of the discount rate, hence when their covariance is positive (negative), it contributes positively (negatively) to the covariance of stock and bond returns. Cashflows are part of the stock-price numerator, while the risk-free rate is in the denominator of both stocks and bonds. Therefore, when the covariance of cashflows and rates is positive (negative), it contributes negatively (positively) to the covariance of stock and bond returns. Above, we show that stock-bond correlation tends to be:

- Positive when rates volatility is high, bond and equity risk premia are trending together, and cashflow growth and interest rates are moving apart.
- Negative when rates volatility is low, bond and equity risk premia are moving apart, and cashflow growth and interest rates are moving in tandem.

A5: Data sources and construction

UST 3m Yield: 3m US Treasury bill rate is available through Fred from 1934. (https://fred.stlouisfed.org/series/TB3MS).

UST 10y Yield: Monthly 10y Constant Maturity Rate is available through Haver from 1953. Before 1953, we use monthly yield of UST with effective maturity 10-20 years from NBER that is available from 1942 to 1967, that well approximates the monthly interpolated UST10Y available annually from Robert Shiller website data before 1953 (http://www.econ.yale.edu/~shiller/data/ie_data.xls).

S&P 500 Total Return: S&P 500 Total Return Index is available since 1970 through DataStream, that is spliced with S&P 500 total return calculated from S&P 500 price and dividends data from Robert Shiller website data (http://www.econ.yale.edu/~shiller/data/ie_data.xls) before 1970.

UST 10y Total Return: Monthly 10y US Treasury bond total return is calculated from 10y US Treasury by assuming: 1) the fresh bond is issued at par at month three and month nine of each year. 2) the maturity of all bonds is 10y, 3) there is no callable feature, 4) the portfolio is entirely rolled into the fresh bond when issued, 5) and coupons are paid semiannually (and therefore the first coupon is due immediately before the rebalancing).

Real Personal Consumption Expenditure: The data is available quarterly from Haver since Q1 1947, from which we also linearly interpolate monthly real PCE.

The Personal Consumption Expenditure Price Index: PCE data are available monthly from Haver from January 1959.

The Consumer Price Index: CPI data are available monthly from Haver from January 1947.

Volatility: The volatility of any macro variable, such as volatility of nominal risk-free rates is calculated with monthly data in the same rolling window in which stock-bond correlation is measured.

Covariance (or Correlation): The covariance (or correlation) of two macro variables, such as covariance (or correlation) of economic growth and interest rates is calculated with monthly data in the same rolling window in which stock-bond correlation is measured.

Stock-bond returns and correlation: Using the monthly S&P 500 total return index as the stock market asset, the non-overlapping, trailing 1m S&P 500 return is:

$$stock_{t+1} = \frac{S\&P\ 500\ Index_{\ t+1}}{S\&P\ 500\ Index_{\ t}} - 1.$$

Using the monthly 10y US Treasury total return index as the bond asset, bond returns are defined similarly. Suppressing return frequency superscripts, the ***time-t*** rolling correlation monthly stock and bond returns calculated over an ***H-period*** window is:

$$\rho_t^H = \frac{\sigma_{sb,t}}{\sigma_{s,t}\sigma_{b,t}} = \frac{\sum_{h=1}^{H}(stock_{t-h} - \overline{stock})(bond_{t-h} - \overline{bond})}{\sqrt{\sum_{h=1}^{H}\left(stock_{t-h} - \overline{stock}\right)^2 \sum_{h=1}^{H}\left(bond_{t-h} - \overline{bond}\right)^2}}$$

where, $\boldsymbol{\sigma_{s,t}}$ ***and*** $\boldsymbol{\sigma_{b,t}}$ are the volatility of stock and bond returns, respectively, $\boldsymbol{\sigma_{sb,t}}$ is their covariance, $\boldsymbol{stock_t}$ and $\boldsymbol{bond_t}$ are defined as stock and bond returns per above, and $\overline{\boldsymbol{stock}}$ and $\overline{\boldsymbol{bond}}$ represent estimated mean returns over the ***H-period*** horizon. Figure A9 reports the resulting stock-bond correlation data and related statistics.

Figure A9: Stock-Bond Correlation Decomposition (1950-2020)

	Stock-Bond Correlation			Bond (UST10y)		Stock (S&P 500)		
	Full Period	Average	Frequency of Correlation >0	Total Return (Annualized)	Volatility (Annualized)	Total Return (Annualized)	Volatility (Annualized)	Stock-Bond Covariance
Regime								
1950-1965	-0.16	-0.08	37%	2.23%	2.78%	16.08%	10.31%	-0.04%
1965-2000	0.28	0.29	97%	7.27%	6.68%	12.24%	12.03%	0.23%
2000-2020	-0.29	-0.30	0%	5.08%	5.92%	6.72%	12.49%	-0.21%
5y Episode Ending…								
1955	0.14	0.06	73%	2.05%	1.90%	21.28%	9.28%	0.02%
1960	-0.33	-0.29	0%	0.09%	3.71%	15.15%	10.82%	-0.13%
1965	-0.09	-0.03	37%	4.54%	2.28%	11.81%	10.73%	-0.02%
1970	0.19	0.24	100%	0.83%	3.61%	5.97%	9.63%	0.07%
1975	0.36	0.31	100%	5.95%	5.71%	-1.47%	14.08%	0.29%
1980	0.33	0.25	100%	4.26%	4.84%	12.71%	12.22%	0.20%
1985	0.30	0.38	100%	11.23%	11.29%	15.32%	13.20%	0.45%
1990	0.22	0.26	100%	13.02%	7.31%	18.77%	12.89%	0.21%
1995	0.45	0.41	100%	6.94%	5.26%	9.58%	9.25%	0.22%
2000	0.11	0.17	78%	8.64%	5.49%	24.78%	11.17%	0.06%
2005	-0.24	-0.25	0%	7.45%	6.46%	-1.05%	13.70%	-0.21%
2010	-0.16	-0.18	0%	5.38%	6.54%	1.93%	15.73%	-0.16%
2015	-0.66	-0.49	0%	4.34%	5.80%	15.21%	10.11%	-0.38%
2020	-0.18	-0.27	0%	3.16%	4.77%	10.78%	8.97%	-0.08%

Source: PGIM IAS. For illustrative purposes only.

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