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The Alchemy of Diversification: A Deep Dive Into the Stock-Bond Correlation

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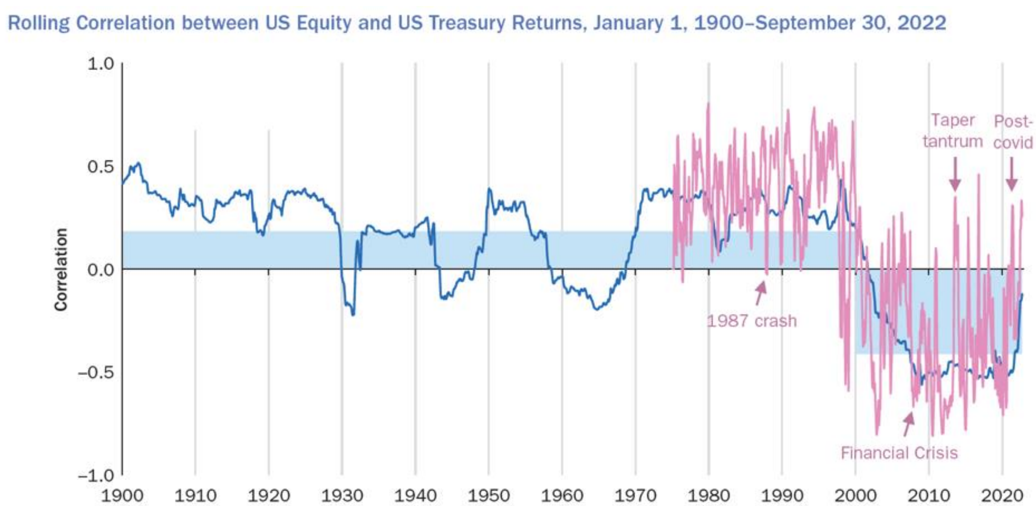
Abstract:

This research delves into the intricate dynamics of the stock-bond correlation, seeking to reveal the underlying factors that drive its fluctuations. Through a comprehensive analysis of empirical data, it investigates the diverse array of influences that contribute to the variability in the relationship between stock and bond returns. Factors such as inflation, unemployment, market volatility, FED policy, and market growth are scrutinized for their impact on altering the correlation pattern. Additionally, the research explores the implications of the stock-bond correlation on portfolio diversification. By explaining the multifaceted nature of the correlation, this study provides valuable insights for investors, policymakers, and financial analysts, aiding them in navigating the complexities of financial markets and shedding light on what causes movements in the correlation of stock and bond returns. Through empirical analysis, it was discovered that inflation, unemployment, and changes in the effective federal funds rate were the most significant driving factors of changes in the stock-bond correlation.

Diversification is the cornerstone of modern-day investing. Financial planners, asset management teams, and investing gurus on Wall Street, preach the same golden rule, “Don’t put all your eggs in one basket.” Even BlackRock, one of the world’s leading providers of investment solutions, has the quote displayed at the top of their diversification webpage. This is because when an investor spreads their money across different sectors, industries, and asset classes, it helps to reduce the impact of any single investment’s poor performance. One asset’s downturn in performance does not destroy the entire investment account. The only caveat to this theory is the potential correlation among investments. What happens if different types of assets start to move in the same direction? What happens if assets historically known to be diversifiers become highly correlated?

The stock-bond correlation is described by financial professionals as the most important correlation in all of modern investing. Since the turn of the century, and for the better part of two decades, the United States enjoyed diversification benefits due to a persistent negative stock-bond correlation. This meant that when stocks performed well, government bonds may not have, but when stocks hit a rocky patch, government bonds picked up the slack in returns. Investors resorted to traditional risk parity asset allocations gaining exposure to bonds through 60/40 or 70/30 portfolios. These strategies helped to hedge against market volatility because government or sovereign bonds (*defined in Appendix A*), backed by the full faith and credit of the United States government, offered a safe haven, consistently providing modest returns during times of stock market turbulence. Investors enjoyed this negative correlation from the late 1990’s to 2020 - the longest negative correlation ever to occur in any country. Because of this, modern day investors have perceived this correlation regime as the norm, however through two different lines representing correlation, *Figure 1* exemplifies that the offsetting behavior of stocks and bonds has not always been a given for investors. The majority of the 20th century saw stocks and bonds positively correlated with an average correlation of about +.30 (Bloomberg, 2023). The blue shaded bars in *Figure 1* represent the average correlation both before and after the regime flip in 1999. Each line on the graph represents a different length of correlation with the dark blue line showing the rolling 10-year correlation based on overlapping three-month returns, and the more volatile pink line representing the rolling three month correlation based on overlapping three-day returns. The blue line appears smoother than the pink line due to frequency of data and the use of monthly returns rather than daily. This helps to minimize short-term noise that may be caused by FOMC announcements or other daily economic news of that nature.



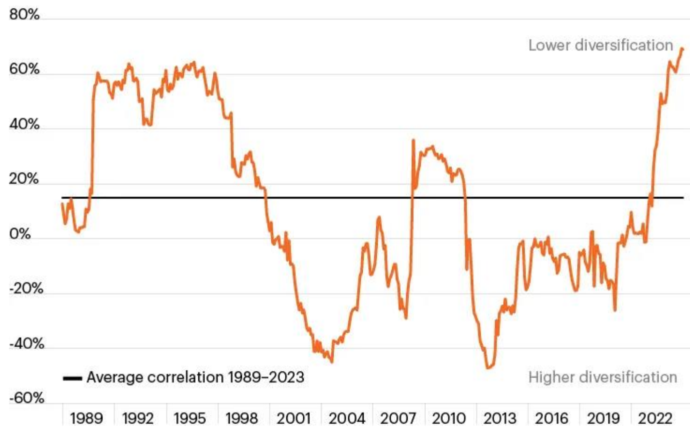
Brixton (2023)

Figure 1

What *Figure 1* does not capture is that the financial landscape took an abrupt turn in 2020. With the onset of Covid-19 and shocks to food and energy prices, inflation rose rapidly, and the stock-bond correlation became highly volatile. These fluctuations and a positive correlation that pushed above +.60, seen in *Figures 2* and *3*, diminished the historic benefit of holding bonds to hedge against equities. This created potentially damaging implications for investors either forcing them to shift investment allocations to other asset classes such as precious metals and alternatives or increase portfolio risk. According to the work of Brixton et al. (2023) if the stock-bond correlation rises from -0.5 to +0.5, a traditional 60/40 portfolio's volatility increases by close to 20% and its max drawdown, the measurement from peak to trough, increases a drastic 30%. A transformation of this nature prompts a few important questions: What causes changes in the stock-bond correlation and is inflation the main driver of change in the stock-bond correlation, or is the change in correlation driven by a mixture of macroeconomic variables?

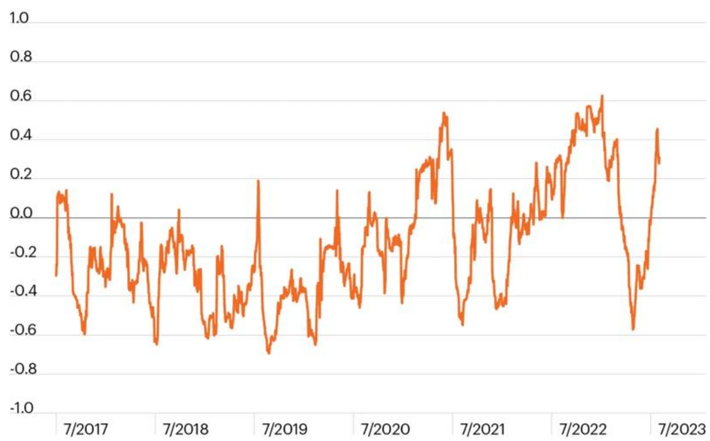
The importance of this research is rooted in the concept that portfolio planning and asset allocation seek to eliminate unsystematic risk through diversification while aligning investments with a client's risk tolerance depending on their investment horizon, income, and insurance coverage. During the 21st century, asset managers have become comfortable allocating funds into U.S. Treasuries as a risk-mitigation tool for equity investments. However, the possible shift to a persistent positive correlation will have investors rethinking their portfolio allocations and ability to "flee to fixed income."

Another representation of the change in the correlation regime that occurred in 1999 can be seen in *Figure 2*. This figure shows the 36-month correlation between the S&P 500 and the Bloomberg Agg. The Bloomberg Aggregate Bond Index is a broad base, market-cap-weighted bond index. It represents intermediate term investment grade bonds traded in the United States and is frequently used as a benchmark for the U.S. bond market. *Figure 2* reveals that with the exception of the period around the 2008 Great Financial Crisis, investors have enjoyed stock-bond diversification for much of the 2000's. In 2020, the correlation line rapidly increased and pushed to levels greater than +.60. When looking at a shorter length of time in the 40-day correlation between the S&P 500 and the Bloomberg Agg, seen in *Figure 3,* it is evident the stock-bond correlation has been highly volatile since 2020. *Figure 3* shows that from July of 2020 to July of 2023 the stock-bond correlation pushed above +.40 four times and below -.40 five times, epitomizing the level of volatility during this era.



