T-bond yields and equities: A nonlinear relationship

From sports to financial markets, the world is a non-linear place. In football, there's the "red zone" where moving the ball often gets harder for even the most potent offensive threats. For stock indexes and Treasury markets, the impact of moves in one market on the other matters more at different points along the curve.

By Stephan Kudyba

As success in the 20 yards out from the end zone is special for football teams (meaning they don't have to rely on unreliable big play scores), various "zones" mark areas of heightened relationships in intermarket analysis. But while football players admit their red zone largely is mental, in trading, it's clearly quantitative.

Identifying such a tradable zone, though, is not so simple and requires a grasp of market fundamentals. For stock indexes and Treasury bonds, the markets examined here, sustained surges in economic growth and subdued inflation have been the relevant macroeconomic themes since the mid-1990s. These markets have reacted accordingly with relatively low yields and strong returns in equity indexes.

Several factors are at the heart of this environment, among them globalization, depressed commodity prices, low corporate borrowing costs and the decreased uncertainty of future financing that comes with stable interest rates.

The theory Traditional fundamental factors behind equity prices largely have comprised the current and expected value of earnings on a firm-level basis. A natural link to this fundamental has been the cost of capital that firms face. The interest rate situation prevailing since 1995 has been relatively low yields with little volatility. Therefore, corporations have been able to expand operations without having to be overly concerned with uncertain borrowing costs.

A second fundamental factor has been the increased flow of funds into stocks. Proliferation of pension plans, 401(k)s, stock compensation and the flexibility of investing in various market sectors has augmented the percentage of private participation in equities. Because yields on the fixed income side of investments have offered little compared to the double digit returns of equities, investors have incurred little opportunity cost in allocating more of their portfolios to stocks.

This scenario changes on occasion in response to significant increases in Treasury yields. With an increased chance of domestic inflation, the Fed has raised its target for the U.S. Fed funds rate by 50 basis points over the past few months. Long bond yields correspondingly rose to about 6.25%. A major question for traders is, "When do rising interest rates affect the current and future earnings estimates of corporations and at what point do they increase allocation of portfolio investment to a less risky fixed income market relative to equities?"

Empirical analysis Traditional economic theory involves the notion of elasticity coefficients (for example, price elasticity). In other words, how much demand changes given a one percent increase in price. With interest rate changes and stock indexes, the problem is forecasting changes in elasticity — when a one percent increase in bond yields more significantly impacts stock values. A trend in lower interest rates often positively impacts stocks, but at some point the influence dissipates. (For example, a move in bond yields from 5% to 4% may have less effect than a move from 7% to 6%.)

A search for such an area of heightened influence is a search for changes in elasticity, or a non-linear relationship between an independent variable (long bond yields) and a dependent variable (stock indexes). While standard regression can identify non-linear relationships between variables, neural networks are a natural application for such an analysis.

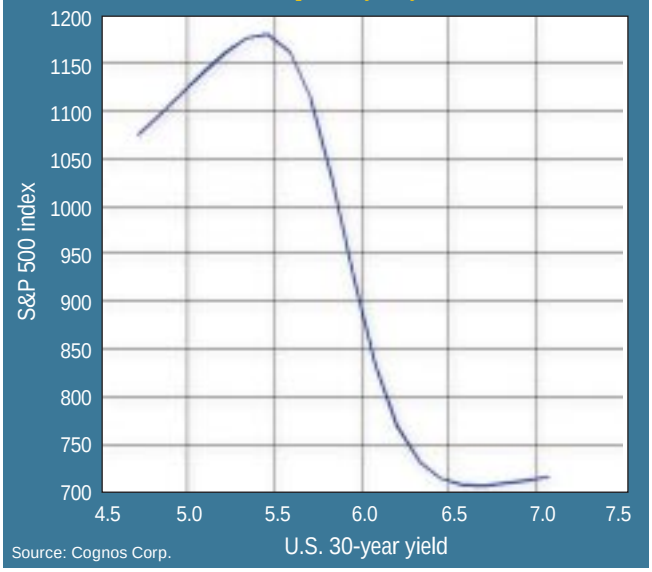
Neural networks are computer algorithms that attempt to mimic the thought process of the human brain. They adjust synapses or connection weights between variables when fed historical data, and attempt to minimize the errors between what occurred in historical data and modeled projections.

