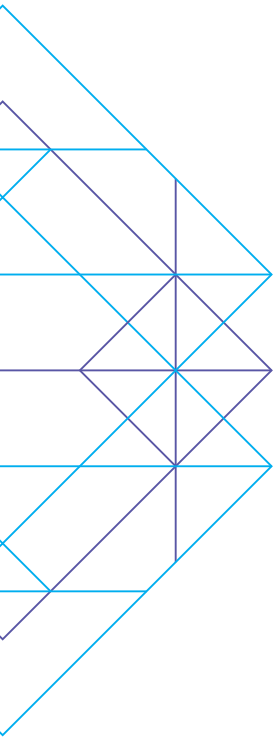
Alternative Thinking | Q2 2022

The Stock/Bond Correlation

Drivers and Implications



Executive Summary

The relationship between stock and bond returns is a fundamental determinant of risk in traditional portfolios. For the past two decades the stock/bond correlation has been consistently negative, and investors have largely been able to rely on their bond investments for protection when equities sell off. But this hasn't always been the case, and macroeconomic changes – such as higher inflation uncertainty – could lead to a reappearance of the positive stock/bond correlation of the '70s, '80s and '90s. This would have broad implications for investors, either increasing portfolio risk or forcing allocation changes likely to reduce expected returns.

In this article we set out practical steps to prepare for such an outcome: first, understanding the drivers and implications of this 'golden parameter' before it loses its luster, and second, revisiting alternatives – which could play a crucial investment role in a positive stock/bond correlation world.

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About the Portfolio Solutions Group

The Portfolio Solutions Group (PSG) provides thought leadership to the broader investment community and custom analyses to help AQR clients achieve better portfolio outcomes.

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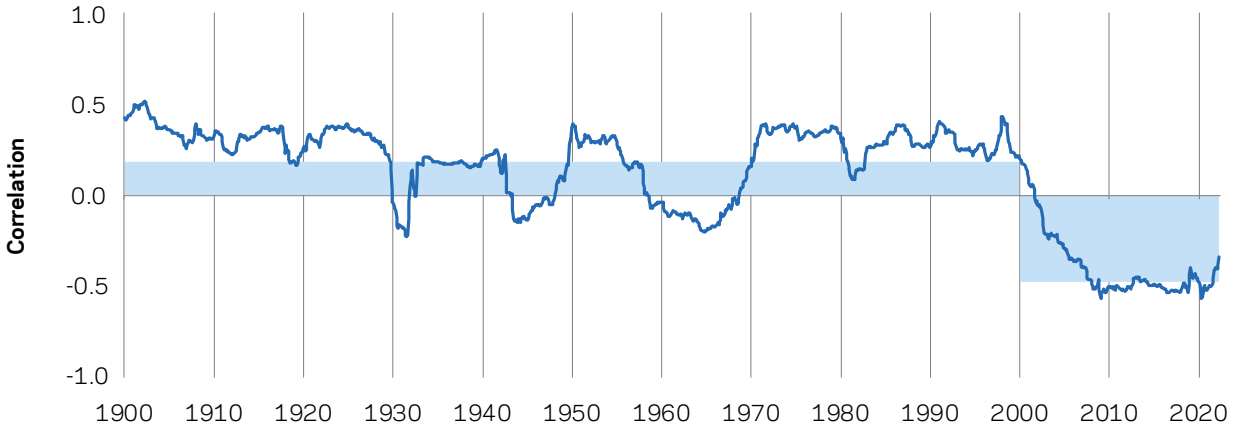
Introduction

For most of the past century, equities have served as the dominant return generator in many portfolios, with bonds as the chief diversifier. In the last 20 years, however, the relationship between the two asset classes has been quite different from earlier history, as **Exhibit 1** shows. Bonds have not just diluted equity risk – as they did for most of the 1900s – but have delivered valuable outsized returns when equity markets suffered losses. For younger investors, this reassuring offsetting behavior has been their only experience (except for a few brief episodes of simultaneous stock and bond losses, such as the 2013 "taper tantrum"). But go back a bit farther, and history tells a different story, one in which a negative stock/bond correlation (henceforth SBC) has been the exception, not the rule.[1]

Exhibit 1: Rolling 10-Year Correlation Between U.S. Equities and U.S. Treasuries
January 1, 1900 – March 31, 2022



Sources: Bloomberg, Global Financial Data, AQR. Based on overlapping 3-month returns at monthly frequency. Shading shows average correlations in 20th and 21st Centuries.

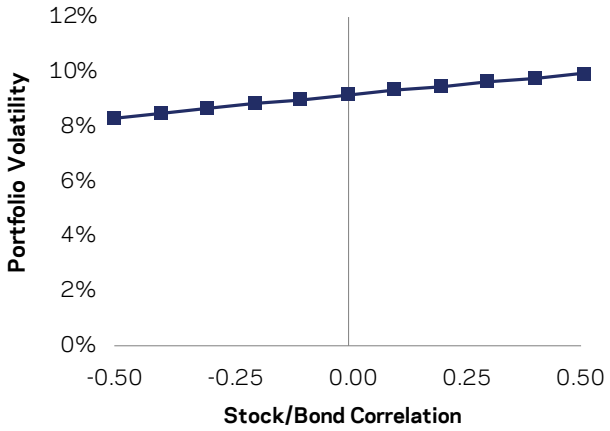
Before we consider the drivers of stock/bond diversification, we ask: why does this matter? What would the consequences be of a higher SBC? Most obviously, it would mean less diversification, and therefore more risk for stock/bond portfolios. In **Exhibit 2, Panel A,** we show the expected volatility of a 60/40 stock/bond portfolio at different levels of assumed correlation between the two asset classes. If the SBC rises from -0.5 to +0.5, 60/40 portfolio volatility – and other measures of risk such as expected drawdowns – increases by around 20%.[2] Such a change in risk profile might require meaningful allocation changes, as we illustrate in **Panel B**. If risk tolerance stays the same, investors would need to decrease their equity allocation to maintain constant portfolio risk, and this equates to lower expected returns for the portfolio. In other words, asset class diversification is not just about risk – it's about returns too.