FS Investments (2023)

Figure 2



FS Investments (2023)

Figure 3

This research seeks to understand what is causing these dramatic swings in correlation and if there is a preliminary indicator amongst macroeconomic variables that signals a strong positive correlation in the near future. Can regime shifts solely be attributed to inflation, or is it a mix of inflation and other fundamental variables such as volatility, unemployment, and growth? Answering this question may provide insight to investors, both institutional and retail, on how to allocate their portfolios during macroeconomic shocks. In order to understand what is perceived as a “normal” correlation, it is important to familiarize oneself with the history of the stock-bond correlation. Along with the history, the examination of previous work and literature provides key contributions to further the concepts within this paper and provide a framework for a regression analysis. This regression analysis will help to determine the key drivers of stock and bond returns and ultimately what may be the most influential factor in shifting the stock-bond correlation.

Background

The stock-bond correlation is a critical gauge of the dynamic relationship between stock and bond returns, serving as a foundational determinant of risk in conventional investment portfolios. The correlation is characterized as positive when stocks and bond returns move in the same direction and negative when they move in opposite directions. From 1976 to 1999, S&P 500 and 10-year U.S. Treasury returns exhibited a modest average correlation of +.32 using a 10-year rolling correlation (SSGA, 2023). Nonetheless, because of the nuances of the period, the concept of a positive correlation is slightly skewed. Notably, during this time frame, whenever stocks faced negative returns, bonds consistently remained positive. This is evident in *Figure 4* when analyzing the returns of past 60/40 portfolios. *Figure 4* shows that in 1977, 1981, and 1990 stocks slipped, but bonds continued to show positive returns. In short, investors experienced the diversification advantages of a negative correlation and the upside potential of a positive correlation. The late 1990’s witnessed the emergence of the dot-com bubble with large, rapid, unstainable increases in technology stock valuations. The bubble further inflated investor overconfidence and speculative trading. Consequently, 2000-2001 the bubble burst, leading to a swift 10% loss in the stock market within a matter of weeks. Following the dot-com bubble a persistent negative correlation between stocks and bonds lasted until 2020, with an average correlation of -.08. With this being said, since 2020, the rolling 24-month correlation has averaged +.65. In 2022, the traditional 60/40 portfolio experienced it's second worst annual return since the inception of the Bloomberg Agg in 1976, (*see Figure 4*) thus making investors begin to question whether bonds were to still the chief diversifier in investment portfolios.

Return Contributions of a 60/40 Portfolio

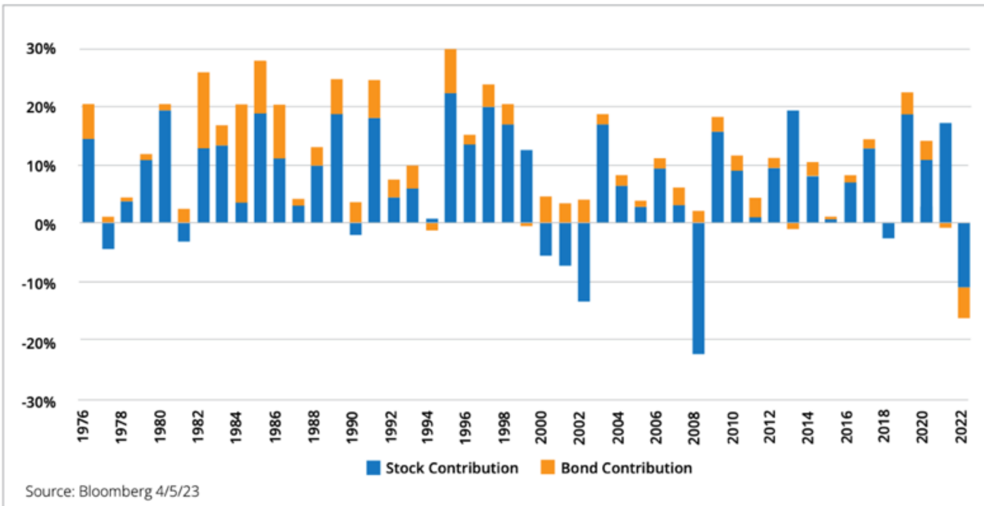


Figure 4

Enfusion, a software-as-a-service company and leading provider of cloud native solutions for investment managers, held a panel discussion with Qontigo's (2023) Asia-Pacific Head of Research, Oliver d'Assier. In the interview, d'Assier discussed the heightened portfolio risk associated with a positive stock-bond correlation and outlined the investment and allocation challenges portfolio managers faced due to market volatility. The Federal Reserve, also known as the FED, rapidly increased interest rates in the fall of 2022, triggering a fire sale of stocks and U.S. treasuries, ultimately resulting in drops in returns and a positive correlation. Portfolio managers were unable to diversify their investment accounts in the traditional way known, and ultimately had to liquidate risky, high-beta, assets to align with risk mandates (*defined in Appendix A*) set by clients. Although there was a temporary shift to a negative correlation in the early months of 2023 - driven by a banking crisis and investor expectations of a monetary pivot - the FED's continued interest rate hikes have sustained a positive correlation through the fall of 2023 and into the early months of 2024.

Literature Review

A positive stock-bond correlation poses challenges for investment managers hedging their risk, as both stock and bond returns move in the same direction. Recent instances of this phenomenon occurred during the financial market downturn in October of 2022 and again in August of 2023. When the market reaches a trough point, investors tend to "flee to safety" because of market uncertainty. This means that they move their capital into lower-beta, less risky assets, such as government bonds, to attempt to minimize losses. This uncertainty can be quantified using indicators such as the VIX (*defined in Appendix A*), abnormal stock turnover, or standard deviation of equity returns. Investors come to realize that they are not being sufficiently compensated for holding risky stocks, as measured by the equity risk premium (ERP), and thus opt to invest in government treasuries instead. Previous research, such as Brixton et al. (2023), consistently highlight that a negative stock-bond correlation has quality implications for diversification potential. The overarching goals of prior research was to identify what was causing swings in correlation, to what magnitude the correlation would change, and how the changes in correlation affected asset allocation.

The majority of prior literature on joint stock-bond returns has cited inflation, expected inflation, growth, and the FED's response to these factors as the leading variables responsible for correlation movement. Andersson et al. (2008) researched the impact of macroeconomic expectations on the correlation between stock and bond returns using the 10-year government bond price indices and S&P 500 returns from January 1991 to August 2006. He researched the effects of an increase in expected inflation and its effects on FED policy. He found that expected inflation likely results in a FED increase in discount rates, which negatively affects the bond market due to bond prices inverse relationship with interest rates. Expected inflation's effect on stocks is more enigmatic because expected future cash flows and discount rates will be altered, though the extent of this effect remains uncertain until inflation is actually experienced. Andersson et al. (2008) concluded that expected inflation is positively related to the correlation between stock and bond returns, and only with the lowest levels of inflation will an investor potentially see a negative correlation. They also discuss how the correlation regime between stocks and bonds directly impacts investment strategies and the potential for shifts in investors risk parity's but is not explicit in what these shifts may be. Similar to the research of Andersson et al., Brixton et al. (2023) discusses the differing effects of inflation and growth on the stock-bond correlation, however they use actual inflation rather than expected. Using 10-year U.S. Treasury and S&P 500 data from January of 1900 to September of 2022, the authors found that positive growth news increases investors' expectations in future cash flows and therefore raises equity prices. It also causes a systematic response from central banks, increasing expectations of a rise in short-term interest rates, leading to a fall in bond prices. When researching inflation, the authors found that higher inflationary numbers directly decreased the value of bonds' fixed nominal cash flows along with raising short-term interest rate expectations, thus causing bond prices to fall. Equity prices also fall during periods of rising inflation due to a decrease in consumer spending and increased cost of inputs. This heightened cost of inputs adversely affects firms' profits, consequently reducing stock prices. Because of the unfavorable effects of inflation on both stocks and bonds, they historically have same-signed sensitivities to inflation news.

To uncover these conclusions, Brixton et al. (2023) developed a model linking unexpected returns to inflation and growth news, assuming that stock and bond returns are driven by growth and inflation shocks (*see in Appendix B*). Through this model they then created a covariance model that used the covariance of stock and bond returns as a dependent variable. The standard deviation of growth and inflation shocks, along with the correlation between growth and inflation functioned as independent variables. Finally, they derived a correlation equation from the covariance because "covariance is effectively a volatility-scaled correlation, so any driver of covariance will have the same directional impact on correlation," (*see Figure 5*). This model linked the correlation of stock and bond returns ($\hat{\rho}_{s,b,t}$) to growth and inflation volatility ($c_g\sigma_{g,t}$ & $c_\pi\sigma_{\pi,t}$), along with the correlation between growth and inflation ($c_{g,\pi}\hat{\rho}_{g,\pi,t}$).

$$\hat{\rho}_{s,b,t} = c_0 + c_g\hat{\sigma}_{g,t} + c_\pi\hat{\sigma}_{\pi,t} + c_{g,\pi}\hat{\rho}_{g,\pi,t} + \varepsilon_t$$

Brixton (2023)

Figure 5

The model confirmed that stocks and bonds have been strong diversifiers when growth news dominates and much weaker diversifiers when inflation news dominates. These predicted signs are highlighted underneath the model, with Brixton et al. (2023) also coming to the conclusion that the sign between the correlation of inflation and growth is ambiguous. The model was tested internationally and found similar results across six developed markets.