To accomplish this, data of two major U.S. stock indexes (the S&P 500 stock index and the Nasdaq 100) were gathered, along with corresponding yields on U.S. 30-year T-bonds. The period of analysis began in 1995 and ended in March of 1999. This segment was chosen to maintain a consistent environment for the relevant macroeconomic factors. That environment includes high growth, low inflation, less volatile and comparatively low interest rates with an increased flow of funds into equities. The neural network analyzed daily closes of the corresponding variables to determine the strength of the cause-and-effect relationship and the characteristic of the rela-

IN THE ZONE

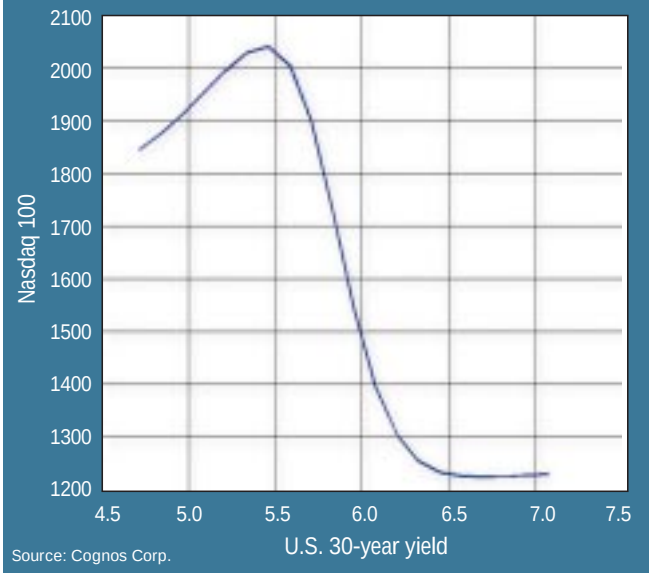
Our neural network identified clear areas of non-linear relationships between our independent and dependent variables.

Non-linear inverse relationship of 30-year yields to S&P 500 index



Source: Cognos Corp.

Non-linear inverse relationship of 30-year yields to Nasdaq 100



Source: Cognos Corp.

tionship (linear or non-linear). They are depicted by the following:

$(NSDQ)_t = a0 + a1(30\text{-year Treasury Yield})_t + e$,
where NSDQ is the daily close of the Nasdaq 100 cash index.

$(S\&P)_t = a0 + a1(30\text{-year Treasury Yield})_t + e$,
where S&P is the daily close of the S&P 500 cash index.

Both stock indexes are dependent variables whose variance is a function of the daily close of the 30-year bond yield. The value *e* is a measure of the residual, or the portion of the variability of stock index prices that was not explained in the model.

The statistical estimates that measure the reliability of the model — that is, how valid long bond yields are in their influence on stock index prices — include an equivalent of an R^2 coefficient and a t-statistic. The R^2 signifies how much of the variation of price movement in stock indexes is explained by moves in T-bond yields. (An R^2 of 1.00 would imply a perfect model. An R^2 of 0.00 would imply an insignificant one.) The t-statistic identifies whether the explanation results from random error or is a reliable estimator. (Any reading more than 2.00 or less than -2.00 is considered statistically significant, with a positive value indicating a direct relationship and a negative value indicating an inverse relationship.) Statistical measures for our model are:

	S&P 500	Nasdaq
R^2 (equiv.)	0.5840	0.5670
Effec. t-stat	-18.90	-22.76
Observations	930	930

In both cases, bond yields explain just over 50% of the variation of the price movement in stock indexes, while effective t-statistics indicate the relationship is reliable and not a function of random error. The effective t-statistic applied in this analysis differs slightly from traditional calculations as it takes into consideration estimation of non-linearity between variables, but its interpretation is generally the same. The negative sign implies an inverse relationship between the independent variable (bond yields) and the dependent (stock indexes), as would be expected.

Finding the zone Having identified an acceptable model, we can expand the analysis to examine the cross-sectional relationship between the independent and dependent variables, making note of non-linearities.

Indeed, non-linear relationships between long bond yields and both stock indexes were unearthed (see "In the zone," left). Yields above the 5.6%-5.7% range begin to affect stock prices inversely, representing a change in elasticity of stock prices to T-bond yields. When analyzing the entire scenario, it appears there exists a range where long-term interest rates significantly impact stocks. Generally, in both cases, a rise in yields from the area beginning at 5.6%-5.7% through 6.4% results in more than a 30% depreciation in the corresponding stock index. At rates above 6.4%, the inverse relationship weakens.

As interest rates rise, capital costs for corporations rise, squeezing earnings estimates. Earnings estimation models of equity and investment analysts may, on the aggregate, produce a glitch in stock valuations and send a signal to investors.

