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Spillover effects among gold, stocks, and bonds

by

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Abstract

In this paper an attempt is made to document the interdependence among stocks, bonds and gold. Gold is an important asset class and has often been seen as a safe haven and counter-cyclical investment vehicle. We present an extension of the work done by Diebold and Yilmaz (2009) using a spillover index methodology to examine whether gold returns and volatilities can predict U.S. stock and bond market movements or vice versa. For the sample period from January 1970 to April 2009, return spillovers appear muted. However, there is some evidence of volatility spillovers of which much is attributable to a spillover from innovations in stocks to bond return volatility. Spillovers in terms of returns are higher during the early 1980s, mid-1990s and the most recent financial crisis. Volatility spillovers have been very elevated in the recent financial crisis as well as late 1970s and early 1990s. The lack of any substantial relationship between gold and stocks and gold and bonds raises the question whether gold price movements can be used as a predictor for stocks and bond prices.

Keywords: Spillover effects, gold, stock market, bond market

Introduction

Gold is an important asset class, but its tangibility makes it quite different from paper assets such as stocks and bonds. Gold's physical attributes give it an important role as a store of value, especially in times of political and economic uncertainty. As a consequence, there has been a continuing interest in the role and impact of gold on financial markets by investors in particular. Tschoegl (1980), Solt and Swanson (1981), and Aggarwal and Soenen (1988) first explored the nature and efficiency of the gold market in the United States of America (USA). While the studies uncovered minor elements of returns dependence and non-normality, they generally concluded in favor of market efficiency due to a belief that none of the distributional vagaries was material enough to present exploitable opportunities. Chua, Sick, and Woodward (1990) and Jaffe (1989) analyzed the benefits of diversifying investment portfolios with gold stocks. Jaffe (1989) found that gold presented diversification benefits. Johnson and Soenen (1997) extended Jaffe's (1989) work by investigating the role of gold in investment portfolios from a global perspective. Johnson and Soenen found that in the period 1984-1995, stocks and bonds dominated the performance of gold as an investment. Davidson, Faff, and Hillier (2003) found that 22 of 24 world industries examined had significant exposures to the gold factor over the period 1975-1994. Davidson et al. concluded that gold has had an important role in international asset pricing models and that corporate exposure to this historically prominent commodity is still strong.

In more recent work, Diebold and Yilmaz (2009) documented interdependence for the asset returns and asset return volatilities of 19 global equity markets for the period January 1992 to November 2007 using a measure they referred to as a spillover index. They noted that the spillover index is time-varying, indicating that the interdependence between markets is also time-varying, and that the pattern of spillovers differed depending on whether they looked at returns or volatilities. In particular, Diebold and Yilmaz found that returns appeared to exhibit a trend of increasing financial market integration, but did not have any drastic jumps. Volatilities, on the other hand, did not exhibit any trend pattern; however, volatilities did have "bursts," many of which Diebold and Yilmaz linked to significant economic events, for example, the East Asian, Brazilian, and Russian crises.

Diversification is important not only across different global markets, but also within various classes of assets. For at least some investors, an investment in gold has been seen as a good hedge or safe haven against stock market movements. Understanding the nature of the interdependence between different classes of assets is important for the portfolio choice of an investor. Lawrence (2003) used quarterly data from 1975-2001 to examine the behavior of returns on U.S. stocks, bonds, and gold. He found a lack of correlation between returns on gold and other financial assets and linked the lack of relationship to the fact that gold returns do not correlate with macroeconomic variables, whereas returns on stocks and bonds do. He concluded that the evidence suggested gold would make for a good portfolio diversifier. Baur and Lucey (2009) used daily data on gold, bonds, and stocks from the U.S.A., United Kingdom, and Germany from November 30, 1995, to November 30, 2005, to examine whether gold acted as a hedge and/or safe haven for stocks and bonds. Their findings suggested that gold was a hedge against stocks and a safe haven in extreme stock market conditions, but for only very short periods.[1]

In this paper, an extension of the work done by Diebold and Yilmaz (2009) is offered. In addition, volatility spillovers are analyzed, not only in stock markets, but also within and across other financial markets. Using the spillover index methodology, we examine whether gold returns and volatilities can predict U.S. stock and bond market movements or vice versa. The reminder of the paper is organized as follows. In the first section, the data used as well as its construction and descriptive statistics is described. In Section 2, the spillover index methodology is outlined. In Section 3, the results for the complete sample period and for a rolling-sample analysis, which allowed testing of time-varying spillovers, is provided. We summarize and conclude in Section 4.

Data

In the analysis, data from various sources have been merged to create a weekly dataset with observations beginning in the second week of January in 1970 (1/9/1970) and ending the last week in April of 2009 (4/24/2009). The reason weekly rather than daily periodicity was selected for the data is threefold: (a) non-availability of daily data on the high-low-open-close (HLOC) before 1986 for gold; (b) the procedure used by Diebold and Yilmaz (2009) in which they make the assumption that the volatility is fixed during the week but is allowed to vary across weeks; and (c) variation in closed markets from asset to asset, making the calculation of daily returns inconsistent between markets.[2] We examine the behavior of both returns and return volatilities of U.S. stocks, bonds, and gold. For the measure of stock returns, the real weekly return on the S&P 500 Index, calculated as the log difference of the weekly real S&P 500 Index (deflated using the Consumer Price Index [CPI]), was used.[3] The measure of gold returns was calculated similarly to the stock returns.[4] The 10-year U.S. Treasury note was used as the bond measure. The data was reported as a nominal annual return, which was converted to a weekly return and then converted to a real return by subtracting the weekly inflation rate (based on the change in the CPI.[5]

Measures of volatility were calculated using weekly open (P_{OPEN}), close (P_{CLOSE}), high (P_{HIGH}), and low (P_{LOW}) price data obtained from the daily HLOC data for the various financial variables.[6] Garman and Klass (1980) derived the best analytic scale-invariant estimator for the weekly return volatility with the following equation:

$$\hat{\sigma}^2 = 0.511(u-d)^2 - 0.019\{c(u+d) - 2ud\} - 0.383c^2 \quad (1)$$

where $u = \ln(P_{HIGH})-\ln(P_{OPEN})$, $d = \ln(P_{LOW}) - -\ln(P_{OPEN})$, $c= \ln(P_{CLOSE})-\ln(P_{OPEN})$.