Ilmanen (2003) also focused on inflation and growth but added two more variables: volatility conditions and monetary policy stance. His motivation behind these factor's was to create a model that incorporated a mix of macroeconomic variables that led to both positive and negative correlation scenarios. Analyzing 20-year U.S. Treasury bonds and S&P 500 returns from 1952 to 2001, Ilmanen made the discovery that "a previous month's bond market strength is positively related to next month's stock market strength, while past equity return is inversely correlated to subsequent bond returns," (Ilmanen 2003). This discovery prompted Ilmanen to pick a range of variables that historically have been factors that heavily drive asset returns, but the question Ilmanen set to answer was whether changes in these factors were creating a positive or negative correlation regime. The dividend discount model framework (*see Figure 6*) provided Ilmanen with a framework to answer this question because it uncovers the drivers of stock and bond prices. Ilmanen's stock and bond price equations, represented by P_S and P_B respectively, are the present value of expected future cash flows, discounted by a rate that includes risk premiums. For the price of stocks, Ilmanen incorporated an expected growth rate of dividends variable *G*(*D*) because stocks have uncertain cash flows. On the bond side, Ilmanen included a variable *C* representing bond cash flows which are fixed, unlike equities. The final two variables included were *Y,* which reflects expectations of future short-term interest rates and the required bond risk premium, and *ERP*, the required equity risk premium.

$$P_S = E[\sum_{t=1}^{\infty}(\frac{1+G}{1+Y_t+ERP_t})^t * D]$$

and

$$P_B = E[\sum_{t=1}^{T}\frac{C_t}{(1+Y_t)^t} + \frac{100}{(1+Y_T)^T}]$$

Ilmanen (2003)

Figure 6

Both Ilmanen (2003) and Molenaar et al. (2023) show that inflation's level of impact on equities and fixed income differs but leads to similarity in returns. When analyzing inflation's level of impact on the stock-bond correlation, Ilmanen expanded his data set to include 10-year

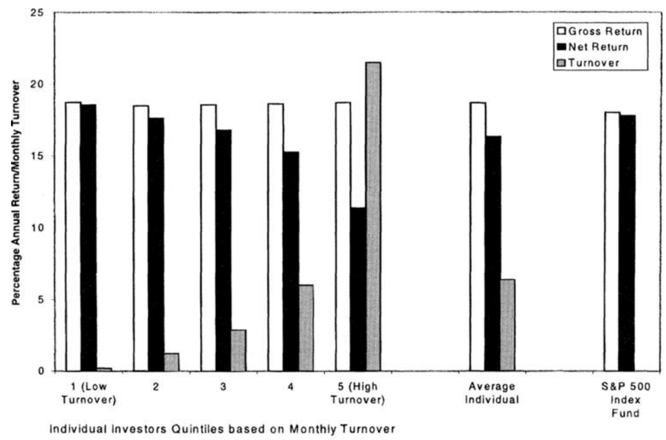
Treasury and S&P 500 returns dating back to 1926. On the fixed income side, Ilmanen found that inflation shocks cause the FED to increase short term interest rates, thus raising bond risk premiums and causing a decrease in returns. As for equities, Ilmanen's findings were slightly more ambiguous due to varying degrees of inflation having varying effects on equities. At high inflation levels, changes in discount rates outweigh changes in cash flow expectations, leading to a decrease in returns across all asset classes, and ultimately causing a positive correlation. Nonetheless, with low inflation levels, discount rates remain stable and growth uncertainty dominates, leading to a lower positive correlation. Regardless of the level of inflation, the result was still a positive correlation between stock and bond returns. Ilmanen did not delineate what he categorized as high and low inflation, but based on Figure 7 within his article, high inflation is an inflationary period approaching 5%, while low inflation is sub 2.5%.

Molenaar et al. (2023) found similar results when analyzing inflation and stock market uncertainty on a global scale, researching developed markets using a range of data from 1875 to 2023. Similar to Ilmanen, the model used by Molenaar et al. (2023) used factors that affect stock and bond valuations. On the fixed income side, government bond yields contain three components - the expected short real interest rate, inflation until maturity of the bond, and the bond risk premium for holding intermediate treasuries rather than short term T-Bills. On the stock side, the authors believed there were four components that made up equity yields. These include the expected short real interest rate, inflation over the life of the stock, the expected growth of dividends, and the equity risk premium. After creating a covariance model between stock and bond returns, Molenaar et al. discovered that positive stock-bond correlations are more common than negative correlations and positive correlations are associated with high inflation and high real risk-free rates. The authors also found that stock bond correlations vary significantly over time and across countries, due to government creditworthiness and differing monetary and fiscal policies. Countries where government bonds are considered higher-beta assets tend to have positive stock-bond correlations and inflation does not have the same effect on correlation variation compared to developed markets with quality creditworthiness. This is because the sovereign bonds of the lower credit quality government have a closer beta and risk level to equities.

Wainscott's 1990 research delves into the implications of the stock-bond correlation on asset allocation. The basis of his research reaffirms the common but important financial axiom that past performance is not indicative of future returns. He attempts to find a sound predictor for the stock-bond correlation citing that past correlations have an inability to predict future correlations. Wainscott determined that a more sound predictor was a common pricing factor between stocks and bonds: their income stream, either dividends or interest. The income streams of both stocks and bonds are relatively stable and easily observable, so Wainscott collected monthly dividend and interest data from the S&P 500 and 20-year U.S. Treasury's from January 1925 to June of 1988, creating a rolling 12-month income return stream. A variable representing the comparison of income streams was implemented into a series of regressions as an independent variable with the 1, 3, 5, and 10-year correlations functioning as the dependent variables. The addition of income differences improved the explanatory power of Wainscott's model, especially in the 10-year correlation. This meant that the income return differences between stocks and bonds is a significant and powerful factor in predicting the future stock-bond correlation. To examine the impacts of correlation on different asset mixes, Wainscott used a standard allocation optimizer, and assumed the same risk tolerance throughout his trials. He calculated the optimal mix of cash, bonds, and stocks at varying levels of positive correlation.

His most notable finding lies in his observation that even with significant changes in the stock-bond correlation, the allocation to stocks remains fairly consistent at 47%. Wainscott's research did not analyze any periods of negative correlation and only looked at changes in asset mixes at differing levels of positive correlation. This is likely due to the fact that Wainscott's research took place in the 1980's and 1990's which was a time of persistent positive correlation. Nevertheless, the allocation patterns of other assets, such as bonds and cash changed significantly. Wainscott found that with a correlation of +0.2, the allocation to bonds constituted 44% of the asset mix. However, with a correlation of +0.6, the allocation to bonds dropped to just 5%. Rather than a modern era "flight to safety" shift into bonds, Wainscott observed a considerable shift towards cash.

Past literature has identified market uncertainty, measured by either the implied volatility from equity index options or the standard deviations of returns, leading to potential swings in the stock bond correlation. Connolly et al. (2005) and Andersson et al. (2008) suggest that abnormal turnover may represent differing investor opinions regarding investment strategies or changes in the available investment opportunities. In both scenarios, abnormal stock turnover indicates a degree of stock market volatility. Connolly et al. (2005), attempts to understand stock market uncertainty's effect on the relationship between stock and bond returns. Their two primary variables measuring market uncertainty are the implied volatility of equity index options and abnormal stock turnover. The stock turnover ratio serves as an indicator of market liquidity, illustrating how easy, or difficult, it is to sell shares in the market. According to previous literature, a low stock turnover ratio suggests that investors are making rational, non-emotional trades; however, it could signify divergent opinions about the correct investment strategy. Conversely, a high stock turnover ratio, while not inherently bad, can imply market uneasiness and volatility due to a change in investment opportunity. *Figure 7* shows the possible correlation between turnover and net returns, with net returns decreasing as turnover increases. At a turnover level near 0, the graphic shows that net return is just under 20%. On the contrary, at a turnover level past 20, the net return falls to around 10%. Nonetheless, in both a low and high turnover scenario, significant fluctuations can serve as leading indicators of a negative correlation between stocks and bonds.



Odean (2002)

Figure 7

Connolly et al. (2005) found that bond returns tend to outperform stock returns when implied volatility substantially increases and when stock turnover is high. Consequently, stock-bond diversification benefits become more significant in times of increased stock market uncertainty. The concept of a “flight to safety” effect is frequently mentioned in past literature including Andersson et al. (2008), Ilmanen (2003), Wainscott (1990), along with major financial institutions such as PIMCO, Vanguard, and State Street Global advisors. “Flight to safety” refers to investors shifting their investments away from equities and into bonds due to a higher risk premium on stocks compared to the term premium of bonds. Dane Smith (2023) from State Street Advisors emphasizes the importance of the equity risk premium, explaining how high inflation increases discount rates and bond yields, causing bond prices to fall while also exerting downward pressure on stocks. These factors elevate the probability of a stock market crash and a potential flight to safety event.