1 See Ilmanen (2003) for early evidence of the correlation sign flip and literature references. Importantly, most literature, including this paper, focuses on virtually default-free government bonds such as U.S. Treasuries. Equity correlations are clearly higher for corporate bonds or sovereign bonds with higher perceived default risk. These can be thought of as having a default-free component and a spread component. For corporates, the spread risk is correlated to equity risk (see Asvanunt and Richardson (2017)).

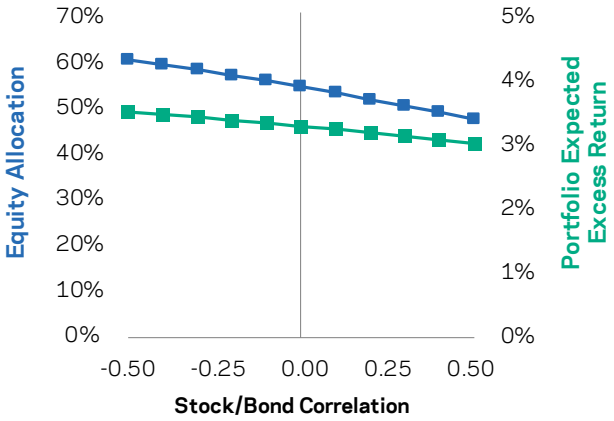
2 Implications would be directionally similar for any portfolio dominated by stocks and bonds, and for alternative measures of risk. For stock/bond portfolios with better risk balance and hence more diversification (such as 40/60), the impact of a change in correlation would be even larger.

Exhibit 2: Implications of Changing Stock/Bond Correlation for a Hypothetical 60/40 Portfolio

A: Expected Volatility of 60/40 Portfolio



B: Allocation Changes to Maintain Portfolio Risk



Source: AQR. Hypothetical 60/40 stock/bond portfolio based on assumption of 15% volatility for stocks and 4% volatility for bonds. For panel B, we solve for the weights required to maintain portfolio volatility (assuming -0.5 SBC as the base case) as we increase the stock/bond correlation assumption. Portfolio expected return assumes 0.3 Sharpe ratio each for stocks and bonds. Hypothetical performance results have certain inherent limitations, some of which are disclosed in the Appendix.

We've shown that a higher SBC could have stark implications for asset allocation, but what could be the catalyst for a reemergence of the positive correlation we've seen historically? Some investors assumed that record low short-term interest rates and bond yields would threaten stock/bond diversification, fearing that yields would not be able to fall further to cushion equity losses. However, low yields in themselves have not been a major problem for stock/bond diversification.[3] While some markets with deeply negative yields may have seen some impairment of stock/bond diversification at times, the last decade has proved that, in general, strong diversification is still possible in a low yield environment.

Others have pointed to the level of inflation, noting that inflation rates were generally higher during periods of positive SBC. But was that the real catalyst? In this paper we explore the theoretical drivers of the SBC and create a framework for understanding it. We find the key determinant to be not the level of inflation, but the relative importance of inflation uncertainty and growth uncertainty – as well as the relationship between growth and inflation news. We think it's important that investors prepare for the possibility of a higher SBC, and we provide a menu of alternative diversifiers that could help create portfolios more resilient to this outcome.

3 See Brooks (2021) for an accessible but comprehensive treatment of drivers of bond yields, including discussion of the impact of potential lower bounds. See also Alternative Thinking (Q2 2021) which uses simulation analysis to show that low starting yields, and the existence of a yield floor, do not necessarily harm the diversification potential of bonds.

What Drives the Stock/Bond Correlation?[4]

First we consider the main macroeconomic drivers of each asset class, starting with growth. Positive growth news raises equity investors' expectations of future cash flows, and hence equity prices. It also raises interest rate expectations, so bond prices fall.[5] In other words, stocks and bonds have opposite sensitivities to growth news. What about inflation? Positive inflation news directly reduces the value of bonds' fixed nominal cash flows, so prices fall. Equities, in theory, give investors a claim on real cash flows, but in practice rising inflation has usually been associated with falling stock prices.[6]

Exhibit 3 illustrates the above contemporaneous relationships using the framework of Ilmanen, Maloney and Ross (2014). We divide 50 years of data into "up" and "down" growth and inflation regimes, and calculate the risk-adjusted return (Sharpe ratio) of stocks and bonds in each regime. The chart shows the difference in Sharpe ratio for each asset class in each regime, compared to its full-period average.

Intuitively, equities strongly prefer 'growth up' environments, while bonds exhibit the opposite relationship. With regards to inflation, both asset classes prefer "inflation down", though bonds' sensitivity is noticeably stronger.

Exhibit 3: Sharpe Ratio in Macroeconomic Environments Minus Long-Term Sharpe Ratio
January 1, 1972 – December 31, 2021

Source: AQR, Robert Shiller Data Library, Bloomberg, Consensus Economics, FRED. U.S. Stocks are the S&P 500. U.S. Bonds are nominal 10-Year U.S. Treasuries. Please see Appendix for more details on the construction of the macroeconomic environment indicators. Past performance is not a reliable indicator of future performance. All returns are gross of fees.

4 There is an extensive literature on stock–bond co-movement, typically examining interactions between real rates, expected cash flow growth, and expected inflation. See, for example, David and Veronesi (2016), Baz, Sapra, and Ramirez (2019), or Campbell, Sunderam, and Viceira (2017), and references therein. For drivers of bond yields, see Brooks (2021).

5 A higher discount rate also puts downward pressure on equity prices, but empirically the change in expected cash flows has tended to dominate this discount rate effect for equities.