Another related result involves reallocation pressures by institutional investors who, with help from their asset allocation programs, adjust portfolio weightings given changes in macroeconomic indicators and market rates and may cause fund managers to decrease weightings on the relatively riskier assets. To test the validity of this model and underlying theory, it is necessary to check its performance on out-of-sample data.

MARKET MOVES

While our out-of-sample data does not match the range in our in-sample test perfectly, the results still imply a valid model.

Date	S&P 500	Nasdaq	30-year yield
7/14/99	1398	2818	5.91
7/15/99	1409	2839	5.92
7/16/99	1418	2864	5.88
7/19/99	1407	2830	5.90
7/20/99	1377	2732	5.89
7/21/99	1379	2761	5.90
7/22/99	1360	2684	5.97
7/23/99	1356	2692	6.03
7/26/99	1347	2619	6.03
7/27/99	1362	2679	6.01
7/28/99	1365	2705	6.01
7/29/99	1341	2640	6.07
7/30/99	1328	2638	6.10
8/2/99	1328	2623	6.13
8/3/99	1322	2587	6.16
8/4/99	1305	2540	6.11
8/5/99	1313	2565	6.04
8/6/99	1300	2547	6.18
8/9/99	1297	2519	6.23
8/10/99	1281	2490	6.24
8/11/99	1301	2564	6.21

Percent changes

	July 16	Aug. 10	% change
30-year yield	5.88%	6.24%	+6.1%
S&P 500	1418	1281	-10%
Nasdaq	2864	2490	-13%

Model verification Since March 1999, the end of our study, inflation fears have been on the rise as April's consumer price index (CPI) report showed a surprising increase in the rate of inflation. The Federal Reserve reacted to the news and tightened the Fed funds rate by 50 basis points. The long bond correspondingly sold off, and 30-year yields increased some 30-40 basis points, reaching a high of about 6.25% in early August.

"Market moves" (above) illustrates a segment of the period that includes the extremes of T-bond yields and equity indexes. It includes daily closing levels of the corresponding markets.

To test the reliability of the inverse relationship between bond yields and major stock indexes as identified by the model, the percentage change in the corresponding stock index at extreme bond yields was calculated. The closest match to the zone identified in our analysis in this out-of-sample data is the low yield of 5.88% on July 16 and the high yield of 6.24% on Aug. 10.

The inverse relationship prevailed in the out-of-sample data while the strength varied from index to index. The model of the Nasdaq produced more robust results, while the S&P 500 weakened a bit more from the historical relationship. Both cases, however, did result in a weakened scenario from the original model, which implied a roughly 30% decrease in equity prices.

The model reflected a significant zone in bond yields with regard to stock indexes, incorporating levels from 5.7% to about 6.4%. The out-of-sample test, in this case, involved yields at about 5.9% on the low end to roughly 6.25% on the upside. Therefore, this sample did not portray the full parameters as analyzed in the model. Stock index levels may have been higher at a yield of 5.7% and lower at 6.4%, and corresponding results may have more closely supported historical findings.

A possible explanation for the divergence between indexes lies within relative returns prior to the testing procedure. The S&P 500 posted just over a 14% return on the year while the Nasdaq outpaced this with about a 29% return. This indicates a spread adjustment between the two indexes was in order. Another factor is that these equity indexes were establishing historic highs. Rising bond yields not only subdued the upside momentum but helped turn market direction.

Application This analysis provides a powerful tool to S&P 500 and Nasdaq futures traders. Generally, if traders have a grasp of potential movements in interest rates, they can adjust their stock index trading strategies accordingly. Significant moves in 30-year yields above the 5.7% mark could signal traders to relinquish buy and hold perceptions and be wary of potential market pull-backs or consider short-selling. On the other end, once bond yields have breached the 6.40% area, much of the damage to stocks may have been done, meaning long trades may be safe again.

Conversely, an expected drop in yields from 6.15% to 6.02%, for example, may result in impressive returns for equity indexes. This was evident in the recent market reaction from the U.S. unemployment report on Aug. 3. Because some of the data indicated a potentially less inflationary economic picture, bond yields retreated from about 6.14% to 6.02%, and stock indexes across the board appreciated more than 2% on the day.

The theoretical make up of predicting stock prices is complex. Although this analysis provides some insightful conclusions, there remains a host of other fundamental factors that influence the valuation of stock indexes. This also is depicted by the R^2 coefficients of the model, which indicate that 30-year yields explain just over 50% of moves in stocks. As the information economy evolves, accurately identifying essential drivers of equity prices will pose a complex issue. While football players always will have a 20-yard line to reference, the zones for intermarket relationships shift with each season. **FM**

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