In summary, previous literature has identified factors such as inflation, growth, market volatility, and the FED's response to inflationary environments, as lead variables causing swings in the stock-bond correlation. Investors utilize the correlation regime between stocks and bonds as a fundamental factor in asset allocation and portfolio management, highlighting the importance of understanding which variables promote coupled or decoupled returns between stocks and bonds. Historically, from the mid-1960's to the late 1990's, the stock-bond correlation was positive and had minimal volatility. However, a significant shift occurred due to the internet bubble of the late 1990's, turning the correlation negative and sustaining this trend until 2020. With the onset of COVID-19, the United States saw a positive correlation once again, but differing from the positive correlation that took place before the turn of the century, this correlation was volatile and had significant spikes. This paper seeks to understand which fundamental macroeconomic variables account for the greatest differences in the stock-bond correlation and the working hypothesis attempts to uncover if inflation is the leading determinant of a positive stock-bond correlation.

Theoretical Model

The theoretical model of this paper is built around the concept of a "flight to safety" scenario. During this market phenomenon investors sell out of what they perceive to be high risk investments and purchase safer investments. Typically, a flight to safety episode is triggered by an unusual or unexpected global event. More recent flights to safety occurred after the 9/11 attacks in 2001 and the subprime mortgage crisis in 2008. In both instances, the initial effects of these events were a fall in asset prices and drops in market liquidity. Other variables that tend to shift during unusual global events affecting the economy include, inflation, growth, and unemployment. Historically, markets also become volatile after an unexpected event such as the ones described previously. For example, after the World Trade Center attacks on September 11th, 2001, the VIX closing value exceeded 49.30 after being just 33.11 on September 9th, 2001. This was a 49% increase in volatility as measured by the VIX. Identifying variables that tend to shift before, during, and after flights to safety has helped to construct a theoretical model. Using the theory below and insights from previous literature, the following theoretical model is derived to show the correlation of stock and bond returns, CORR (BR,SR) in period t as a function of five macroeconomic indicators, two interactive variables, and the error term e_t.

$$\text{Corr}(BR,SR_t) = \beta_{0t} + \beta_1\text{Inflation}_t +/- \beta_2\text{Unemployment}_t - \beta_3\text{Volatility}_t + \beta_4\text{FEDPolicy}_t - \beta_5\text{Growth}_t +/- \beta_6\text{FEDUNEMP}_t +/- \beta_7\text{FEDINF}_t + e_t$$

The current inflation rate plays a pivotal role in analyzing market returns because the general increase in prices of goods and services means the same amount of money buys fewer goods and services. This has several implications for investors. First, investors are often concerned not just with nominal returns (the actual monetary gains), but with real returns (gains adjusted for inflation). For example, if an investment provides a 5% return, but inflation is 3%, the real return is only approximately 2%. Factoring in inflation helps investors assess the true growth of their wealth. Nonetheless, the goal of investing is not just to grow wealth but to maintain or increase purchasing power. If returns do not outpace inflation, the investor may find that their future purchasing power has diminished. Historically an increase in inflation has led to coinciding losses in stock and bond returns suggesting a positive correlation and thus $B_1>0$. A mix between rising costs and uncertain revenue growth can cause a dip in corporate profit margins, which negatively reflects on equity prices. Consumer spending also decreases when inflation rises. Bonds don't perform well during times of high inflation because inflation erodes the purchasing power of a bond's future cash flows. A bond is a fixed rate investment meaning that if inflation is high or increasing, the return on a bond is reduced in real terms. In general, high inflation injects a level of uncertainty into the markets causing corporate growth to slow, effecting investor confidence and ultimately decreasing their willingness to take on risk by holding stocks.

The unemployment rate is a crucial economic indicator with significant implications for investors and their future returns. High unemployment reduces consumer spending meaning that consumers have less disposable income, leading to decreased spending within the economy and financial markets. This can impact various industries and company profitability. High unemployment may lead to reduced demand, which subsequently affects corporate earnings. A slack in corporate earnings may have an adverse effect on stocks. This is developed through the theory that with more people out of work, there may be less demand for company's products, causing stock prices to fall. Investors tend to want to allocate their funds in profitable, stable businesses and when unemployment increases, the likelihood of decreased profitability also increases. Conversely, low unemployment may indicate a strong economy with higher consumer spending, potentially boosting corporate profits. Unemployment rates effect on government bonds is more ambiguous. This is because it is unclear whether investors allocate their capital in U.S. Treasuries during periods of high unemployment or if they decide that investing can wait, and keeping cash on hand is the safest decision when there is a potential that they will be jobless. If investors decide to invest in bonds because they have a higher yield than cash sitting in a checking account it should be noted that bond prices and yields have an inverse relationship. This means that when rates decrease, the prices of existing bonds tend to rise. Conversely, rising interest rates lead to lower bond prices. Therefore, in an environment of high unemployment bond prices may rise, but only if investors are willing to invest. Because of the uncertainty around the unemployment rate's effect on bonds, the sign of B_2 is uncertain.

Market volatility, or the degree of asset price variation over time, is a key factor in analyzing potential returns. Volatility serves as a measure of risk, meaning that with higher volatility and greater degree of price fluctuation, there is the potential for larger gains but also larger losses suggesting a positive relationship between risk and expected returns. Volatility can be measured in a few ways; however, the majority of past research, including Connolly et al. (2005) uses either the VIX or standard deviations of returns. Factoring in market volatility helps investors set realistic expectations based on risk tolerance, influencing how they allocate capital to manage risk. Connolly et al. (2005) has indicated that the return volatility and the correlation environment are directly related. Bond returns tend to be high relative to stock returns during days when implied volatility increases. Investors "flee to safety" because they feel the need to sell out of stocks and invest into bonds when their equity investments are subject to large swings. This then increases the equity risk premiums on stocks, causing their prices to fall and reduces bond risk premiums, causing their prices to rise. In summary, high equity market volatility is associated with a negative stock-bond correlation, thus making $B_3<0$.

The FED's, most common use of monetary policy is to control inflation and unemployment. By targeting a specific inflation rate, central banks aim to maintain price stability which has a direct effect on investment's real returns. The most prominent FED tool is the federal funds rate which can be changed to alter borrowing costs in the United States. The federal funds rate is the interest rate at which depository institutions or banks lend reserve balances to other depository institutions overnight. This effective rate can be used to identify whether the

FED is implementing contractionary or expansionary monetary policy. Factoring in monetary policy is important for investment returns because decisions made by the FED have a significant impact on the nation's economic environment, employment rates, and financial markets. Changing the effective funds rate to influence borrowing costs in the economy has direct effects on various asset classes and currencies. The federal funds rate is raised to attempt to slow down the economy and tamper inflation. Businesses are discouraged from taking on new projects because their borrowing costs are too high. On the contrary, a low federal funds rate is expansionary and borrowing costs decrease which promotes corporate spending. Bond prices also reap rewards from a lower federal funds rate because bonds move in an inverse fashion to interest rates. This means that as the federal funds rate starts to fall, bond yields fall in tandem and thus their prices rise. In a reverse scenario, contractionary policy and a high federal funds rate makes borrowing more expensive and firms cannot afford to take out the same loans. This causes corporate earnings to fall making their shares less appetizing to investors. On the fixed income side, when interest rates increase, yields rise, and bond prices fall. This means that in both expansionary and contractionary scenarios, a positive stock-bond correlation is created. This leads to $B_4>0$.

Economic growth is a fundamental factor for assessing potential returns in both the stock and bond markets. Corporate earnings are closely tied to economic growth, impacting sales and profits. In a growing economy, companies tend to experience increased demand for their goods and services, leading to higher profits. The growth of the U.S. economy can be measured using the Industrial Production index which provides monthly data compared to GDP which is only released on a quarterly basis. Growth news is likely to cause a wedge between stock and bond performance. Historically, when there is rising growth within an economy, investors demand higher-beta securities and move out of low beta, leading to a negative stock-bond correlation. On the contrary, when risk appetite is low, investors tend to sell equities and buy bonds for downside protection. This can be referred to as “risk-on, risk-off” behavior, which causes equity and bond premiums to regularly diverge and is supportive of the theory that $B_5<0$.

The two main controls of the U.S. FED are unemployment and price stability. Examining the first control, the FED monitors employment and may adjust monetary policy with changes in the unemployment rate. In response to an economic slowdown, including a rise in unemployment, the FED may implement expansionary policies, including the lowering of interest rates. This promotes borrowing, stimulating economic activity and ideally lowering the unemployment rate. To account for the additional effect the federal funds rate may have on unemployment and the initial ideology that the FED may start an easing cycle because of high unemployment, an interaction variable between the two independent variables was created and named FEDxUNEMP. The expected sign of B_6 is uncertain. The second main control of the FED is price stability. This means that in response to a spike in inflation, the FED may implement monetary policy, such as the raising of the federal funds rate in order to slow the economy down. The likely result of this increase in interest rates is a decrease in corporate borrowing, helping to slow corporate spending and ultimately decrease economic activity. To account for this relationship between the FED and inflation, an interactive variable, INFxFED, was created. The INFxFED variable’s expected sign is also uncertain.