6 This tendency has been well-documented and the reasons much discussed, perhaps starting with Lintner (1975). Possible drivers can be broadly categorized as behavioral or rational, with the former including investors' tendency to discount real cash flows with nominal discount rates (the so-called 'money illusion'), and the latter including inflation's impact on firms' operating efficiency, political uncertainty and long-term expectations for real rates.

So empirically we find that stocks and bonds have opposite sensitivities to economic growth, but directionally similar sensitivities to inflation. In other words, growth shocks drive stock and bond returns in opposite directions, while inflation shocks drive them in the same direction. The *relative importance* of growth and inflation news, therefore, suggests itself as potential driver of the SBC. In the next section we set out this hypothesis more formally and then test it on nearly a century of data across several markets.

A Simple Model to Understand the SBC

In the previous section we showed empirical evidence confirming the intuition that stocks and bonds have opposite sensitivities to economic growth, and similar sensitivities to inflation. Now we use this relationship to create a simple model linking returns to inflation and growth news, assuming that stock returns (r_s) and bond returns (r_b) are driven by growth shocks (e_g) and inflation shocks (e_π).[7]

$$r_s = b_{s,g}e_g + b_{s,\pi}e_\pi \quad (1)$$

$$r_b = b_{b,g}e_g + b_{b,\pi}e_\pi \quad (2)$$

$$\text{where } b_{s,g} > 0 \text{ and } b_{s,\pi}, b_{b,g}, b_{b,\pi} < 0$$

Stocks like growth but dislike inflation

Bonds dislike growth and inflation

According to this model, the covariance between stocks and bonds is:

$$\text{cov}(r_s, r_b) = (b_{s,g}b_{b,g})\sigma_g^2 + (b_{s,\pi}b_{b,\pi})\sigma_\pi^2 + (b_{s,g}b_{b,\pi} + b_{s,\pi}b_{b,g})\sigma_{g,\pi} \quad (3)$$

− + −/+

When growth uncertainty is high, s/b correlation tends to be negative

When inflation uncertainty is high, s/b correlation tends to be positive

Growth/inflation correlation can also matter - see later

The covariance tends to be negative when growth variance is high (the betas of stocks and bonds to growth are positive and negative respectively – so their product is negative) and positive when inflation uncertainty is high (the betas of stocks and bonds to inflation are both negative, so their product is positive). If we assume that variance is a measure of uncertainty, this is consistent with our intuition from the previous section stocks and bonds are stronger diversifiers when growth news dominates, and weaker diversifiers when inflation news dominates.

We can translate this logic from stock/bond covariance to correlation. Covariance is effectively a volatility-scaled correlation, so any driver of covariance will have the same directional impact on correlation. A consistent model for the SBC links it to growth volatility, inflation volatility, and the growth-inflation correlation:

$$\hat{\rho}_{s,b} = c_o + c_g\hat{\sigma}_g + c_\pi\hat{\sigma}_\pi + c_{g,\pi}\hat{\rho}_{g,\pi} + \varepsilon \quad (4)$$

Model Predicts this should be negative

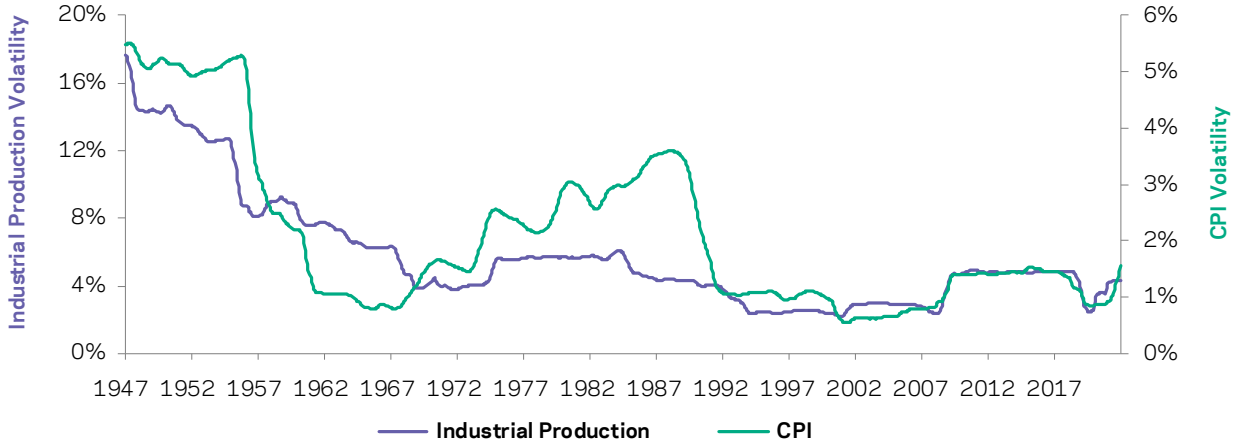
Model predicts this should be positive

7 This simple macro model is based on in-house notes from Jordan Brooks in the mid-2010s. Technically, the dependent variable in equations (1) and (2) is the *unexpected* return.

