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A By-Line Cointegration Analysis of Underwriting Margins and Interest Rates in the Property-Liability Insurance Industry

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ABSTRACT

It is shown in this article that the risk-free interest rate is not cointegrated with the profitability of each line of insurance in the property-liability industry. This counters the accepted aggregate results. Two distinct interpretations of this result are that the risk-free interest rate does not belong in the pricing models of each line or that the premium rates of at least some lines are not being set at competitive levels.

Introduction

The theoretical relationship between interest rates and property-liability insurance underwriting margins is negative. Each of the three most well-known insurance pricing models—the capital asset pricing model, the discounted cash flow model, and the option pricing model—has, as a general result, this negative relationship (Haley, 1993).[1]

Haley (1993) empirically verified that the aggregate underwriting margin for the property-liability insurance industry from 1930 through 1989 was indeed negatively cointegrated with the 90-day Treasury bill yield for new issues (risk-free interest rate).

This article extends the work of Haley by determining whether the cointegrating relationship that was found at the aggregate level also exists at the micro level—that is, for individual lines of insurance coverage. Venezian (1985) reports that individual lines of coverage have profit cycles which differ in length from that of the industry, as well as from each other. Fields and Venezian (1989) show that the relationship between the risk-free interest rate and individual lines of insurance from 1960 through 1985 varies across lines.

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[1] Cummins (1990) gives a very good review of the financial asset pricing models as they apply to insurance pricing.

They caution against treating profit cycles as a singular industry-wide phenomenon, as such treatment would result in aggregation bias.

In general, for an aggregated time series to be integrated of order one—that is, nonstationary and denoted as I(1)—only one component of the aggregation needs to be I(1). It will be shown below that, of the 17 property-liability coverage lines analyzed here, nine are stationary and eight are nonstationary. Three of the nonstationary lines are significantly, negatively cointegrated with the risk-free interest rate, and two lines show weak evidence of a negative cointegrating relationship. The time period of this study, with some variation across lines, is 1949 through 1992. The underwriting profits are for U.S. stock property-liability insurers and were obtained from *Best's Aggregates and Averages* (A. M. Best, 1949–1992); the interest rate data (90-day Treasury bill yield for new issues) were obtained from the *Survey of Current Business* (U.S. Department of Economic Analysis, 1949–1992).

This article first very briefly discusses unit root testing and the results of the tests performed on the individual coverage lines. Second, a cointegration analysis is performed with the nonstationary lines and the risk-free interest rate. The final section presents concluding remarks.

Unit Root Testing

In order to make this work a congruent extension of the aggregate results mentioned above, it must be acknowledged that the aggregate underwriting margin is a weighted average of the individual lines. So the underwriting margin of each line of coverage is not the time series to be evaluated for a unit root; rather, what needs to be tested is a series of weighted values from each line. This is seen in equation (1) as

$$r_u = w_1 r_1 + w_2 r_2 + \ldots + w_i r_i, \tag{1}$$

where r_u = the aggregate underwriting margin,
r_i = the underwriting margin for line i, and
w_i = the industry market share of line i.

The market share, w_i, is computed as earned premiums for line i over total earned premiums for the industry. For the purposes of unit root testing, the $w_i r_i$ time series are used. The series can also be written as

$$w_i r_i = \frac{\text{underwriting profits of line i.}}{\text{total industry earned premiums}} \tag{2}$$

An argument could be made for using written premiums in equation (2) instead of earned premiums. Written premiums, as a cash flow measure, are more immediately sensitive to price changes than earned premiums. Earned premiums, due to the overlapping of policies sold, reflect a weighted average of premium rates for the current year and the preceding year. Earned premiums were chosen because it is the figure reported on the insurer's statement of income, and it was used in the previously cited aggregate calculations. Further, the profits figure used here is before-dividends profits.

The objective of a unit root test is to determine whether a time series is stationary. A strictly stationary series has a fixed mean and a constant variance and is characterized by a tendency to fluctuate about the mean. The widely used and accepted Augmented Dickey-Fuller (ADF) unit root tests are utilized here.[2] The null hypothesis of an ADF test holds that the first-order autocorrelation coefficient is exactly equal to one. If the first differences of a nonstationary series are stationary, the series is said to contain one unit root and, as indicated above, is denoted I(1).