Data

The time-series data within this research consists of monthly nominal, 10-year U.S. Treasury returns and monthly real, S&P 500 returns dating from January of 1967 to September of 2023. Gathered from the Robert Shiller data series, these monthly returns were converted into twelve-month moving averages and then used to make three different rolling correlations: a three-year, a five-year, and a ten-year correlation. These varying lengths of correlation were used to observe how independent variable's relationships with the stock-bond correlation change due to smoothing. The 36-month or 3-year correlation was used as a baseline length of correlation because it represents the length of an average business cycle. The 5 and 10-year correlations were utilized because they represent a longer length of time that helps to minimize short-term noise such as FOMC comments, daily macroeconomic data releases, and other economic news that may be captured in the 3-year correlation. There are 5 independent variables that are measured using monthly data obtained from the FRED St. Louis FED database. Their definitions and methods of measurement can be seen in *Figure 8*, along with the definition of the dependent variable.

Variable	Definition
SBCorrelation	Correlation of S&P 500 and 10-year U.S. Treasury returns from 1967-2023. Three lengths of correlation were used (3, 5, & 10-year)
Inflation	Personal Consumption Expenditure percent change from the previous year
Growth	Industrial Production index's percent change from the previous year
Unemployment	Percentage point change of unemployment rate from the previous year
Federal Funds Rate	Actual effective federal funds rate
Volatility	12-month standard deviation of S&P returns

Figure 8

The Industrial Production index is a monthly economic measure of real output in the manufacturing, mining, electric, and gas industries. It is published in the middle of every month by the Federal Reserve Board and is commonly used by economists as a way of measuring overall economic growth. This variable was chosen as a proxy for growth rather than GDP because U.S. GDP data is released quarterly, and monthly data was needed for the regression. Personal Consumption Expenditure is a measure of the spending on goods and services by citizens within the United States. PCE was used instead of CPI because it is the FED's first choice as a measure of inflation. This is because PCE includes a more comprehensive coverage of goods and services compared to CPI.

Descriptive Statistics (665 observations)

Variable	Date	SBCorr: 3-Year	SBCorr: 5-Year	SBCorr: 10-Year	Inflation	FEDFunds	Unemployment	Growth	Volatility
Min	1967	-0.905262	-0.82027	-0.71765	-14.357	0.050	-8.700000	-17.26213	0.9263
1st Quartile	1981	-0.537247	-0.51830	-0.43412	4.631	1.587	-0.700000	0.04872	2.3020
Median	1995	0.156417	0.23650	0.20009	6.384	5.075	-0.300000	2.59940	3.0554
Mean	1995	0.001555	0.01851	0.03659	6.702	4.977	-0.004627	2.06097	3.2881
3rd Quartile	2009	0.463138	0.47070	0.37285	8.868	7.065	0.3750000	4.88426	3.9749
Max	2023	0.853551	0.69464	0.53589	29.651	19.100	11.100000	16.18326	8.3851
Std Dev	N/A	0.53	0.49	0.40	3.08	3.87	1.22	4.50	1.34

Figure 9

Figure 9 highlights the descriptive statistics of the variables within the regression, focusing on seven key metrics. These included the minimum and maximum, the 1st and 3rd quartile, the median and mean, and the standard deviation. When analyzing the three different durations of correlation, there is a common trend with the mean close to a value of zero. This is an interesting finding because the minimum and maximum varies widely for each length of correlation. For example, the 3-year stretches from -0.9053 to 0.8536, however the mean is virtually zero with a value of 0.0016. Nonetheless, the smoothing of economic noise is evident across the three lengths of correlation with the minimum and maximum values getting closer together as the correlation becomes longer. The 10-year correlation minimum and maximum values are only -0.7177 and 0.5359 respectively.

The inflation variable contains outliers with a minimum of -14.357 and a maximum of 29.651. These inflation values alter the overall effect of inflation on the stock-bond correlation given that they are well over three standard deviations from the mean. In a similar vein, unemployment has a wide range between its minimum of -8.7 and maximum of 11.1, but it's mean is virtually zero with a value of -0.004. Again, these major swings in unemployment occurred in the beginning and end of the COVID-19 pandemic. The Growth variable also displayed outliers greater than 3 standard deviations from the mean. These values can be attributed to the economic effects of the Covid-19 pandemic. The IP index value plunged in April of 2020 which is evident in the minimum value and soared in April of 2021, seen in the maximum value. Apparent in the descriptive statistics of the dataset, the effects of the Covid-19 pandemic were significant on major macroeconomic variables. In the first 3 months of the pandemic (April, May and June of 2020) minimum outliers in unemployment, growth, and inflation were produced. Likewise, in the last two major months of Covid-19 (April and May of 2021) these same macroeconomic variables produced maximum outliers. The pandemic significantly distorted the magnitudes of the independent variables within the regression. Because of this, it was determined that these five months should be excluded from the dataset in order to understand most accurately what shifts the stock-bond correlation. While it is important to account for unpredicted events such as Covid-19, the major outlier values did not improve the empirical analysis of the models within this research. The Federal Funds variable has a notable maximum value of 19.100 which took place in June of 1981. This was a result of FED chairman, Paul Volcker's, attempt to combat stagflation that had lingered throughout the 1970's. Although the value is an outlier compared to the rest of the federal funds values, there is not a reason for it to be excluded from the dataset because there was a sustained period of time with similar interest rates. The Volatility variable produced a maximum of 8.385 which was a result of the Great Financial Crisis in 2008 and 2009.

Results

Utilizing the theoretical model and data from the sections above, multiple regressions were performed. This can be seen in *Figures 10 & 11*.

Output of Stock-Bond Correlation Regressions

	Dependent variable:		
	SBCorrelation3yr	SBCorrelation5yr	SBCorrelation10yr
	(1)	(2)	(3)
Inflation	0.018**	0.045***	0.041***
	(0.008)	(0.007)	(0.006)
FEDFunds	0.044***	0.035***	0.042***
	(0.006)	(0.005)	(0.004)
Unemployment	0.154***	0.111***	-0.0001
	(0.025)	(0.023)	(0.018)
Growth	0.063***	0.039***	-0.005
	(0.006)	(0.006)	(0.004)
Volatility	0.001	0.004	-0.012
	(0.017)	(0.015)	(0.012)
Constant	-0.468***	-0.551***	-0.398***
	(0.067)	(0.062)	(0.049)
Observations	665	665	665
R^2	0.357	0.373	0.403
Adjusted R^2	0.352	0.368	0.398
Residual Std. Error (df = 659)	0.424	0.390	0.312
F Statistic (df = 5; 659)	73.094***	78.328***	88.811***
Note:			*p<0.1; **p<0.05; ***p<0.01

Figure 10

Figure 10 displays the regression outputs of the 3-year, 5-year, and 10-year rolling correlations. The dependent variable within each regression is the varying length of stock-bond correlation, while the independent variables include, Inflation, FEDFunds, Unemployment, Growth, and Volatility. The interactive variables between FEDFunds, Unemployment, and Inflation were not included within the first output. Across all three regressions the FEDFunds variable was significant at the 1% level, while Inflation was only significant at the 1% level in the 5 and 10-year regressions. It was significant at the 5% level in the 3-year correlation. The FEDFunds and Inflation variables both exhibited the hypothesized expected signs, showing that they each have a positive effect on the stock-bond correlation. With a one percentage point increase in the PCE inflation value from a year ago, the stock-bond correlation increases by 0.018 in the 3-year, 0.045 in the 5-year, and by 0.023 in the 10-year. In terms of the FEDFunds variable, with a one percentage point increase of the effective federal funds rate, the stock-bond correlation increases by 0.044 in the 3-year, 0.035 in the 5-year, and 0.042 in the 10-year.

The Unemployment variable is significant at the 1% level in the 3 and 5-year, but not significant in the 10-year regression. There was not a hypothesized sign for the unemployment variable due to the ambiguous effect unemployment has on bonds, but the regression output shows that Unemployment's effect on the stock-bond correlation is positive. Unemployment's size effect on the stock-bond correlation was the largest compared to any other independent variable. With a one percentage point increase of the unemployment rate from the previous year, there is a 0.154 increase in the 3-year correlation and a 0.111 increase in the 5-year correlation. Similar to the Unemployment variable, the Growth variable was significant at the 1% level in the 3 and 5-year regressions, but not in the 10-year. It also did not exemplify the expected negative sign.

The size effect of the Growth variable varied between the different lengths of correlation. In the 3-year correlation, a one percentage point increase of the IP index from a year ago created a 0.063 increase in the stock-bond correlation. In the 5-year correlation a one percentage point increase caused a 0.039 increase in correlation. Volatility was not significant in any of the regressions.