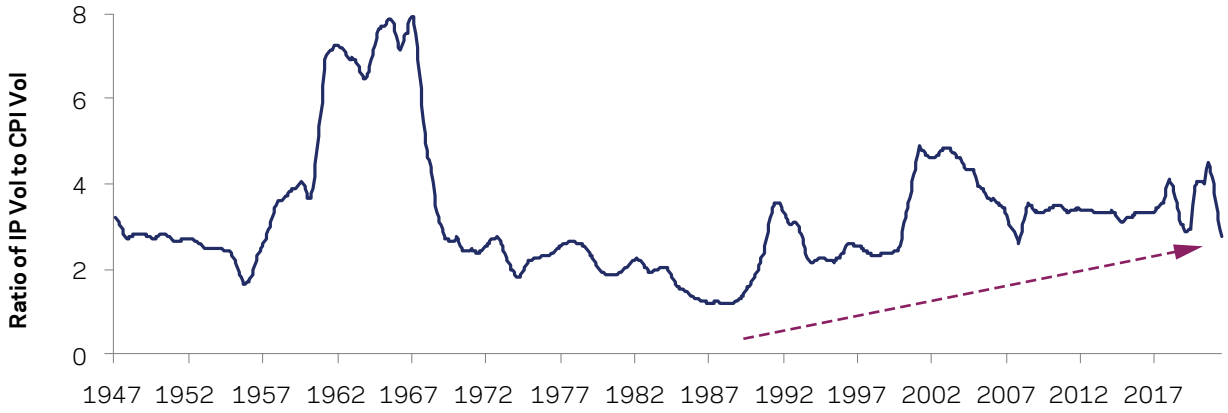
We can estimate the coefficients in this model directly by using actual data to estimate its LHS and three RHS variables. For *growth uncertainty* we use rolling 10-year volatility of year-on-year changes in U.S. industrial production, and for *inflation uncertainty* we use rolling 10-year volatility of year-on-year changes in CPI, both going back to 1936. The third explanatory factor is the *correlation between growth and inflation*, which we proxy with the rolling 10-year correlation between 12-month changes in industrial production and 12-month changes in CPI. We plot our first two explanatory variables in **Exhibit 4, Panel A** and their ratio in **Panel B.** The relative importance of growth uncertainty has been increasing over the last few decades (red arrow), which is consistent with a fall in stock/bond correlation according to our model. The peak in the early 60s coincides with an earlier dip in the SBC as shown in **Exhibit 1**.

Exhibit 4: Data Inputs for Our Simple Model

A: U.S. YOY Industrial Production (IP) and Consumer Price Index (CPI), Rolling 10-Year Volatility
December 1, 1936 – March 31, 2022



B: Ratio of Industrial Production Volatility to CPI Volatility (from above)
December 1, 1936 – March 31, 2022



Source: AQR, FRED. U.S. YOY Industrial Production is the 12-month change in Industrial Production. U.S. YOY Consumer Price Index is the 12-month change in the CPI for All Urban Consumers: All Items in U.S. City Average. Panel A is the rolling 10-year realized volatilities of these two series. Panel B is the ratio of the two series in Panel A.

We can now use this data to run the regression in equation (4), with the rolling 10-year U.S. SBC as our dependent variable. The results are shown in **Exhibit 5** and confirm our hypothesis that the SBC is negatively related to growth risk and positively related to inflation risk. Statistical significance is hard to judge in this setting, where our variables are already estimated quantities and we have few independent (10-year) observations. But the economic significance is substantial: an inflation risk beta of 12 implies that a fall in inflation volatility from, say, 4% to 1% is associated with a decline in the SBC of 3%*12 = 0.36. During periods when growth uncertainty is dominant, as in the last two decades, the SBC is likely to be negative. If we expect higher inflation uncertainty in the 2020s, we might also expect to see a rising SBC.

It's also interesting to note the apparently statistically significant *negative* beta on the third variable – the growth/inflation correlation. This is intuitive too: given that stocks have a stronger sensitivity to growth, and bonds have a stronger sensitivity to inflation, equation (3) tells us this coefficient will be negative.[8] During periods of demand-driven inflation news (positive growth/inflation correlation), the SBC is more likely to be negative. See appendix for more details.

What about the *level* of inflation as a driver of the SBC? If we add it as a fourth variable in our regression, the loading is not significant and the R^2 is unchanged. In other words, once you control for inflation *uncertainty* – which is what should matter according to our model – the level of inflation is not a big driver of the SBC.

Exhibit 5: Stock/Bond Correlation Regression Results

December 1, 1936 – March 31, 2022

	Intercept	Growth Risk	Inflation Risk	Growth/Inflation Correlation
Beta	-0.12	-2.00	12.62	-0.38
t-stat	-1.5	-2.2	5.5	-5.7
R^2		71%		

Source: AQR, Robert Shiller Data Library, FRED. U.S. Stocks are the S&P 500. U.S. Bonds are nominal 10-Year U.S. Treasuries. For the regressions, the LHS variable is the rolling 120-month stock/bond correlation. Growth is the 12-month change in Industrial Production. Inflation is the 12-month change in the CPI. Growth Risk is the rolling 10-year volatility of Growth. Inflation Risk is the rolling 10-year volatility of Inflation. Growth/Inflation Correlation is the rolling 10-year correlation between Growth and Inflation. T-stats are based on Newey-West adjusted standard errors using 119 lags, though this may not fully account for the impact of overlapping observations.

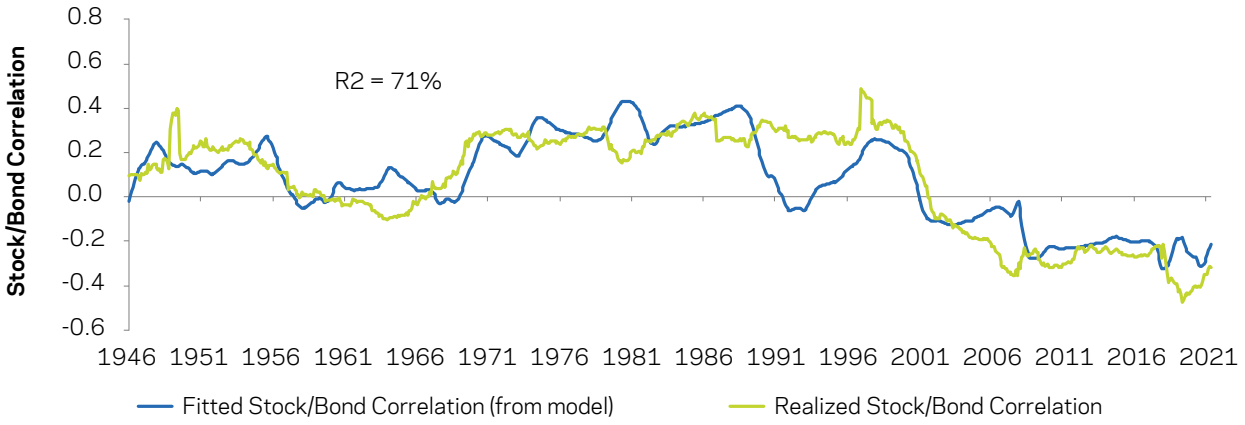
We use the coefficients from **Exhibit 5** to generate a fitted SBC at each point in time, and **Exhibit 6** plots this alongside the realized rolling 10-year SBC. The fitted SBC is a good visual match, reflecting the high explanatory power of these three variables (an R^2 of 71%)[9].