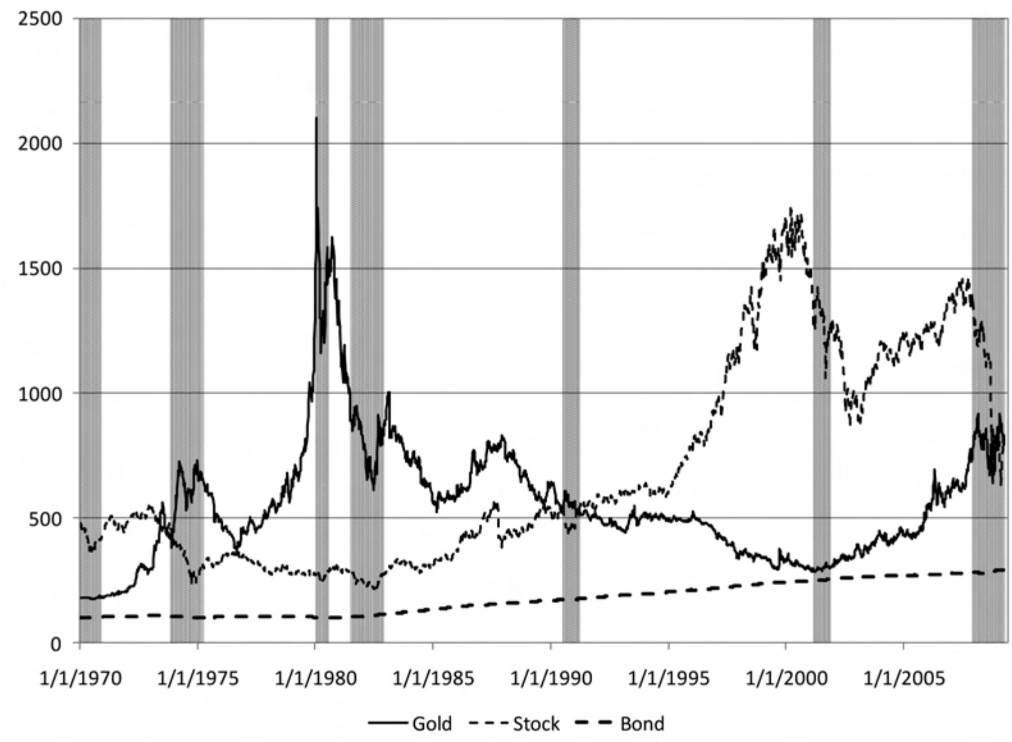

Figure 1. Real prices/indexes for stocks, bonds, and gold.

Figure 1 displays the weekly real price or index for the stock, bond, and gold series. As can be seen in the graph, gold prices saw a steep increase in the late 1970s, corresponding to the drastic increase in inflation, followed by a steep decline in the first half of the 1980s. More recently, there again has been an increase in gold prices following the end of the 2001 recession through the beginning of the most recent recession. Even today, prices remain elevated above the average levels experienced over the last 30 years; however, the levels are nowhere near as high as the levels experienced during the late 1970s. Real stock prices climbed steadily during much of the 1980s and early part of the 1990s, a period of almost uninterrupted economic expansion before the technological boom of the late 1990s was followed by the bursting of the dot.com bubble in the early part of the 2000s, and most recently, the 2007-2008 economic and financial crisis. The real bond index that was created shows a slow, steady increase over the sample period, demonstrating a safe, consistent investment.

Looking at the descriptive statistics reported in Table 1 over the sample period, gold has enjoyed the highest average weekly real return, followed by bonds and stocks. The variation in weekly returns is similar for gold and stocks but much higher than for bonds. On the other hand, variation in bond returns is relatively stable, offering the most consistent return. Investments in stocks and gold are generally more risky than bonds but stocks and gold offer higher returns for certain periods, indicated by the higher maximum values of gold and stocks as opposed to bonds. As reported by Baur and Lucey (2009), gold, despite its presumably safe haven property, appears relatively risky in terms of the standard deviation and the minimum and maximum values. Table 1 shows that the price volatility is similar for all three financial assets on average, but slightly less for gold; however, for stocks and gold, there is more variation in the volatility measure. The Jarque-Bera statistic, a test for normality based on the skewness and kurtosis measures combined, is zero for all variables reported.[7]

Table 1
Descriptive Statistics for Key Variables

Statistic	Real price/index			Weekly real return			Volatility of real price/index		
	Gold	Stock	Bond	Gold	Stock	Bond	Gold	Stock	Bond
Mean	554.56	689.30	174.47	0.000743	0.000244	0.000517	0.000494	0.000549	0.000516
Median	510.11	520.40	166.86	0.000382	0.001847	0.000572	0.000189	0.000311	0.000350
Maximum	2100.63	1744.87	290.08	0.288302	0.129163	0.005476	0.025866	0.029284	0.001823
Minimum	176.69	207.32	99.37	-0.223920	-0.198867	-0.002141	0.000000	0.000005	0.000000
Std. Dev.	241.08	413.38	64.72	0.027190	0.022997	0.000852	0.001269	0.001121	0.000525
Skewness	1.56	0.82	0.28	0.38	-0.56	0.14	9.47	14.19	0.86
Kurtosis	7.47	2.30	1.57	14.55	8.60	5.20	131.81	294.87	2.49
Jarque-Bera	2537	271	202	11442	2789	422	1449398	7352352	275
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Observations	2052	2052	2052	2051	2051	2051	2052	2052	2052

Table 2
Correlations over the Entire Sample Period

	Returns			Volatilities		
	Stocks	Gold	Bonds	Stocks	Gold	Bonds
Stocks	1.000			1.000		
Gold	-0.015	1.000		0.186	1.000	
Bonds	0.070	-0.056	1.000	0.083	0.007	1.000

In Table 2, the correlations among the returns and volatilities over the entire sample are displayed. As first predicted by Merton (1973), the correlation between gold returns and stock market returns is negative but weak. Gold returns are correlated negatively with bonds returns. The results suggest that gold could serve as a hedge and hence could reduce a portfolio's volatility. Stocks and bonds have a positive and slightly larger correlation. The finding that gold is a hedge for stocks and bonds implies that investors receive compensation for losses caused by negative stock or bond returns through positive gold returns. Considering that all reported correlations are very small, gold as well as bonds also qualify as diversifiers

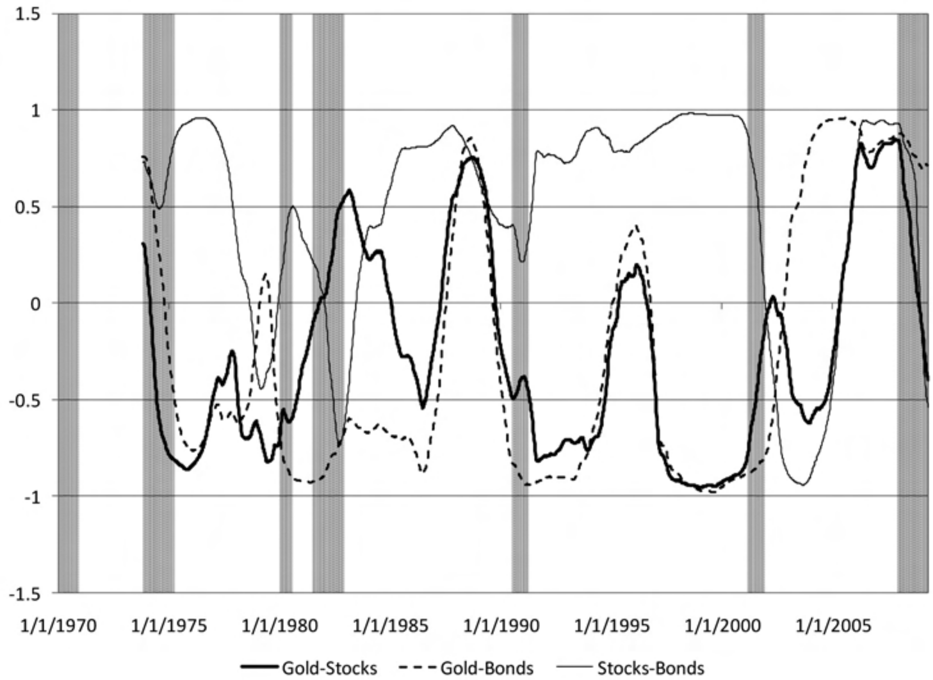

Figure 2. Correlations of stock, bond, and gold prices/index.