The results of the unit root testing for each coverage line and the risk-free interest rate are presented in Table 1. The Bayesian information criteria were used to determine the order of each equation. The lag lengths were allowed to vary from one through four. The results of the unit root tests partition the property-liability industry into two components—stationary and nonstationary. Figures 1A and 1B display the stationary and nonstationary portions of the industry and illustrate the summed values of the individual r_i^* series.

Determining whether the underwriting margin of a particular coverage line is stationary is of great significance because a stationary variable cannot have a long-term relationship with a nonstationary variable. That is, if a stationary variable is regressed on a nonstationary variable, the coefficient must necessarily equal zero (see Engle and Granger, 1991, chap. 4).

Cointegration Results

The maximum likelihood cointegration estimation procedures of Johansen and Juselius (1990) are employed here. These methods are of a vector autoregression construct, and therefore the estimates are sensitive to the choice of lag length (Hafer and Sheehan, 1991; Boswijk and Franses, 1992). Sims's (1980) modified likelihood ratio test is used for the selection of lag length (see also Sarker, 1993, and Judge et al., 1985, p. 686).[3] The purpose of cointegration estimation is to determine whether a stationary linear combination of two (or more) nonstationary variables exists. Such a situation can be interpreted as a long-term equilibrium relationship.

The results for each nonstationary line of coverage regressed with a constant and the risk-free interest rate are presented in Table 2. The trace and maximal eigenvalue tests of significance are performed on each regression. The dimension of a trace and a maximal eigenvalue test is equal to the number of vari-

[2] For thorough discussions of unit root testing, see Banerjee et al. (1993, chap. 4), Engle and Granger (1991, chap. 1), and Pantula et al. (1994).

[3] The lag selection here refers to the number of ΔX lags in the Johansen and Juselius formulation. Following the Johansen and Juselius notation, then, this lag is (k-1). Also, while only the observations that each model held in common were used for the likelihood ratio tests, the estimates in Table 2 were generated with the complete sample for each line to conserve on the number of observations.

Table 1
Augmented Dickey-Fuller Unit Root Tests
for 17 Lines of Property-Liability Insurance

Stationary Variables	*t-value*	*N*	*Lags*
Glass[a]	-3.416	38	4
Auto Property Damage[b]	-4.124	42	1
Surety[b]	-3.549	42	1
Boiler and Machinery[b]	-3.028	42	1
Fire[c]	-3.692	40	1
Allied Lines[c]	-5.075	38	3
Ocean Marine[c]	-3.125	40	1
Inland Marine[c]	-4.261	40	1
Commercial Multiple Peril[d]	-3.210	35	1

	t-value		*N*		*Lags*	
Nonstationary Variables	*Levels*	*First Differences*	*Levels*	*First Differences*	*Levels*	*First Differences*
Other Liability[b]	-2.343	-5.418	42	41	1	1
Auto Liability[b]	-2.855	-6.281	42	41	1	1
Workers' Compensation[b]	-0.929	-4.698	42	41	1	1
Fidelity[b]	-2.157	-6.538	41	41	2	1
Burglary and Theft[b]	-2.582	-3.330	40	40	3	2
Group Accident and Health[c]	-1.709	-3.515	40	39	1	1
Nongroup Accident and Health[c]	-1.399	-3.570	40	39	1	1
Homeowners[e]	1.864	-0.012	35	34	2	2
(Second Differences)	-5.870		34		1	
Risk-Free Interest Rate[b]	-2.155	-5.252	42	41	1	1

Note: N = sample size. The null hypothesis in the ADF tests is that the variables contain a unit root, while the alternative is that the variables are I(0). If the reported t-value is greater than the critical t-value, the null hypothesis is accepted. For N = 25, the 5 percent and 10 percent critical values of the ADF tests are -3.00 and -2.63, respectively (see Fuller, 1976, p. 373.)

[a] Glass had annual observations for 1949 through 1991.
[b] Annual observations for 1949 through 1992.
[c] Annual observations for 1951 through 1992.
[d] Commercial multiple peril had annual observations for 1956 through 1992.
[e] Homeowners had annual observations for 1955 through 1992.

ables minus the number of cointegrating vectors being tested for, r. Since each of these regressions is bivariate, the gamut of null hypotheses is $r = 0$ and $r \leq 1$. A table of critical values for the trace test and the maximal eigenvalue test, dimensions one through five, can be found in Johansen and Juselius (1990). If the test value is greater than the critical value, the null hypothesis is rejected. The tests of different dimensions for a given equation can be regarded as a series of tests, ordered from the lowest dimension to the highest. For instance, in this study the $r \leq 1$ hypothesis is of dimension one, while the $r = 0$ hypothesis is of dimension two. If $r \leq 1$ is accepted and $r = 0$ is rejected, the regression is regarded as having one cointegrating vector. If both $r \leq 1$ and $r = 0$ are accepted, no cointegrating relationship exists.