To conclude, the 3-year correlation had an adjusted R^2 of 0.35, the 5-year regression had an adjusted R^2 of 0.37, and the 10-year had an adjusted R^2 of 0.40. The FEDFunds, Unemployment, and Growth variables had the greatest effect on the 3-year stock-bond correlation, while in the 5-year regression, Inflation and Unemployment had the largest impacts. Lastly, within the 10-year regression, Inflation and FEDFunds had the largest impacts on the stock-bond correlation. This means that when analyzing the long-term stock-bond correlation, price stability and the FED's reaction to an increase in prices are the two key characteristics for investors to monitor.

Inclusion of Interactive Variables

	Dependent variable:		
	SBCorrelation3yr	SBCorrelation5yr	SBCorrelation10yr
	(1)	(2)	(3)
Inflation	0.103***	0.116***	0.064***
	(0.008)	(0.008)	(0.007)
FEDFunds	0.201***	0.179***	0.082***
	(0.012)	(0.011)	(0.010)
Unemployment	0.250***	0.168***	0.030
	(0.023)	(0.022)	(0.020)
Growth	0.032***	0.019***	-0.015***
	(0.006)	(0.005)	(0.005)
Volatility	-0.002	0.012	-0.015
	(0.014)	(0.014)	(0.012)
FEDUNEMP	-0.034***	-0.020***	-0.011***
	(0.003)	(0.003)	(0.003)
INFFED	-0.019***	-0.017***	-0.005***
	(0.001)	(0.001)	(0.001)
Constant	-0.977***	-1.025***	-0.526***
	(0.067)	(0.063)	(0.057)
Observations	665	665	665
R^2	0.541	0.527	0.426
Adjusted R^2	0.536	0.522	0.420
Residual Std. Error (df = 657)	0.359	0.339	0.306
F Statistic (df = 7; 657)	110.597***	104.507***	69.649***
Note:			*p<0.1; **p<0.05; ***p<0.01

Figure 11

Figure 11 shows the second regression output including the two interactive variables, FEDUNEMP and INFFED. The incorporation of these variables changed the signs and significance of other independent variables. Once again, FEDFunds is significant and positive in all three regressions, but notably, Inflation became significant and positive at the 1% level in all three regressions. Also similar to the last model, Unemployment is significant and positive at the 1% level in the 3 and 5-year regressions, but not the 10-year. Through both regressions it can be inferred that Unemployment is more significant in the short-term compared to a longer length of correlation. A major change within *Figure 11's* regression is that the Growth variable became significant in all three regressions and exhibited the expected negative sign in the 10-year correlation. Volatility was once again insignificant across all three regressions.

Interactive variables help to account for the relationships between the effective federal funds rate and both unemployment and inflation. Both interactive variables were significant at the 1% level, and both displayed negative signs for all three regressions. This means that each interactive variable has a negative effect on the stock bond correlation. With the inclusion of the interactive terms, the size effects of Inflation, Unemployment, and FEDFunds are altered. For example, using the partial derivative of each interactive term it can be concluded that with the data's average federal funds rate of 5%, Inflation increases the stock-bond correlation by 0.039 in the 10-year regression. The same method can be applied to the FEDFunds variable. Using an average inflation rate of 6.7%, the FEDFunds variable increases the stock-bond correlation by 0.055 in the 10-year regression. Unemployment is also a component of the interactive variables, but because the average change in the unemployment rate during this data's time period was zero, the Unemployment variable can be interpreted without the altering effects of the interaction. The incorporation of the interactive variables also changed the coefficients of

Growth. In the 3-year correlation, a one percentage point increase of the IP index from a year ago created a 0.032 increase in the stock-bond correlation, while in the 10-year correlation a one percentage point increase caused a -0.015 decrease in the stock-bond correlation. This means that in the long run, Growth has the expected negative effect on the stock-bond correlation while in the short run Growth's effect is positive. Volatility is still insignificant in all three regressions.

To conclude, the regressions including the interactive variables had more explanatory power with the 3-year regression having an adjusted R^2 of 0.54, the 5-year having an adjusted R^2 of 0.52, and the 10-year having an adjusted R^2 of 0.42. The FEDFunds and Unemployment variables had the greatest effect on the 3-year stock-bond correlation. Inflation and Growth also had a positive impact on the correlation. Examining the 5-year regression, FEDFunds again had the largest impact on the correlation with Inflation, and Unemployment having similar positive impacts. Lastly, within the 10-year regression, Inflation and FEDFunds had the largest impacts on the stock-bond correlation, with Growth having a negative impact.

Econometric Testing

Time series data requires econometric testing for multicollinearity, specification error, and serial correlation. A chow test was also performed to determine if there was a significant structural change between time periods.

Tests for Multicollinearity:

Severe multicollinearity can be tested for using both the VIF test and a correlation matrix.

- VIF

Inflation	FEDFunds	Unemployment	Growth	Volatility
2.115649	1.827093	3.426414	2.689116	1.809216

Figure 12

- Correlation Matrix

	Date	SBCorrelation3yr	Inflation	FEDFunds	Unemployment	Growth	Volatility
Date	1.00000000	-0.57939327	-0.6429340	-0.70954643	-0.14226408	-0.1837866	-0.06046375
SBCorrelation3yr	-0.57939327	1.00000000	0.4194468	0.46904714	-0.06479518	0.3421209	-0.05754987
Inflation	-0.64293395	0.41944676	1.0000000	0.60596675	-0.32420888	0.4365157	-0.18731938
FEDFunds	-0.70954643	0.46904714	0.6059667	1.00000000	0.07072530	0.1029086	0.01750623
Unemployment	-0.14226408	-0.06479518	-0.3242089	0.07072530	1.00000000	-0.7659395	0.66399348
Growth	-0.18378662	0.34212090	0.4365157	0.10290863	-0.76593950	1.0000000	-0.52564937
Volatility	-0.06046375	-0.05754987	-0.1873194	0.01750623	0.66399348	-0.5256494	1.00000000

Figure 13

After analyzing both the VIF test (*see Figure 12*) and the correlation matrix (*see Figure 13*) it is evident that there is not multicollinearity within the model because the VIF's do not exceed a value of five and there is not a correlation above or below +/–.80.

Tests for Specification Error:

Specification error can be tested for using the Ramsey Reset Test. This was performed to determine whether there were omitted variables not included within the regression, subsequently causing specification error.

- Ramsey Reset Test

```
	RESET test

data:  honorsmodel3yr
RESET = 55.496, df1 = 3, df2 = 656, p-value < 2.2e-16
```

Figure 14

Analyzing *Figure 14* it is evident there is specification error and potentially omitted variables within the regressions. Due to the intricacies of the economy, specification error was likely because it was inevitable to omit variables and account for every control and extenuating factor.

Test for Serial Correlation:

Serial correlation can be tested for by performing either the Durbin-Watson or LM tests.

- Durbin-Watson Test

```
        Durbin-Watson test

data:  honorsmodel3yr
DW = 0.053862, p-value < 2.2e-16
alternative hypothesis: true autocorrelation is greater than 0
```

Figure 15

- LM Test

```
        Breusch-Godfrey test for serial correlation of order up to 1

data:  honorsmodel3yr
LM test = 632.66, df = 1, p-value < 2.2e-16
```

Figure 16

After performing both the Durbin-Watson (*see Figure 15*) and LM tests (*see Figure 16*) it was determined that there was indeed serial correlation within the regressions. Serial correlation incorrectly reduces the standard errors of the independent variables within the model. Nonetheless, this can be corrected for by first performing the Newey-West function to correct the standard errors of the independent variables and then using the Wald Test of Estimated Coefficients to create robust standard errors. The corrected model with inflated standard errors can be seen below in *Figure 17*.

Corrected Standard Errors

	Dependent variable:	
	SBCorrelation3yr	
	OLS	*coefficient test*
	(1)	(2)
Inflation	0.103***	0.103***
	(0.008)	(0.017)
FEDFunds	0.201***	0.201***
	(0.012)	(0.037)
Unemployment	0.250***	0.250***
	(0.023)	(0.060)
Growth	0.032***	0.032*
	(0.006)	(0.018)
Volatility	-0.002	-0.002
	(0.014)	(0.055)
FEDUNEMP	-0.034***	-0.034**
	(0.003)	(0.016)
INFFED	-0.019***	-0.019***
	(0.001)	(0.003)
Constant	-0.977***	-0.977***
	(0.067)	(0.262)
Observations	665	
R^2	0.541	
Adjusted R^2	0.536	
Residual Std. Error	0.359 (df = 657)	
F Statistic	110.597*** (df = 7; 657)	
Note:		*p<0.1; **p<0.05; ***p<0.01

Figure 17

Serial correlation does not bias the coefficients of the independent variables so that aspect of the regression can interpreted in the same way as previous outputs. What should be noted, is the increase in standard errors and the Growth and FEDUNEMP variables only being significant at the 10% and 5% levels respectively. All other signs and significance stayed the same.

Test for Structural Change:

- Chow Test

```
        Chow test

data:  Final_Honors_Data_3yr$SBCorrelation3yr ~ Final_Honors_Data_3yr$Date
F = 304.52, p-value < 2.2e-16
```

Figure 18

The Chow test (*see Figure 18*) shows that there is a significant structural change within the regression. This simply means that two regressions would help explain the model better than one during this period of time. Although this is an important piece of information, it is beyond the scope of this research and could be applied to future research.