in combination with stocks. In terms of volatilities, stock return volatilities show a positive correlation with both gold and bonds, but stronger for gold, while there is very little correlation between gold and bonds.

Figure 2 illustrates the correlations of the stock, bond, and gold prices with one another using a 200-week sample period rolling window. Each point represents the correlation of the 200 weekly observations ending on that date. Generally, a positive correlation between stocks and bonds in terms of prices under regular market conditions is evident, but the correlation turns very negative during stock market downturns, such as in 1979 with the oil crisis, 1980-1981 with the recession, 2000 with the technology bubble, and 2001 after September 11. In contrast, a similar correlation pattern appears between stocks and gold as well as bonds and gold for the majority of the sample, with the exception of the period from the late 1970s to the early 1980s and just following the 2001 recession. The pattern of correlation between stocks and bonds is different from the other two pairs of correlations. All correlations fluctuate over a large range of values, from very negative correlations to very positive correlations, depending on the sample period.

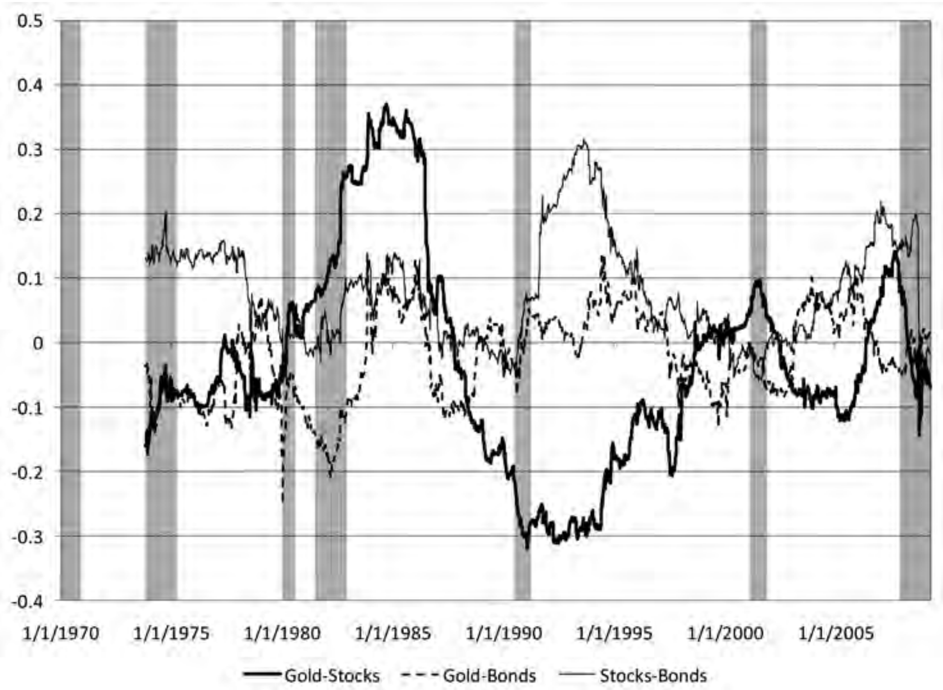

Figure 3. Correlations of stock, bond, and gold weekly returns.

Figure 3 illustrates the correlations between the returns of the three asset classes. The correlation of gold and bond returns fluctuates between -0.1 and 0.1, with the exception of the early 1980s where it is slightly more negative. The correlation of stock and bond returns is generally positive regardless of the sample period and usually weaker in the later phases of expansions and during recessions. The correlations of stocks and gold returns show both stronger negative and positive correlations than the gold and bond returns. The statistics further illustrate that gold prices move more in tandem with bond prices than they do with stocks. In a recent paper, Baur and Lucey (2009) showed that the return of gold is positive on the day an extreme negative shock in the stock market occurs. However, the gold price declines in the days following the extreme negative shock, and the initial positive effect is reduced to zero after about 15 days. In other words, Baur and Lucey found that gold is a safe haven only in the short term; gold loses value as an investment in the longer term.

Econometric Methodology

Our analysis investigating the co-movement between both returns and return volatilities of stocks, bonds, and gold followed the method set forth in Diebold and Yilmaz (2009), generating what they term a *spillover index*. The spillover index is calculated using a vector autoregression model (VAR) and its associated variance decomposition. In the following, a brief overview of the methodology is given.[8]

Consider a simple VAR system that contains *P* lags and *N* variables. The VAR can be written in its reduced form as follows:

$$X_t = c + \sum_{p=1}^{P} A_p X_{t-p} + v_t \quad (2)$$

where A_p is an N x N matrix of regression coefficients, c is an N-vector of constants, and v_t is an N-vector of innovations. The elements of v_t are assumed to be serially uncorrelated, but they can be correlated with one another. The covariance matrix of v_t is given by Σ_v. The VAR can be rewritten in its moving average representation as follows:

$$X_t = c + \sum_{i=0}^{\infty} \phi_i u_{t-i} \quad (3)$$

where $u_t = Pv_t$ and P^{-1} is the lower triangular Cholesky Factorization of Σ_v and $\Phi_i = M_i P^{-1}$, where

$$M_i = \sum_{j=1}^{\min(i,p)} A_j M_{i-j}$$

and $M_0 = I$. It can be shown that the h-step ahead forecast error covariance matrix is given by the following:

$$\Sigma_{fe,h} = \Sigma_{fe,h-1} + M_{h-1}\,\Sigma_v M'_{h-1} \quad (4)$$

where $\Sigma_{fe,o} = O_N$.