Figure 1A

Weighted Underwriting Margin for Stationary Lines of Property-Liability Insurance (Percent)

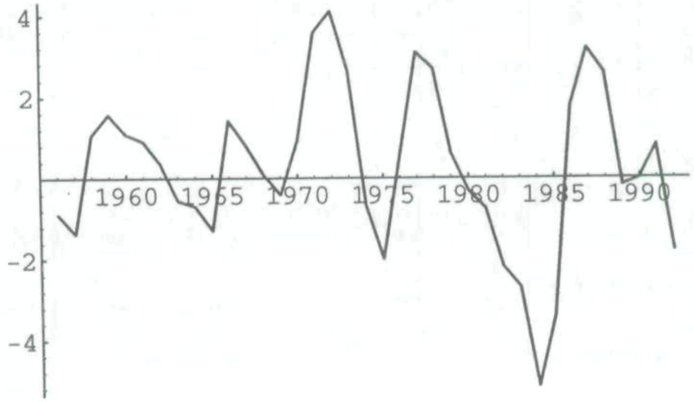

Figure 1B

Weighted Underwriting Margin for Nonstationary Lines of Property-Liability Insurance (Percent)

Note: The time period of Figure 1A is 1956 through 1992 (to include commercial multiple peril), whereas the time period of Figure 1B is 1951 through 1992.Figure 1B does not include homeowners because it is an I(2) series, not I(1).

The results of the trace test and the maximal eigenvalue test indicate that the other liability, auto liability, and group accident and health coverage lines are all negatively cointegrated at at least the 90 percent level of significance. The results for the fidelity profit variable show a negative cointegrating relationship that is significant at the 80 percent level (critical values not reported) for both the trace and the maximal eigenvalue tests, but the coefficient nearly equals zero. The maximal eigenvalue statistic for the workers' compensation variable is significant at slightly less than the 80 percent level. The results for the nongroup accident and health variable are not significant. The burglary and

Table 2
Maximum Likelihood Cointegration Estimation of Individual Property-Liability Insurance Coverage Lines and the Risk-Free Interest Rate

	Other Liability	*Auto Liability*	*Workers' Compensation*	*Fidelity*	*Burglary and Theft*	*Group Accident and Health*	*Nongroup Accident and Health*
Modified Likelihood Ratio Hypothesis							
1 Lag = 2 Lags	12.54	5.21	7.11	3.00	2.15	4.68	3.65
2 Lags = 3 Lags	7.58	—	—	—	—	—	—
Eigenvalues							
	0.427	0.307	0.222	0.248	0.552	0.348	0.188
	0.071	0.111	0.074	0.117	0.092	0.056	0.093
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Significant Eigenvector (βs)							
Dependent Variable	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Constant	-1.420	-0.097	-0.367	-0.057	0.027	-0.349	-0.435
Risk-Free Interest Rate	0.360	0.198	0.211	0.0003	-0.001	0.073	0.056
Weights (αs)							
Dependent Variable	-0.606	-0.833	-0.198	-0.037	-0.027	-0.039	-0.009
Risk-Free Interest Rate	0.150	0.190	-0.108	0.010	0.118	-0.355	-0.472
Trace Test							
$r = 0$	25.85	20.32	13.76	17.20	37.74	19.36	11.33
$r \leq 1$	3.02	4.95	3.23	5.22	4.04	2.29	3.63
Maximal Eigenvalue Test							
$r = 0$	22.83	15.37	10.53	11.98	33.70	17.05	7.70
$r \leq 1$	3.02	4.95	3.23	5.22	4.04	2.29	3.63