Conclusion

From the beginning of the 21st century till the onset of Covid-19, investors enjoyed the benefits of a negative stock-bond correlation. This allowed them to hedge their risk by investing part of their portfolio into equities and part of their portfolio into fixed income. If equities performed poorly, investors could flee to government bonds because they functioned as a diversifier. After the Covid-19 pandemic and a decrease in price stability, the correlation between stock and bond returns pushed positive. Correlation values exceeded levels of +.80 in 2022 and 2023. This meant that investors no longer had the same ability to diversify away their risk by investing in both stocks and bonds. This research set out to understand what caused this sudden swing in correlation and why correlation between stock and bond returns has changed in the past. Through empirical modeling, it was determined that inflation and unemployment, along with the FED's manipulation of the effective federal funds rate, were the most significant driving factors of a positive stock-bond correlation. Until inflation cools to the FED's historical target level of 2%, a flight to safety into fixed income will likely not be achievable because stocks and bonds are highly correlated and both delivering negative returns. This can be used as a cautionary tale for investment managers when observing changes in the macroeconomic environment.

Understanding that inflation, among other factors, has the potential to drive the stock-bond correlation to a point where investors cannot flee to fixed income, is essential when making diversification decisions during their allocation process.

Reflecting on the study and specifics within this research, a few suggestions for future research arise. First, specific time periods play a significant role in the characteristics of the stock-bond correlation, and it may be worthwhile to make this the forefront of a study. Instead of looking at what causes changes in the stock-bond correlation, one could look at different time periods that exemplify certain economic environments, such as stagflation, and attempt to understand how the stock-bond correlation reacts within this specific frame of time. It may also be interesting to add an international component. The study above focuses largely on U.S. indexes, the U.S. Federal Reserve, and U.S. Treasuries. While this was necessary within this research because the focus was domestic, it may be interesting to see if different developed markets produce different results in terms of what macroeconomic variables shift the stock-bond correlation. Central banks also function differently around the globe and varying degrees of monetary policy with different strategies to handle price stability and unemployment, may change the significance of the interest rate variable. Lastly, it would be beneficial for future studies to expand upon the findings of this study and other previous literature to formulate a way for investors to utilize this information in the asset allocation process. This study highlights the importance of diversification and ultimately found that inflation, unemployment, and the federal funds rate were the lead factors shifting the stock-bond correlation, but future research should attempt to understand how investors can take this information and utilize it to hedge their risk.

Appendix A

Basic Terminology

- VIX: The CBOE Volatility Index or the VIX is a real-time index that represents the market's expectations for the relative strength of near-term price changes of the S&P 500 index.
- Fixed Income Assets: Investment securities that pay investors fixed interest or dividend payments until their maturity data. These include government bonds, corporate bonds, municipal bonds, and certificates of deposits.
- Risk Mandates: A set of rules or restrictions of how a pool of assets can be invested and how much risk can be taken on.
- ERP: Equity risk premium or ERP is the difference between returns on equity/individual stock and the risk-free rate of return.
- RFR: The risk-free rate of return is the theoretical rate of return of an investment with zero risk. The risk-free rate represents the interest an investor would expect from an absolutely risk-free investment over a specific period of time. The real risk-free rate can be calculated by subtracting the current inflation rate from the yield of the Treasury bond matching your investment duration.
- Market Sentiment: Market sentiment refers to the overall attitude of investors toward a particular security of financial market. It is the feeling or tone of the market.
- Sovereign Bonds: A debt security issued by a national government to raise money for financing government programs, paying old debt, paying interest or current debt, and any other government spending needs.
- Cyclically Adjusted Earnings Yield: A valuation method that uses real earnings per share over a 10-year period to smooth out fluctuations in corporate profits.

Appendix B

Expansion Upon Brixton et al. Models

The first model Brixton et al. (2023) proposed, linked the relationship between actual and expected returns of stocks and bonds to inflation and growth shocks. The authors predicted that stocks like growth but dislike the inflation and bonds dislike growth and dislike inflation. This leads to a positive sign in front inflation and a negative sign in front of growth.

$$r_t^s - E_{t-1} r_t^s = b_g^s e_t^g + b_\pi^s e_t^\pi \qquad (1)$$

$$r_t^b - E_{t-1} r_t^b = b_g^b e_t^g + b_\pi^b e_t^\pi \qquad (2)$$

where $b_g^s > 0$ and $b_\pi^s, b_g^b, b_\pi^b < 0$

Stocks like growth but dislike inflation

Bonds dislike growth and inflation

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

$$\mathrm{cov}_t(r_s, r_b) = (b_{s,g} b_{b,g})\boldsymbol{\sigma}^2_{g,t} + (b_{s,\pi} b_{b,\pi})\boldsymbol{\sigma}^2_{\pi,t} + (b_{s,g} b_{b,\pi} + b_{s,\pi} b_{b,g})\boldsymbol{\sigma}_{g,\pi,t} \qquad (3)$$

In Brixton's second model the covariance of stock and bond returns is dependent on the variance of growth and inflation and the correlation between growth and inflation. The authors found that the covariance tends to be negative when growth variance is high as shown by the negative sign associated with the growth variance variable. As for inflation, the covariance tends to be positive when inflation variance is high. This can be seen by the positive sign in front of the growth variance variable. These conclusions were aligned with the authors original predictions that stocks and bonds were stronger diversifiers when growth shocks occurred and weaker diversifiers when inflation news occurred.

Appendix C

Web Links:

Molenaar:
https://deliverypdf.ssrn.com/delivery.php?ID=206100072072118031084089093086099073116045093077065045102112108100025124110000001118000017006006033051111103070020018102095022105040068036092022094089076025014028050047063107116117092069077124090116122108114065127099025085112064114099018089000066113&EXT=pdf&INDEX=TRUE

Andersson:
https://www.researchgate.net/publication/227357771_Why_Does_the_Correlation_Between_Stock_and_Bond_Returns_Vary_Over_Time

Connolly:
https://www.jstor.org/stable/27647190?searchText=stock+bond+uncertainty&searchUri=%2Faction%2FdoBasicSearch%3FQuery%3Dstock%2Bbond%2Buncertainty&ab_segments=0%2Fbasic_search_gsv2%2Fcontrol&refreqid=fastly-default%3A0abcf1803e1adbfb5d83a7468f32b31d&seq=1

Li:
https://www.nber.org/papers/w27861

Wainscott:
http://www.jstor.org/stable/4479348

Ilmanen:
https://www.aqr.com/Insights/Research/Journal-Article/Stock-Bond-Correlations

Brixton:
https://www.aqr.com/Insights/Research/Journal-Article/A-Changing-Stock-Bond-Correlation

Yakov:
https://www.jstor.org/stable/4478932

Data Sources:
- Stock and Bond Returns (Used 12-month moving averages of stock and bond returns to create a 3 different rolling correlations): Robert Shiller Data Series

FRED St. Louis FED:
- Growth: 12-month % change in Industrial Production Index
- Volatility: 12-month standard deviation of S&P returns
- Inflation 12 Month Change in Personal Consumption Expenditure
- Unemployment Data: Change in Unemployment rate from a year ago
- Effective Funds Rate: Actual Effective Federal Funds Rate