The model captures well the lower-frequency changes in the SBC (positive from late 60s through mid 80s; negative after 2000), though it misses some of the shorter-lived movements.

8 The third coefficient in equation (3) is the sum of two products: $b_{s,g}\, b_{b,\pi} + b_{s,\pi}\, b_{b,g}$. The first product is negative, the second positive. Given the importance of growth news for stocks and inflation news for bonds, we'd expect the first term to dominate and the coefficient to be negative.

9 Note that this is an explanatory rather than a predictive relationship. In other words, we are testing the extent to which changes in these three variables can explain changes in the SBC during this period.

Exhibit 6: Visually Testing our Model
Realized U.S. Stock/Bond Correlation and Macro Model Forecast, Rolling 10-Year
December 1, 1936 – March 31, 2022



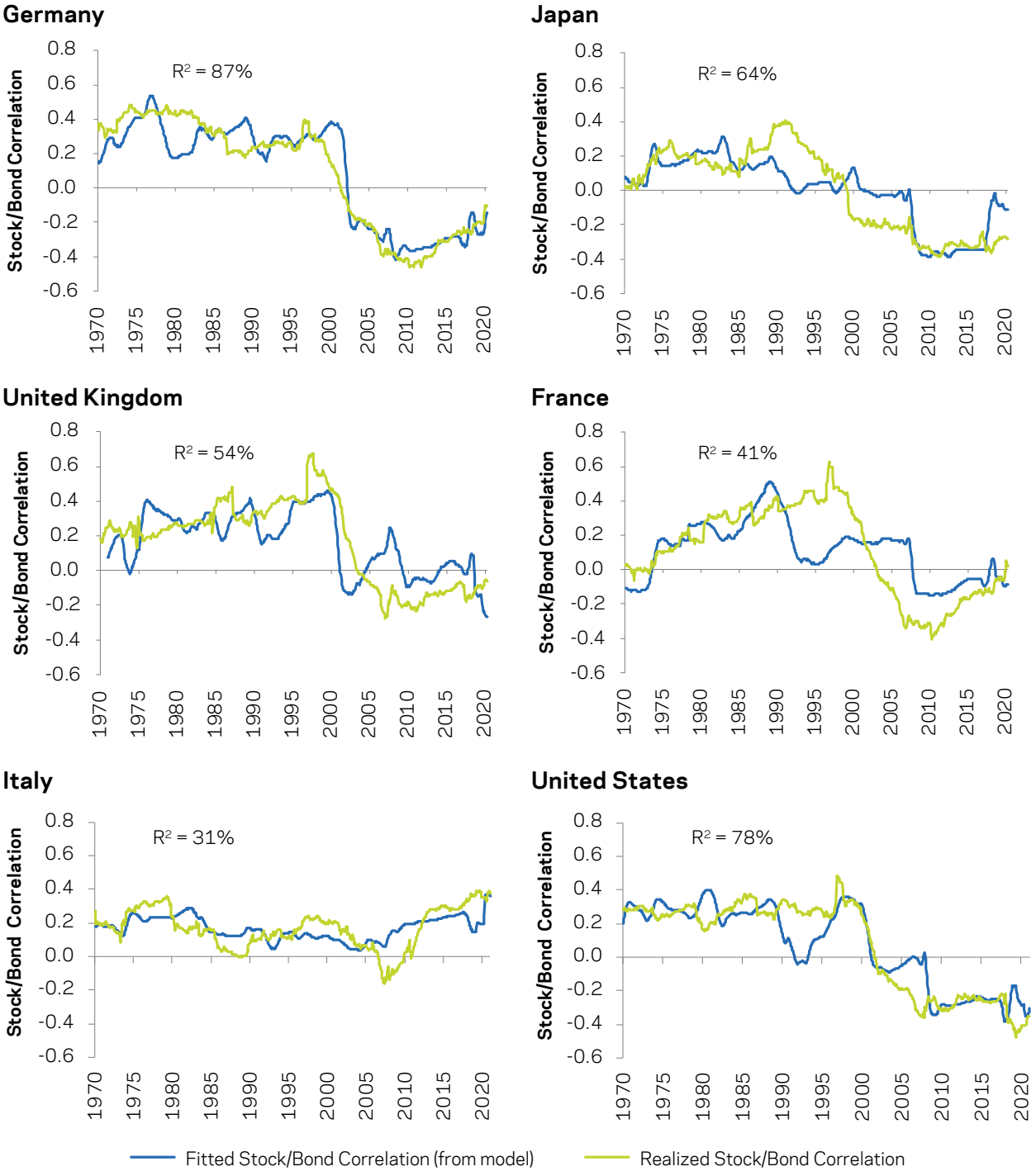
Source: AQR, Robert Shiller Data Library, FRED. U.S. Stocks are the S&P 500. U.S. Bonds are nominal 10-Year U.S. Treasuries. For the regressions, the series being analyzed is the rolling 10-year stock/bond correlation. Growth (IP) is the 12-month change in Industrial Production. Inflation (CPI) is the 12-month change in the CPI. Growth Risk is the rolling 10-year volatility of Growth. Inflation Risk is the rolling 10-year volatility of Inflation. Growth/Inflation Correlation is the rolling 10-year correlation between Growth and Inflation. The fitted correlation above uses the regression betas/alpha from the previous exhibit. Hypothetical performance results have certain inherent limitations, some of which are disclosed in the Appendix.