The forecast error variance decomposition represents the portion of the variance to variable *I* that is the result of innovations (shocks) to variable *J* represented as a percentage. The variance decompositions resulting from shocks of other variables will depend on the off-diagonal entries of the Φ_i matrices relative to the on- and off-diagonal entries, just as the spillover index will depend on this same relationship. The forecast error variance decomposition for variable *I*, at forecast horizon *H*, attributable to variable *J* is given by the following:

$$VD_{I,J}^{H} = 100\,\frac{\Sigma_{h=0}^{H-1}\phi_{h,I,J}^{2}}{\Sigma_{h=0}^{H-1}\Sigma_{j=1}^{N}\phi_{h,I,j}^{2}} \quad (5)$$

The spillover index for forecast horizon *H* is calculated as follows:

$$SPILL^{H} = 100\,\frac{\Sigma_{h=0}^{H-1}\Sigma_{\substack{i,j=1\\ i\neq j}}^{N}\phi_{h,i,j}^{2}}{\Sigma_{h=0}^{H-1}\Sigma_{i,j=1}^{N}\phi_{h,i,j}^{2}} \quad (6)$$

Note the denominator for the spillover index calculation is simply the sum of the traces of the forecast error covariance matrices.

Results

For the results that are displayed, vector autoregression (VAR) containing three variables (stocks, gold, and bonds) with two lags of each variable were used. Results for the weekly real returns as well as the weekly return volatilities were produced. The ordering of the VAR matters in terms of the impact of innovations (shocks) to a particular variable that can have a contemporaneous impact on the other variables. By ordering the stock variable first, the assumption is that stocks can have a contemporaneous impact on gold and bonds. Ordering gold second implies that gold can have a contemporaneous impact on bonds, but not on stocks. The results of the VAR estimation are represented in the Appendix. The spillovers are examined first by looking at the entire sample period. Tables 3 and 4 respectively display the spillovers for the weekly real returns data at the 2-week and 10-week forecast horizons. The entries in the tables represent the variance decompositions.

Table 3
Spillover Table, Stocks, Gold, and Bonds Returns (Full Sample for 2-Week Horizon)

To	From			
	Stocks	Gold	Bonds	Contribution from others
Stocks	99.9696	0.0112	0.0192	0.0304
Gold	0.2166	99.6206	0.1627	0.3794
Bonds	0.1367	0.0502	99.8131	0.1869
Contributions to others	0.3533	0.0614	0.1819	0.5967
Contribution including own	100.323	99.6821	99.995	Spillover Index = 0.1989%

Table 4
Spillover Table, Stocks, Gold and Bonds Returns (Full Sample for 10-Week Horizon)

	From			
To	Stocks	Gold	Bonds	Contribution from Others
Stocks	99.395	0.2622	0.3428	0.605
Gold	0.2199	99.467	0.3131	0.533
Bonds	0.1713	0.2919	99.5367	0.4633
Contributions to Others	0.3913	0.5542	0.6558	1.6013
Contribution including own	99.7863	100.0211	100.1926	Spillover Index = 0.5338%

Note that virtually all of the 2-week and 10-week ahead forecast error variance is attributable to shocks in the variable ordered first (above 99%). The contributions from shocks to other variables are negligible. As a result, the spillover index is very small (0.20% and 0.53%). The variance decompositions of the volatilities are displayed in the next set of tables (see Tables 5 and 6).

Table 5
Spillover Table, Stocks, Gold, and Bonds Volatilities (Full Sample for 2-Week Horizon)

To	From			
	Stocks	Gold	Bonds	Contribution from Others
Stocks	99.409	0.5886	0.0023	0.5910
Gold	0.8223	99.0227	0.1550	0.9773
Bonds	9.213	0.4109	90.3761	9.6239
Contributions to Others	10.0353	0.9995	0.1574	11.1921
Contribution including own	109.4443	100.0222	90.5335	Spillover Index = 3.7307%

Table 6
Spillover Table, Stocks, Gold, and Bonds Volatilities (Full Sample for 10-Week Horizon)

To	From			
	Stocks	Gold	Bonds	Contribution from Others
Stocks	98.4422	1.5432	0.0146	1.5578
Gold	3.215	96.5223	0.2627	3.4777
Bonds	23.7894	1.0334	75.1773	24.8227
Contributions to Others	27.0043	2.5766	0.2774	29.8582
Contribution including own	125.4465	99.0989	75.4547	Spillover Index = 9.9527%

In these results, there seems to be evidence of at least some spillover. The spillover index for the 2- and 10-week ahead forecast horizons are 3.73% and 9.95%. Looking at the tables, much of the spillover is from stocks to bonds: almost a quarter of the forecast error variance for bond volatilities can be attributed to innovations to the volatilities of stocks. Again, no substantial spillover is found between gold volatility and stocks or bonds. Gold seems to form a separate asset class although it is seen generally as a safe haven instrument; in the end, its low and slightly negative correlation with stocks and bonds (see Table 2) makes it a great diversifier in an investment portfolio.

While there is not much spillover or predictability across the entire sample, it is still possible that over certain periods there could be. In order to examine the potentially dynamic nature of the relationship between financial assets, the methodology used in Diebold and Yilmaz (2009) is followed when looking at 200-week rolling window samples. Diebold and Yilmaz looked at equities for 19 countries and documented increased spillovers in terms of returns over the sample period that they examined as well as spikes in volatility spillovers that corresponded with certain economic events.

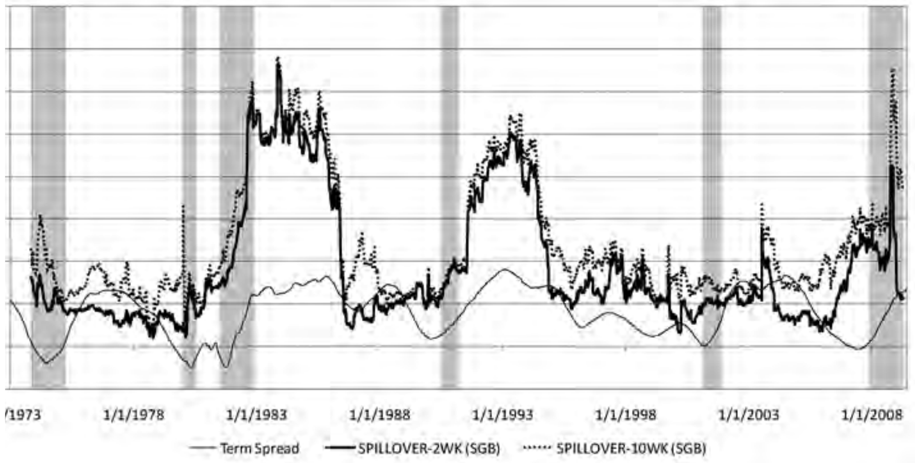

Figure 4. Spillovers for returns at the 2-week and 10-week forecast horizon.

Figure 4 presents the spillover index for 2-week and 10-week forecast horizons where the spillover index using a 200-week sample period that ends in the period displayed in the graph is estimated; hence the first 200 weeks of the sample do not appear in the figure. As can be seen in the graph, normally the spillover index value is around 2-4%; however, during certain periods, the spillover increases to as much as 14%. Also plotted in the figure is the term premium or spread between a return on a 10-year U.S. Treasury Bond and a 3-month U.S. Treasury bill, displayed as a 52-week moving average. The spillover index for both 2-week and 10-week horizons has a correlation of approximately 0.44 with the spread. Periods of increased spread therefore correlate with periods of increased spillover.