Appendix D

R-Code:

```
summary(Honors_Data_Excluding_Outlier_Months)
honorsmodel<-
lm(SBCorrelation~Inflation+FEDFunds+Unemployment+Growth+Volatility+Time, data =
Honors_Data_Excluding_Outlier_Months)
summary(honorsmodel)
honorsmodel3yr<-
lm(SBCorrelation3yr~Inflation+FEDFunds+Unemployment+Growth+Volatility+FEDUNEMP+I
NFFED, data = Final_Honors_Data_3yr)
```

```
summary(honorsmodel3yr)
honorsmodel5yr<-
lm(SBCorrelation5yr~Inflation+FEDFunds+Unemployment+Growth+Volatility, data =
Final_Honors_Data_5yr)
summary(honorsmodel5yr)
honorsmodel10yr<-
lm(SBCorrelation10yr~Inflation+FEDFunds+Unemployment+Growth+Volatility, data =
Final_Honors_Data_10yr)
summary(honorsmodel10yr)
library(stargazer)
stargazer(honorsmodel3yr, honorsmodel5yr, honorsmodel10yr, type = "text", title = "Output of 3
different Length Correlations")
library(corrplot)
cor(Honors_Data_Excluding_Outlier_Months)
library(ggplot2)
library(gplots)
boxplot(Honors_Data_Excluding_Outlier_Months$Growth, ylab = "Growth", main = "Growth
Boxplot")
boxplot(Honors_Data_Excluding_Outlier_Months$Inflation, ylab = "Inflation", main =
"Inflation Boxplot")
FEDUNEMP<-(Final_Honors_Data_3yr$FEDFunds * Final_Honors_Data_3yr$Unemployment)
INFFED<-(Final_Honors_Data_3yr$FEDFunds * Final_Honors_Data_3yr$Inflation)
library(car)
linearHypothesis(honorsmodel5,c("FEDFunds + FEDUNEMP"))
linearHypothesis(honorsmodel5,c("Unemployment + FEDUNEMP"))
honorsmodel5<-
lm(SBCorrelation~Inflation+FEDFunds+Unemployment+Growth+Volatility+Time+FEDUNEM
P, data = Final_Honors_Data_R_Ready)
summary(honorsmodel5)
honorsmodel6<-
lm(SBCorrelation~Inflation+FEDFunds+Growth+Volatility+Time+FEDUNEMP, data =
Final_Honors_Data_R_Ready)
summary(honorsmodel6)
stargazer(honorsmodel,honorsmodel5,honorsmodel6, type = "text")
library(stargazer)
stargazer(honorsmodel, honorsmodel5, type = "text")
library(stats)
library(dplyr)
library(rlang)
inflationlag<-dplyr::lag(Final_Honors_Data_3yr$Inflation)
```

```
honorsmodel2<-
lm(SBCorrelation~inflationlag+FEDFunds+Unemployment+Growth+Volatility+Time, data =
Final_Honors_Data_3yr)
summary(honorsmodel2)
fedfundslag<-dplyr::lag(Final_Honors_Data_3yr$FEDFunds)
unemplag<-dplyr::lag(Final_Honors_Data_3yr$Unemployment)
growthlag<-dplyr::lag(Final_Honors_Data_3yr$Growth)
honorsmodellagged<-
lm(SBCorrelation~inflationlag+fedfundslag+unemplag+growthlag+Volatility+Time, data =
Final_Honors_Data_3yr)
summary(honorsmodellagged)
#create a subset
PERIOD1<-subset(Final_Honors_Data_R_Ready, Final_Honors_Data_R_Ready$Date <=
1981.12)
honorsmodel3<-
lm(SBCorrelation~Inflation+FEDFunds+Unemployment+Growth+Volatility+Time, data =
PERIOD1)
summary(honorsmodel3)
PERIOD2<-subset(Final_Honors_Data_R_Ready, Final_Honors_Data_R_Ready$Date >=
1982.01 & Final_Honors_Data_R_Ready$Date <= 2008.08)
summary(PERIOD2)
summary(PERIOD1)
honorsmodel4<-
lm(SBCorrelation~Inflation+FEDFunds+Unemployment+Growth+Volatility+Time, data =
PERIOD2)
summary(honorsmodel4)
cor(Final_Honors_Data_R_Ready$SBCorrelation, Final_Honors_Data_R_Ready$Inflation)
summary(Final_Honors_Data_R_Ready$SBCorrelation)
summary(Final_Honors_Data_R_Ready$Inflation)
cor(PERIOD1$SBCorrelation, PERIOD1$Inflation)
cor(PERIOD2$SBCorrelation, PERIOD2$Inflation)
library(urca)
adf_test<-ur.df(Final_Honors_Data_R_Ready$SBCorrelation, type = "none", selectlags =
"AIC")
summary(adf_test)
adf_test<-ur.df(Final_Honors_Data_R_Ready$Inflation, type = "none", selectlags = "AIC")
summary(adf_test)
adf_test<-ur.df(Final_Honors_Data_R_Ready$Unemployment, type = "none", selectlags =
"AIC")
summary(adf_test)
```

```
adf_test<-ur.df(Final_Honors_Data_R_Ready$FEDFunds, type = "none", selectlags = "AIC")
summary(adf_test)
adf_test<-ur.df(Final_Honors_Data_R_Ready$Growth, type = "none", selectlags = "AIC")
summary(adf_test)
adf_test<-ur.df(Final_Honors_Data_R_Ready$Volatility, type = "none", selectlags = "AIC")
summary(adf_test)
honorsmodel7<-lm(SBCorrelation~Inflation+Unemployment+Growth+Volatility+Time, data =
Final_Honors_Data_R_Ready)
summary(honorsmodel7)
FEDINF<-(Final_Honors_Data_R_Ready$FEDFunds *
Final_Honors_Data_R_Ready$Inflation)
honorsmodel8<-
lm(SBCorrelation~Inflation+FEDFunds+FEDINF+Unemployment+Growth+Volatility+Time,
data = Final_Honors_Data_R_Ready)
summary(honorsmodel8)
#Econometric Testing
#multicollinearity
library(car)
vif(honorsmodel3yr)
vif(honorsmodel5yr)
vif(honorsmodel10yr)
cor(Final_Honors_Data_3yr)
#specification error
library(lmtest)
#Ho: No specification Error
#Ha: Specification Error
resettest(honorsmodel3yr, power = 2:4)
resettest(honorsmodel5yr, power = 2:4)
resettest(honorsmodel10yr, power = 2:4)
#serial correlation
dwtest(honorsmodel3yr)
dwtest(honorsmodel5yr)
dwtest(honorsmodel10yr)
dwtest(honorsmodel2)
dwtest(honorsmodellagged)
bgtest(honorsmodel3yr)
bgtest(honorsmodel5yr)
bgtest(honorsmodel10yr)
library(orcutt)
orcutt1<-cochrane.orcutt(honorsmodel3yr)
```

```
summary(orcutt1)
library(strucchange)
sctest(Final_Honors_Data_3yr$SBCorrelation3yr~Final_Honors_Data_3yr$Date, type =
"Chow", point = 397)
breakpoint<-397
chow_test<-chow.test(honorsmodel3yr, break = breakpoint)
print(chow_test)
timepd1<-subset(Final_Honors_Data_3yr,Final_Honors_Data_3yr$Date >= 1967.12 &
Final_Honors_Data_3yr$Date <= 1981.12)
summary(timepd1)
timepd2<-subset(Final_Honors_Data_3yr,Final_Honors_Data_3yr$Date >= 1982.01 &
Final_Honors_Data_3yr$Date <= 2008.08)
summary(timepd2)
timepd3<-subset(Final_Honors_Data_3yr,Final_Honors_Data_3yr$Date >= 2008.09 &
Final_Honors_Data_3yr$Date <= 2020.12)
summary(timepd3)
honorsmodel3yrtimeperiod<-
lm(SBCorrelation3yr~Inflation+FEDFunds+Unemployment+Growth+Volatility+FEDUNEMP1
+INFFED1, data = timepd1)
summary(honorsmodel3yrtimeperiod)
honorsmodel3yrtimeperiod2<-
lm(SBCorrelation3yr~Inflation+FEDFunds+Unemployment+Growth+Volatility+FEDUNEMP2
+INFFED2, data = timepd2)
summary(honorsmodel3yrtimeperiod2)
honorsmodel3yrtimeperiod3<-
lm(SBCorrelation3yr~Inflation+FEDFunds+Unemployment+Growth+Volatility+FEDUNEMP5
+INFFED5, data = timepd3)
summary(honorsmodel3yrtimeperiod3)
FEDUNEMP1<-(timepd1$FEDFunds * timepd1$Unemployment)
INFFED1<-(timepd1$FEDFunds * timepd1$Inflation)
FEDUNEMP2<-(timepd2$FEDFunds * timepd2$Unemployment)
INFFED2<-(timepd2$FEDFunds * timepd2$Inflation)
timepdpositive<-subset(Final_Honors_Data_3yr,Final_Honors_Data_3yr$Date >= 1967.12 &
Final_Honors_Data_3yr$Date <= 2000.11)
summary(timepdpositive)
timepdnegative<-subset(Final_Honors_Data_3yr,Final_Honors_Data_3yr$Date >= 2000.12 &
Final_Honors_Data_3yr$Date <= 2023.09)
summary(timepdnegative)
FEDUNEMP3<-(timepdpositive$FEDFunds * timepdpositive$Unemployment)
INFFED3<-(timepdpositive$FEDFunds * timepdpositive$Inflation)
```

```
FEDUNEMP4<-(timepdnegative$FEDFunds * timepdnegative$Unemployment)
INFFED4<-(timepdnegative$FEDFunds * timepdnegative$Inflation)
FEDUNEMP5<-(timepd3$FEDFunds * timepd3$Unemployment)
INFFED5<-(timepd3$FEDFunds * timepd3$Inflation)
honorsmodel3yrpositive<-
lm(SBCorrelation3yr~Inflation+FEDFunds+Unemployment+Growth+Volatility+FEDUNEMP3
+INFFED3, data = timepdpositive)
summary(honorsmodel3yrpositive)
honorsmodel3yrnegative<-
lm(SBCorrelation3yr~Inflation+FEDFunds+Unemployment+Growth+Volatility+FEDUNEMP4
+INFFED4, data = timepdnegative)
summary(honorsmodel3yrnegative)
coeftest1<-coeftest(honorsmodel3yr, vcov = vcovHC(honorsmodel3yr))
stargazer(honorsmodel3yr, coeftest1, type = "text")
library(sandwich)
corrected<-NeweyWest(honorsmodel3yr, lag = 1)
corrected
coeftest2<-coeftest(honorsmodel3yr, corrected)
coeftest2
stargazer(honorsmodel3yr, coeftest2, type = "text")
bgtest(coeftest2)
```

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