Note: The 2.5 percent significance level critical χ^2 value with four degrees of freedom is 11.1433. The time period for the other liability, auto liability, workers' compensation, fidelity, and burglary and theft variables is 1949 through 1992. The time period for the group and nongroup accident and health is 1951 through 1992. The asymptotic 90 and 95 percent trace test criticals, for dimension = two, are 17.957 and 20.168, respectively. The asymptotic 90 and 95 percent criticals, for dimension = one, are 7.563 and 9.094, respectively. The asymptotic 90 and 95 percent criticals for the maximal eigenvalue test, for dimension = two, are 13.781 and 15.752, respectively. The asymptotic 90 and 95 percent criticals for the maximal eigenvalue test, for dimension = one, are 7.563 and 9.094, respectively (see Johansen and Juselius, 1990).

theft profit variable is significantly cointegrated with the interest rate, but the relationship has a (very small) positive coefficient, 0.001, which is contrary to any theoretical notion. The homeowners profit variable was not tested for a cointegrating relationship with the interest rate because the unit root tests concluded it to be integrated of order two, I(2).

The eigenvector (cointegrating relation) reported for each nonstationary variable in Table 2 is the eigenvector that corresponds to the largest eigenvalue. The original eigenvector has been normalized over the dependent variable and, using the other liability profit variable as an example, the cointegrating equation is written as follows:

$$r^{*}_{OL} = 1.42 - 0.360 r_f, \tag{3}$$

where r^{*}_{OL} = the other liability profit variable, and
r_f = the risk-free interest rate.

The dependent variable error-correction weights for each of the coverage lines showing evidence of a cointegrating relationship with the risk-free interest rate are negative as expected. But only the other liability and auto liability lines appear to adjust with any speed whatsoever. The workers' compensation and the group accident and health lines' adjustment coefficients are very close to zero.

The error-correction weights measure the speed at which an out-of-equilibrium position adjusts back toward equilibrium. A negative adjustment factor is expected because, when a particular coverage line is operating above the equilibrium path (as measured by a positive error term from the cointegrating equation), premium rates will be reduced in the market's effort to move toward equilibrium. No interpretation is given to the interest rate error-correction weights, because it is unreasonable to expect interest rates to accommodate the insurance markets.

Conclusion

The general inference to be rendered here about the property-liability insurance market is that each line of coverage does not have a long-term equilibrium relationship with the risk-free interest rate. Interpretation of this result must proceed in one of two directions. First, a normative conclusion can be drawn which says that the pricing models for the stationary lines should not contain the risk-free interest rate. Rather, a more nebulous risk factor is appropriate. A second overarching interpretation regards the pricing models as sound but considers the observed stationary behavior of some lines, and the rejection of the cointegration hypothesis for some of the nonstationary lines, as indication that premium rates are not being set at competitive levels in all lines.

As a caveat, it should be stated that these results are just an incremental step toward a better understanding of the role of interest rates in insurance pricing. Two aspects of this study have potential for future research. First, the insurance industry went through a period of price deregulation in the late 1960s, prior to which investment income was generally ignored in the setting of prices. Therefore, one would not expect to find a strong relationship between interest rates and underwriting margins until about 1970. Close inspection of Figure 1B lends support to this notion. Just prior to 1970, the summed underwriting margins of the nonstationary lines begins a distinct downward trend. On the other hand, the results of Haley (1993), which cover 1930 through 1989, find solid evidence of a cointegrating relationship between the aggregate underwriting margin and the risk-free interest rate, with two-thirds of the data set occurring prior to 1970.[4]

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[4] A post-1970 by-line analysis was also done as part of this study, but the results were not significant, probably due to the relatively short time period and annual observations. Hakkio and Rush (1991) show that, in a cointegration study, the length of the time period is of greater importance than the number of observations.

A second area of further investigation is the stationarity tests. Figures 1A and 1B provide strong visual evidence that the property-liability market can be partitioned into stationary and nonstationary components.[5] But exactly where the partition is to be placed is not easily determined. ADF unit root testing is widely used in the literature, but it is not the only method available. A different method may result in a slightly different classification of lines; for example, the fidelity profit variable may be considered stationary under a different test. A factor influencing these tests is the fact that some of the lines evaluated here (homeowners and commercial multiple peril) were introduced during the time period under consideration. This is probably the reason for the I(2) conclusion on the homeowners variable.

[5] An ADF test was done on the summed variables in Figures 1A and 1B. The summation levels represented in Figure 1A have an ADF t-value of -4.790, indicating stationarity. The summation levels in Figure 1B have an ADF t-value of -1.628, while the first difference has an ADF t-value of -5.127, which together indicate nonstationarity.

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