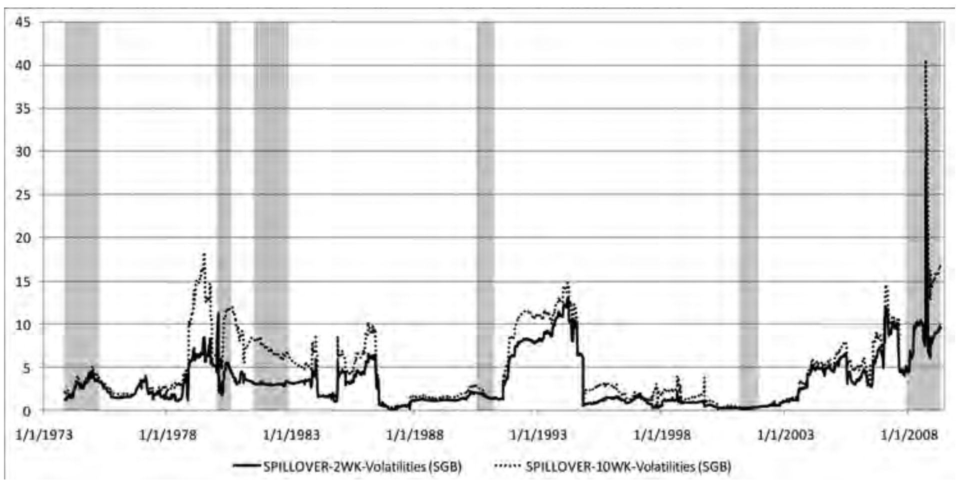

Figure 5. Spillovers for volatilities at the 2-week and 10-week forecast horizon.

Figure 5 displays the spillover index for the volatilities. Once again, several periods where there is very little spillover are apparent, followed by a period in which the spillover increases dramatically. Notice that the volatility spillover has been very high recently.

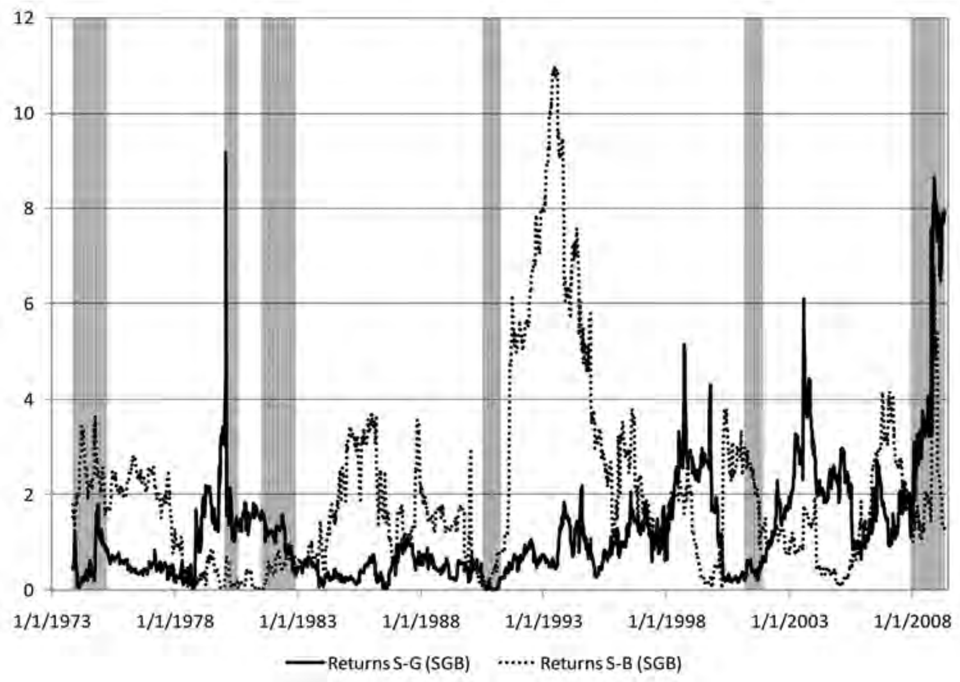

Figure 6. Source of spillover: Influence on stock returns from gold and bonds.

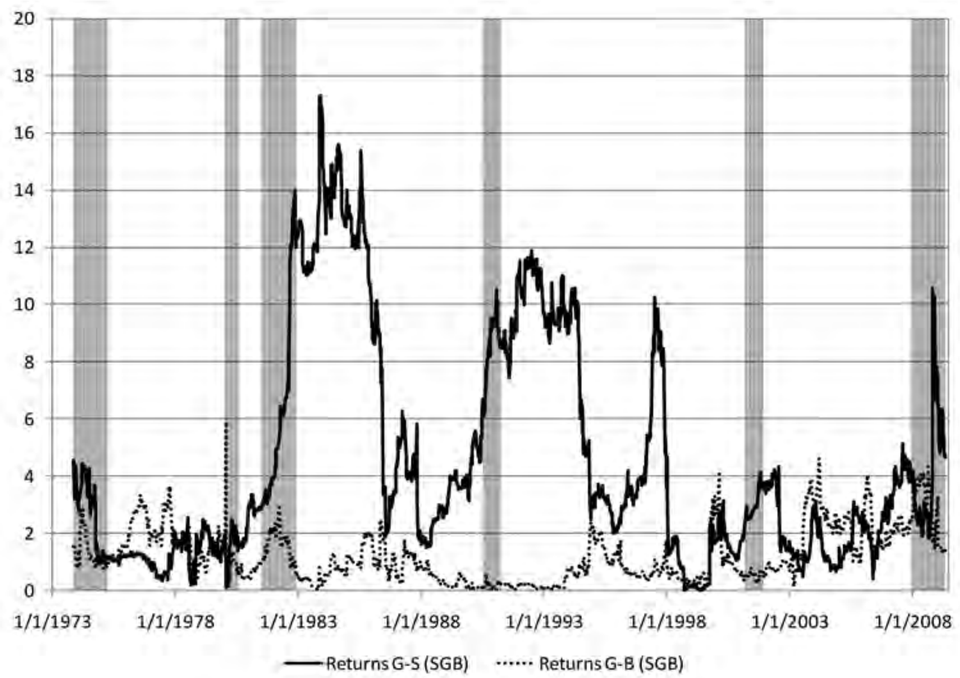

Figure 7. Source of spillover: Influence on gold returns from stocks and bonds.