International Evidence

So far we've focused on U.S. data, but do our conclusions hold internationally? In **Exhibit 7** we plot the same visual representation of our model as in **Exhibit 6** but for Germany, Japan, France, the U.K., and Italy. Here we use returns for local equity and bond markets and local measures of industrial production and CPI over a slightly shorter history, from 1960 (we include the U.S. over the same period for comparison). The results are remarkably consistent – especially strong for Germany where the model realizes an R^2 of 87%, but also good for Japan and the U.K. which realize R^2s of 64% and 54% respectively. The model is weaker for France, and weaker still for Italy where credit risk may be a significant driver. Italian bonds have more credit risk than the other bonds we study (which explains the higher average SBC), and also more time variation in credit risk (which explains the lower explanatory power of a model that ignores credit risk).

Exhibit 7: International Evidence

Realized Stock/Bond Correlation and Macro Model Forecast International Data, Rolling 10-Year
January 1, 1960 – December 31, 2021



Source: AQR, FRED, GFD. Data ends December 2021 due to less timely data for international Industrial Production and CPI on the FRED website. For the regressions, the series being analyzed is the rolling 10-year stock/bond correlation. Growth (IP) is the 12-month change in Industrial Production for each country. Inflation (CPI) is the 12-month change in the CPI for each country. Growth Risk is the rolling 10-year volatility of Growth. Inflation Risk is the rolling 10-year volatility of Inflation. Growth/Inflation Correlation is the rolling 10-year correlation between Growth and Inflation. The fitted correlations above use the same regression methodology as the previous slide but uses each country's stock and bond returns and CPI and Industrial Production measures. Hypothetical performance results have certain inherent limitations, some of which are disclosed in the Appendix.

Limitations of the Model

Growth and inflation news are important but they are not the *only* drivers of stock and bond returns (as our simplified model assumes), so they are also unlikely to be the only drivers of the SBC. Here we list some other candidates. Firstly, a pure monetary policy shock would move stocks and bonds in the same direction via the discount rate. Such shocks are hard to measure as they often coincide with (or are a response to) growth and inflation shocks, but they may be responsible for some of the higher-frequency variation in the SBC (for example, the positive spike during the 2013 'taper tantrum'). We mentioned the role of credit risk. A related driver is "flight to safety" which has tended to intensify the negative SBC as long as bonds are deemed a safe asset (e.g., during the Financial Crisis of 2008).

Luck may be another driver. The period of negative SBC has been characterized by well-communicated monetary policy and rock-solid credibility of central banks' ability to manage inflation risks. It has also been characterized by demand-pull inflation, which has made the central banks' work easier by aligning their two mandates. Good policy or good luck? Probably a bit of both.

One phenomenon that has *not* driven the SBC is the secular downward trend in real rates and related richening of both stocks and bonds – the SBC remained negative even as both asset classes experienced this tailwind. It follows that a reversal in the trend – a return to rising yields and cheapening of both asset classes – would not necessarily produce a positive SBC, *unless* it were accompanied by (or a response to) a sustained rise in inflation uncertainty.

We have shown results for rolling 10-year variables, and explained long-term changes in the SBC regime. If we test the same model on shorter horizons (say, 5-year or 3-year), the signs of coefficients stay the same but the explanatory power weakens. This could be because other drivers become more important at shorter horizons, or it could be because our proxies are less accurate measures of the variables at shorter horizons. Either way, shorter-term fluctuations in the SBC are likely to be harder to explain or predict using macroeconomic fundamentals.

How to Navigate a Changing SBC

Awareness is half the battle. Investors should communicate the importance and drivers of the SBC to their stakeholders, and the implications of a possible change in regime. This process could include:

- Putting together a dashboard to track realized SBC as well as indicators of inflation risk such as option-implied inflation volatility and economist forecast dispersion,
- Performing asset allocation scenario analysis where you shock the correlation matrix,
- Having a plan to respond to reduced diversification.

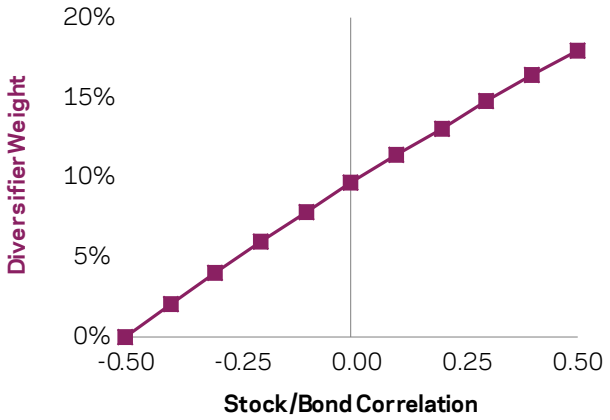
Alternatives are likely to be an important tool for navigating a changing SBC. If the performance of stock and bond allocations becomes more correlated, a 'third allocation' – diversifying to both traditional asset

classes – may be able to make up the diversification deficit.