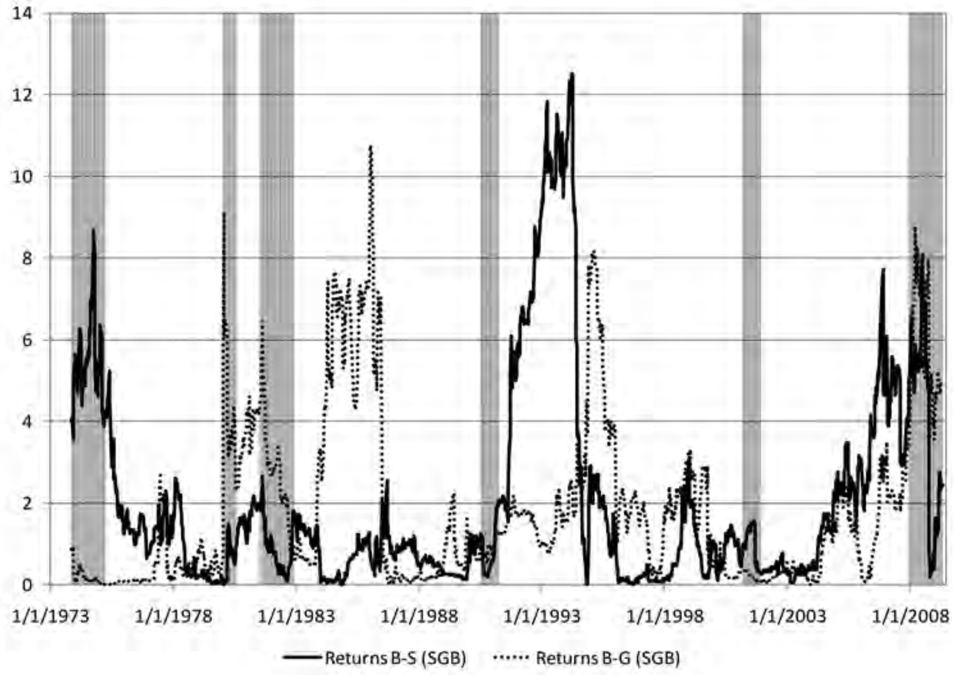

Figure 8. Source of spillover: Influence on bond returns from gold and stocks.

Figures 6, 7, and 8 display the direction of the spillovers—that is, the innovations contributing to increasing the size of the spillovers, along with NBER (National Bureau of Economic Research) recession dates. As can be seen in the second panel of Figure 8, the spillover from bond innovations to stocks and gold are relatively mild, whereas several periods in which innovations in stocks and gold seem to influence the returns of the other variables are apparent. In particular, gold had an increased spillover effect on stocks in the late 1970s and in 2009 and an increased spillover effect on bonds in the mid-1980s, mid-1990s and more recently.

Conclusions

In this paper, an attempt was made to document the interdependence among stocks, bonds, and gold. For the full sample of data examined, return spillovers appear muted; however, some evidence exists of volatility spillovers for the entire sample. Much of the volatility spillover is attributable to a spillover from innovations in stocks to bond return volatility. By examining short sample windows, it was found that spillovers are dynamic in nature. Spillovers in terms of returns are higher during the early-1980s, mid-1990s, and the most recent financial crisis. Volatility spillovers have been very elevated in the most recent financial crisis as well as in the late 1970s and early 1990s. There does not seem to be any trend in the spillovers, just periods when the spillovers increase, stay elevated for a period, and then return to “normal” levels.

Historically, gold and commodities in general have been a major asset class for investment purposes. Gold has often been seen as a safe haven or counter-cyclical investment vehicle. It is well known that gold returns tend to fall when there is a bull trend in the equity market, and vice versa. The lack of any substantial relationship between gold and stocks and gold and bonds raises a question about whether gold price movements can be used as a predictor for stock or bond prices. The extremely low spillover effect from gold to stocks and to bonds, especially with respect to returns, highly restricts the forecasting power of gold with regard to both other asset classes. However, gold’s low and slightly negative correlation with stocks and bonds remains a big positive from the perspective of portfolio construction. Gold remains an important asset class for the portfolio investor but seems to have a life of its own because no significant spillover effects with either the stock or the bond market are apparent. Considering the safe haven attribute of the US dollar in times of economic or political uncertainty, it may be of interest as an area for future research to investigate to what extent the trade-weighted value of the US dollar has any bearing on the spillover effects of stocks and bonds.

References

Aggarwal, R., & Soenen, L. (1988), The nature and efficiency of the gold market. *Journal of Portfolio Management*, *14*, 18-21.

Baur, D. G., & Lucey, B. M. (2009). Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold. Retrieved from http://ssrn.com/abstract=952289

Chua, J., Sick, G., & Woodward, R. (1990). Diversifying with gold stocks. *Financial Analysts Journal*, *46*, 76-79.

Davidson, S., Faff, R., & Hillier, D. (2003). Gold factor exposures in international asset pricing. *International Financial Markets, Institutions and Money*, *13*, 271-289.

Diebold, F. X., & Yilmaz, K. (2009). Measuring financial asset return and volatility spillovers, with application to global equity markets. *The Economic Journal*, *119*, 158-171.

Engle, R. & Russell, J. (1998). Autoregressive conditional duration: A new model for irregularly spaced transaction data. *Econometrica*, *66*, 1127-1162.

Garman, M. B., & Klass, M. J. (1980). On the estimation of security price volatility from historical data. *Journal of Business*, *53*(1), 67-78.

Hasbrouck, J. (1999). Measuring the information content of stock trades. *Journal of Finance, 46*, 179-207.

Jaffe, J. (1989). Gold and gold stocks as investments for institutional portfolios. *Financial Analysts Journal*, *45*, 53-59.

Johnson, R., & Soenen, L. (1997). Gold as an investment asset: Perspectives from different countries. *Journal of Investing*, *6*, 94-99.

Lawrence, C. (2003, March). Why is gold different from other assets? An empirical investigation. London, United Kingdom: World Gold Council.

Merton, R. (1973). An intertemporal capital asset pricing model. *Econometrica*, *41*, 867-887.

Solt, M., & Swanson, P. (1981). On the efficiency of the markets for gold and silver. *Journal of Business, 54*, 453-478.

Tschoegl, A. (1980). Efficiency in the gold market – A note. *Journal of Banking and Finance*, *4*, 371-379.

Footnotes

1 A hedge is defined as a security that is uncorrelated with stocks or bonds on average, whereas a safe haven is a security that is uncorrelated or negatively correlated with stocks and bonds in case of a market crash.

2 It is well known that, more than in weekly or lower frequency data, daily financial data is affected by market microstructure frictions such as infrequent trading. We refer to the seminal papers by Hasbrouck (1991) and Engle and Russell (1998) for the modeling of financial data at the transaction level.

3 Daily data for the S&P 500 Stock Index was downloaded from www.yahoo.com.

4 Daily gold price data are based on AM - PM London gold price fixings until daily data were available from DataStream. Open gold prices were available on 1/5/1979, high and low gold prices were available on 10/6/1989, and closing gold prices were available on 12/30/1977).

5 The formula used to convert the nominal annual return is wntb10=((1+(antb10/100))^(1/52))-1, where wntb10 is the weekly nominal return and antb10 is the annual nominal return. Weekly inflation is assumed to be constant across the month and is calculated as winfl=((1+(minfl/100))^(1/4)) -1.

6 Because the 10-year U.S. Treasury note is not reported as a price, an index series based on the weekly return values was created and then the volatility measure based on the index series created.

7 The probability values of zero indicate that the null hypothesis of normality can be rejected.

8 A more detailed description is contained in Diebold and Yilmaz (2009). We try to make the relationship between the spillover index and the variance decomposition matrix clearer.

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Appendix: Vector Auto Regression Estimates

Estimation of VAR includes weekly real returns of stocks, gold, and bonds (ordered as shown).

	Stock return equation		Gold return equation		Bond return equation	
	Coefficient	*t*-stat	Coefficient	*t*-stat	Coefficient	*t*-stat
Stock return (*t*-1)	-0.0443	-2.0049	0.0563	2.1512	0.0001	0.2518
Stock return (*t*-2)	0.0402	1.8184	0.0086	0.3275	0.0001	0.2282
Gold return (*t*-1)	0.0091	0.4870	0.0367	1.6588	-0.0002	-0.7080
Gold return (*t*-2)	-0.0417	-2.2328	0.0343	1.5507	-0.0004	-1.2005
Bond return (*t*-1)	0.8184	0.6280	-2.8256	-1.8317	0.9445	42.7519
Bond return (*t*-2)	0.8780	0.6739	1.2189	0.7903	-0.0630	-2.8519
Constant	-0.0006	-0.9959	0.0015	2.1326	0.0001	6.0476
R-squared	0.0104		0.0082		0.7928	
Adj. *R*-squared	0.0074		0.0053		0.7921	
Sum sq. resids	1.0726		1.5031		0.0003	
S.E. equation	0.0229		0.0271		0.0004	
F-statistic	3.5609		2.8046		1301.8260	
Log likelihood	4832.6960		4486.9930		13186.9900	
Akaike AIC	-4.7103		-4.3729		-12.8648	
Schwarz SC	-4.6911		-4.3536		-12.8456	
Mean dependent	0.0003		0.0007		0.0005	
S.D. dependent	0.0230		0.0272		0.0009	
Determinant resid covariance (dof adj.)	5.83E-14		Akaike information criterion		-21.9494	
Determinant resid covariance	5.77E-14		Schwarz criterion		-21.8917	
Log likelihood	22508.11					

Note: Sample period for estimation is 1/9/1970 until 4/24/2009 (two observations lost in estimation). Sample includes 2049 observations.

Estimation of VAR includes weekly volatilities of stocks, gold, bonds (ordered as shown).

	Stock return equation		Gold return equation		Bond return equation	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Stock Return (t-1)	0.4509	19.5863	0.0080	0.2963	0.0000	1.6176
Stock Return (t-2)	0.1034	4.6871	0.1109	4.3029	0.0001	5.0777
Gold Return (t-1)	0.0730	3.8704	0.4181	18.9629	0.0000	0.0245
Gold Return (t-2)	-0.0007	-0.0389	0.0922	4.1728	0.0000	0.5302
Bond Return (t-1)	-9.7108	-0.2539	-90.6082	-2.0265	1.2926	58.6900
Bond Return (t-2)	9.8008	0.2559	90.7102	2.0262	-0.2917	-13.2271
Constant	0.0002	5.3357	0.0002	5.4393	0.0000	6.5479
R-squared	0.2882		0.2413		1.0000	
Adj. R-squared	0.2861		0.2391		1.0000	
Sum sq. resids	0.0018		0.0025		0.0000	
S.E. equation	0.0009		0.0011		0.0000	
F-statistic	137.78		108.27		316000000	
Log likelihood	11360.80		11040.82		26645.81	

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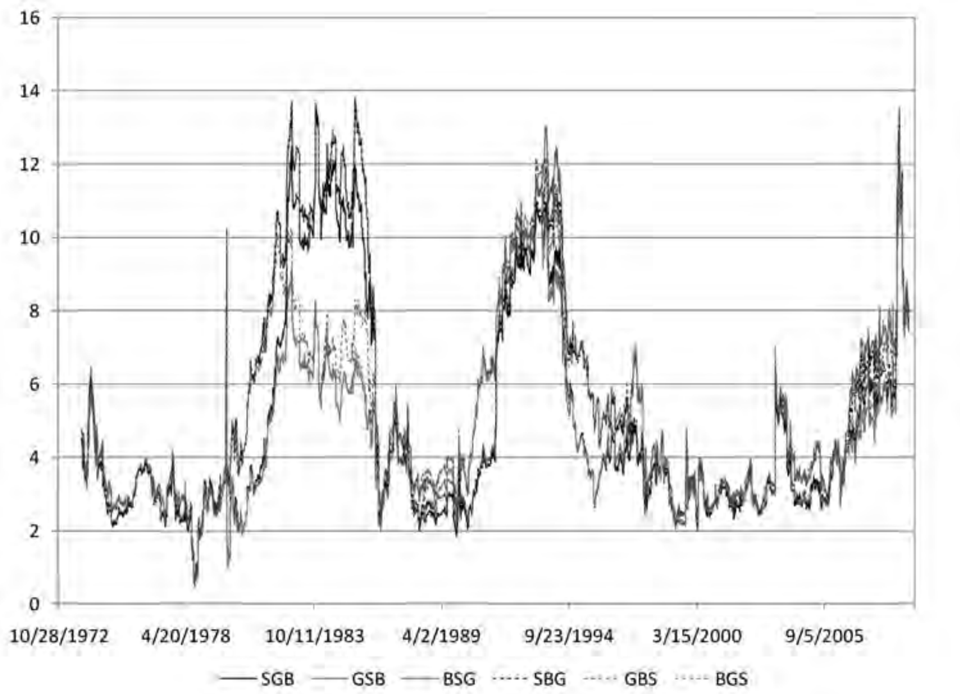
Akaike AIC	-11.0823	-10.7700	-26.0018
Schwarz SC	-11.0631	-10.7507	-25.9826
Mean dependent	0.0006	0.0005	0.0005
S.D. dependent	0.0011	0.0013	0.0005
Determinant resid covariance (dof adj.)	2.97E-25	Akaike information criterion	-47.95297
Determinant resid covariance	2.94E-25	Schwarz criterion	-47.89532
Log likelihood	49148.82		