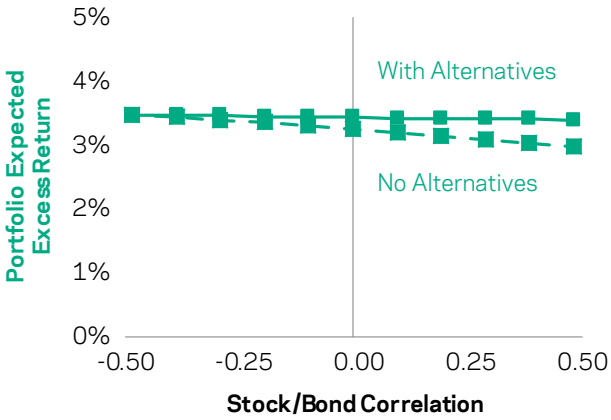
Recall in **Exhibit 2, Panel B** where we showed how much the stock weight in a stock/bond portfolio would have to be reduced to maintain portfolio risk as the SBC increased, and the associated reduction in expected return. What if we could instead reallocate to an alternative diversifier and maintain both portfolio risk and return? In **Exhibit 8, Panel A**, we show the allocation to a hypothetical alternative diversifier (assumed to be uncorrelated to stocks and bonds) required to maintain portfolio risk as the SBC increases. In **Panel B** we see that, unlike simply reallocating to bonds, reallocating to such a diversifier could help to maintain both portfolio risk and return.

Exhibit 8: Adding a Diversifier to Your Portfolio

A. Hypothetical Diversifier Weight Required to Maintain Portfolio Risk as SBC Increases



B. Expected Return When Maintaining Portfolio Risk With and Without Alternatives



Source: AQR. We assume a 0.3 Sharpe ratio for stocks, bonds, and alternatives. We assume 15% volatility for stocks, 4% volatility for bonds, and 10% volatility for alternatives, with alternatives 0-correlated to stocks and bonds. As we increase the SBC assumption, we hold everything else equal but solve for the alternatives capital weight that results in a portfolio with the same volatility as the 60/40 portfolio with SBC=-0.5, keeping the ratio of stocks to bonds fixed at 60:40. In panel B the solid line is expected excess return with alternatives, and the dotted line is without. Hypothetical performance results have certain inherent limitations, some of which are disclosed in the Appendix.

What real-world investments could fit the bill of our hypothetical diversifier in **Exhibit 8**? Some alternatives are better suited to this challenge than others:[10]

- **Illiquid alternatives** like private equity and private credit may provide some cushion against short-term volatility due to their lack of mark-to-market pricing, but their diversification potential is limited as they inherit the same underlying economic exposures as their public market equivalents.
- **Commodities** have been lowly correlated to both stocks and bonds on average, and have delivered stronger diversification during periods of inflation uncertainty. Brixton, Maloney, and Ooi (2022) highlight the benefits of a diversified allocation, showing that a broad basket of commodities has delivered inflation protection as strong as any individual commodity sector.

10 We described these diversifiers in more detail in a 2021 white paper, "Time to Diversify – But into What?", including a discussion of the pros and cons of illiquid and liquid alternatives.

- **Long/Short Equity and Multi-Asset Alternative Risk Premia** strategies use financial tools like shorting and leverage to deliver returns less correlated to stocks and bonds. Some are constructed to be market-neutral, and these most closely reflect the assumptions of our hypothetical diversifier in **Exhibit 8**. The performance of these strategies is largely unrelated to the macro environment, making them good strategic diversifiers.
- Dynamic strategies like **Trend** and **Macro** take directional views at any point in time, but are lowly correlated to markets over the long term. Brixton, Maloney, and Thapar (2021) show that these strategies have tended to thrive on macroeconomic volatility, for example outperforming during both upside and downside inflation shocks.

Conclusion and Outlook

In recent decades, stock/bond investors have benefited not only from falling yields and rising valuations, but also from the strong diversification between their two main allocations. We have become accustomed to a negative correlation between stocks and bonds, but this was not the historical norm prior to the 2000s, with the average correlation positive in the 20th century. A rising SBC would have implications for portfolio risk and therefore also asset allocation and expected returns. It would add another headache to the challenges of low starting yields, equity risk concentration and heightened macroeconomic risks in the 2020s.

We studied theoretical drivers of the SBC and presented a simple model relating it to growth uncertainty, inflation uncertainty and the correlation between growth and inflation. An empirical test of this model confirmed that stocks and bonds have been stronger diversifiers when growth news dominates and weaker diversifiers when inflation news dominates. We tested this model internationally and found similar results across six developed markets.

Our practical recommendations included educating stakeholders, monitoring the SBC and its macro drivers, and – most importantly – rethinking portfolio diversifiers. We listed a menu of alternative diversifiers, which could help not only to manage risk and improve diversification, but also to enhance portfolio returns in a challenging environment of high valuations, monetary policy tightening, and heightened macroeconomic risks.

Outlook: At the time of writing, May 2022, inflation uncertainty is undoubtedly higher than it has been for several decades. But long-term expectations remain reasonably well-anchored, and central bank credibility broadly intact. The SBC has wavered but remains mostly negative.[11] A sustained shift to a positive SBC regime would probably require a rise in longer-term inflation uncertainty accompanied by further supply-driven inflation shocks and/or monetary policy errors, and this scenario remains a tail risk for investors.

11 The rolling 65-day correlation between U.S. equity and Treasury returns turned positive during Q2 2021, but returned to negative territory for most of H2 2021 and the first four months of 2022.

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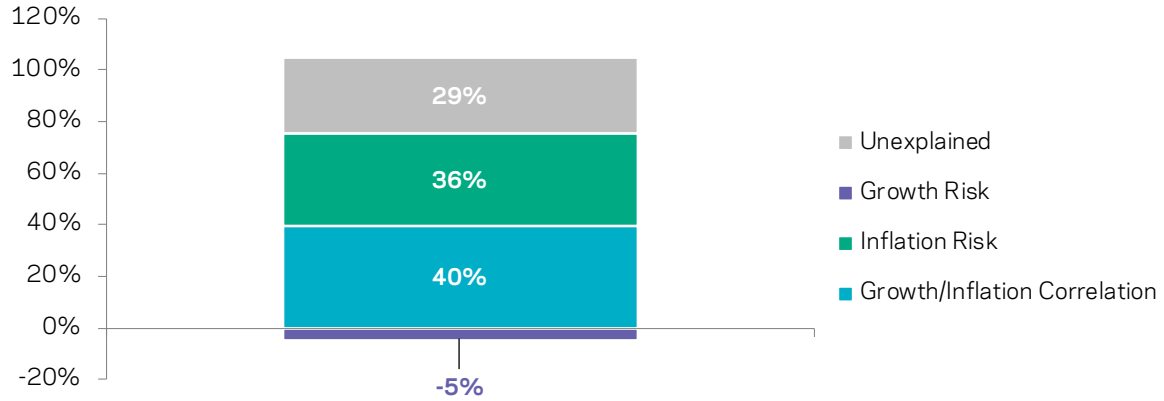
Appendix: Additional Results

In the main body of the paper, we introduce a three-factor model for explaining the stock/bond correlation. While we show that each factor is statistically significant (t-statistics > 2), some readers may be wondering which factors are more *economically* significant – or rather, which factors explain more of the variation in the SBC over time. In **Exhibit A1**, we decompose the variance of the SBC into its three drivers (as well as the portion that is unexplained by the model). While all three drivers have significant betas, it is clear from the risk decomposition that *inflation risk* explains much more of the variation than *growth risk*, with the growth/inflation correlation also very important.

Exhibit A1: Variance Decomposition of the Stock/Bond Correlation
December 1, 1936 – March 31, 2022

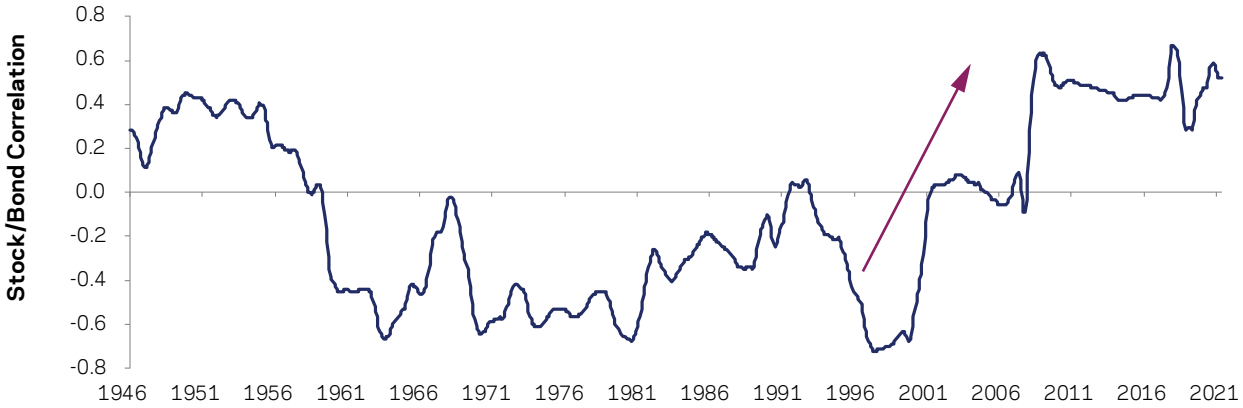


Source: AQR, Robert Shiller Data Library, FRED. U.S. Stocks are the S&P 500. U.S. Bonds are nominal 10-Year U.S. Treasuries. For the regression, the LHS variable is the rolling 120-month stock/bond correlation. Growth is the 12-month change in Industrial Production. Inflation is the 12-month change in the CPI. Growth Risk is the rolling 10-year volatility of Growth. Inflation Risk is the rolling 10-year volatility of Inflation. Growth/Inflation Correlation is the rolling 10-year correlation between Growth and Inflation.

Given the growth/inflation correlation factor's importance in explaining SBC variance, we include **Exhibit A2** below which charts this factor over time, according to our proxies. This exhibit supplements **Exhibit 4**, which displays our proxies for the model's other two factors, growth and inflation risk. Visually, it is clear that the correlation between growth and inflation news flips sign around the same time that the SBC's sign flips (in the early 2000s) – though in the opposite direction. Intuitively, this represents a shift from cost-push to demand-pull inflation. Though not shown here, we find a similar and consistent pattern in the international data.

Exhibit A2: Growth/Inflation Rolling 10-Year Correlation

December 1, 1936 – March 31, 2022



Source: AQR, Robert Shiller Data Library, FRED. Growth is the 12-month change in Industrial Production. Inflation is the 12-month change in the CPI. Growth/Inflation Correlation is the rolling 10-year correlation between Growth and Inflation.

Methodology for Growth and Inflation 'Up' and 'Down' Analysis (Exhibit 3)

Each of our macro indicators combines two series, which are first normalized to Z-scores: that is, we subtract a historical mean from each observation and divide by a historical volatility. When we classify our quarterly 12-month periods into, say, 'growth up' and 'growth down' periods, we compare actual observations to the median so as to have an equal number of up and down observations. The underlying series for our **growth indicator** are the Chicago Fed National Activity Index (CFNAI) and the "surprise" in industrial production (IP) growth over the past year. CFNAI combines 85 monthly indicators of U.S. economic activity. The other series – the difference between actual annual IP growth and the forecast a year earlier – is narrower but more directly captures the surprise effect. We use median forecasts from the Survey of Professional Forecasters data as published by the Philadelphia Fed. Our **inflation indicator** is also an average of two normalized series. One series measures the level of inflation (CPIYOY minus its mean, divided by volatility), while the other measures the surprise element in realized inflation (CPIYOY minus consensus economist forecast a year earlier). For further detail and discussion see Ilmanen, Maloney and Ross (2014).

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