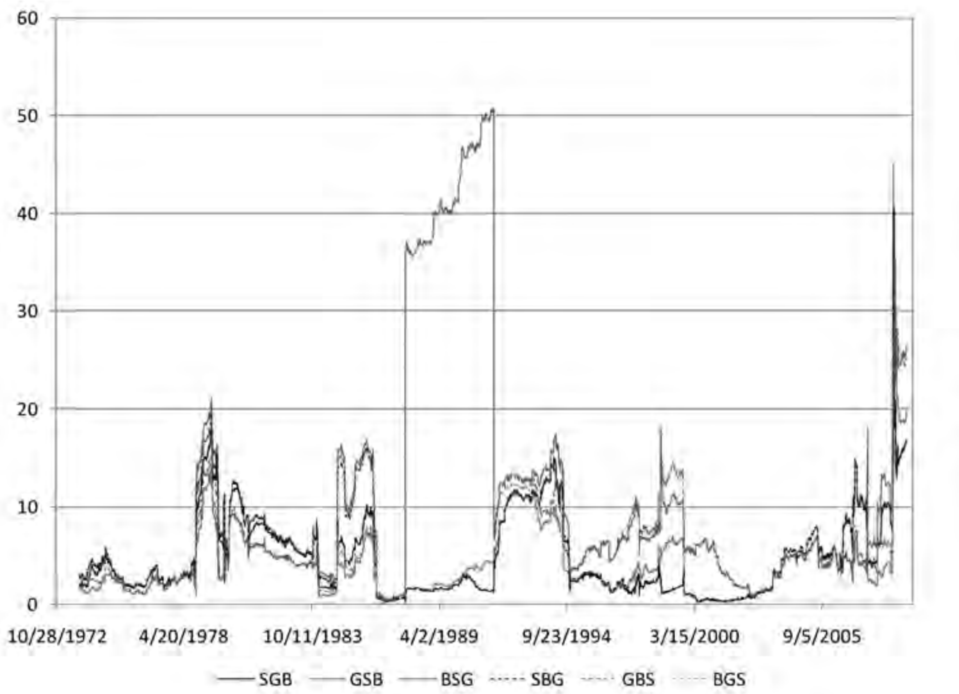
Note: Sample period for estimation is 1/9/1970 until 4/24/2009 (two observations lost in estimation). Sample includes 2049 observations.

10-Week Forecast Horizon, 200-Week Window Estimation, 2 Lags, Various Orderings in VAR, Returns



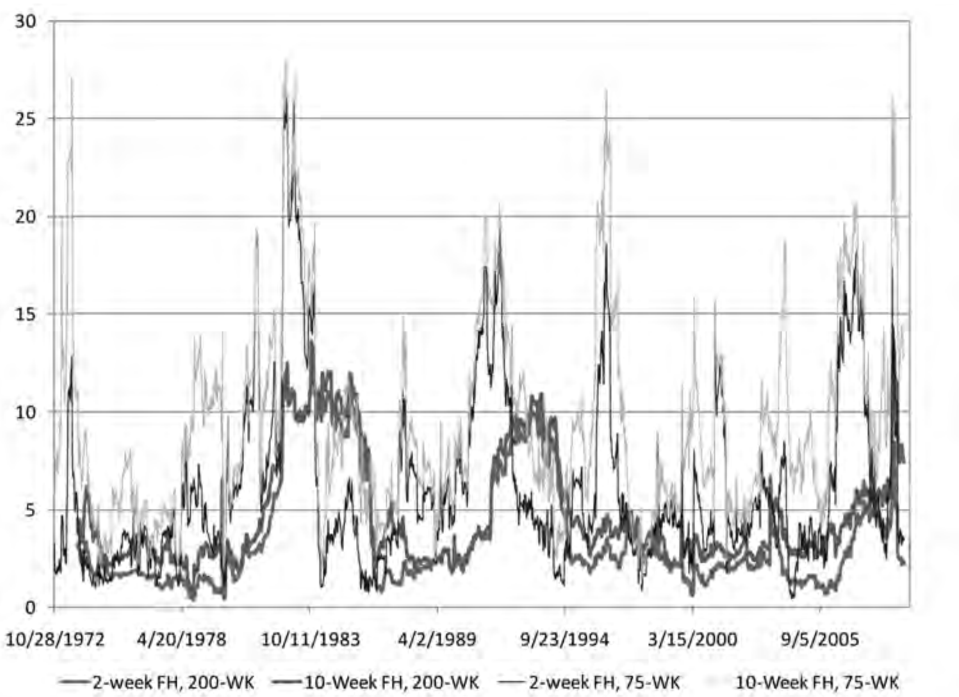
Note: S = Stock, B = Bond, G = Gold

10-Week Forecast Horizons , 200-Week Window Estimation, 2 Lags, Various Orderings in VAR, Volatilities



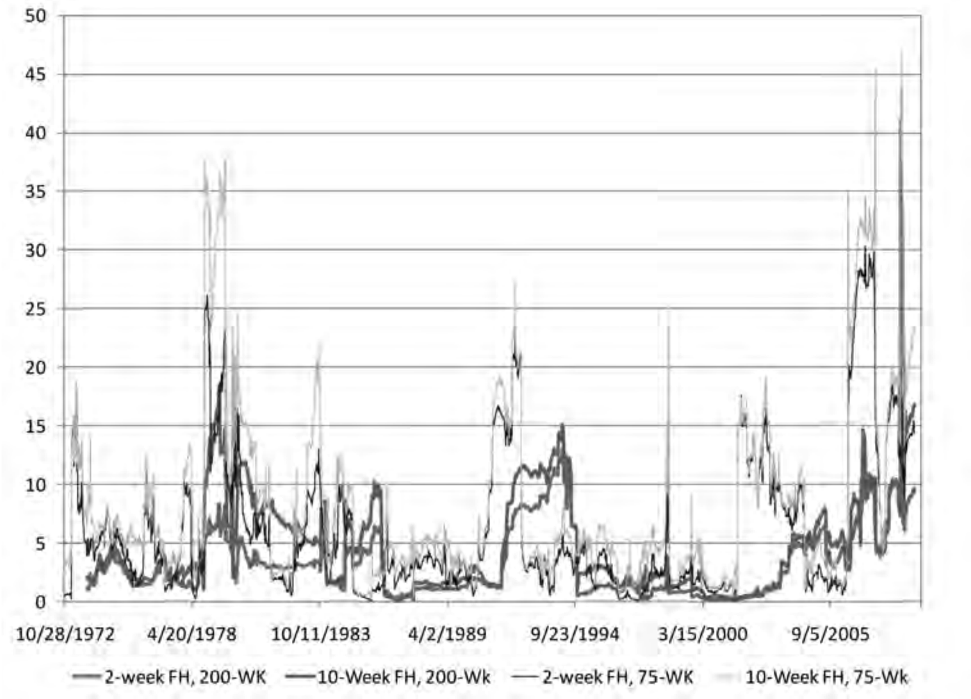
Note: S = Stock, B = Bond, G = Gold

Various Forecast Horizons, Various Window Estimation, 2 Lags, SBG Orderings in VAR, Returns



Note: S = Stock, B = Bond, G = Gold

Various Forecast Horizons, Various Window Estimation, 2 Lags, SBG Orderings in VAR, Volatilities



Note: S = Stock, B = Bond, G = Gold