

Do Property-Casualty Insurance Underwriting Margins Have Unit Roots?

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Revised April 2002

* Contact author. An earlier version of this paper was presented at the 2000 Annual Meeting of the American Risk and Insurance Association in Baltimore.

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Abstract

A growing literature analyzes determinants of insurance prices using time series data on insurer underwriting margins. If the variables analyzed are stationary, conventional regression models may be appropriately used to test hypotheses. Based on pre-tests for a unit root, several studies have instead used cointegration analysis to analyze the long run relationship between purportedly non-stationary underwriting margins and macroeconomic variables. We apply a battery of unit root tests to investigate whether underwriting margins are stationary under different assumptions concerning deterministic components in the data generating process (DGP). When linear and/or quadratic trends are included in the assumed DGPs, the tests reject the null hypothesis of a unit root for loss ratios, expense ratios, combined ratios, and economic loss ratios during 1953-1998 for many of the individual lines examined and for all lines combined. Consistent with prior work on whether macroeconomic variables have unit roots, a simulation of test power for underwriting margins during the sample period demonstrates that non-rejections of the null hypothesis of a unit root could easily reflect low power. The overall findings suggest that conventional regression methods can be used appropriately to analyze underwriting margins after controlling for deterministic influences and transforming any non-stationary regressors.

1. Introduction

A large literature examines time-series variation in property-casualty insurance underwriting margins, such as loss ratios and combined ratios (see Harrington and Niehaus, 2000, for a review). Many studies provide evidence that historical underwriting margins have been cyclical. A smaller but important literature estimates the relationship between underwriting margins, measures of insurance capacity, and macroeconomic variables to test theories of the determinants of insurance prices (e.g., Gron, 1994; Winter, 1994). Econometric modeling of underwriting margins may grow in importance as theoretical work on insurance price fluctuations progresses.

A critical issue in time series regression analyses is whether the underwriting margins and relevant explanatory variables are stationary. If underwriting margins or one or more regressors are non-stationary, then least squares regression results are essentially

meaningless (see, e.g., Enders, 1995, pp. 216 ff. for detailed discussion). An exception to this distressing conclusion arises if the regression disturbance is nonetheless stationary, which requires that the regressand and regressors be cointegrated (integrated of the same order) and implies a linear long run relationship among the variables (Engle and Granger, 1987).¹ Least squares regression thus provides meaningful inferences only when the regressand and regressors are either all stationary or cointegrated. In either case, whether underwriting margins have unit roots is of considerable importance in applied work.

Testing for unit roots, initially developed by Granger and Newbold (1974), exploded following Nelson and Plosser's (1982) evidence that many economic time series had unit roots. Such testing eventually became standard operating procedure in econometric studies using time series data.² Early time series analyses of underwriting results are often silent on stationarity (see, e.g., Venezian, 1985; Cummins and Outreville, 1987; Doherty and Kang, 1988). A few studies analyze first differences in underwriting margins, which is appropriate if margins are difference stationary. Several more recent studies employ cointegration analysis and error correction models to analyze short and long run relationships between underwriting margins, interest rates, and other macroeconomic variables (Haley, 1993, 1995; Grace and Hotchkiss, 1995; Choi and Thistle, 1997).

Haley (1993) reports that property-casualty insurer underwriting profit margins are cointegrated with interest rates with a negative long run relationship. Grace and Hotchkiss (1995) present evidence with quarterly data that combined ratios, the short-

¹ Two variables are integrated of the same order if they must be differenced the same number of times to become stationary.

² Dickey and Fuller (1979, 1981) developed empirical methods to test for unit roots. Engle and Granger (1987) initiated cointegration analysis and error correction models.

term interest rate, the CPI, and real GDP are cointegrated. Choi and Thistle (1997) report that underwriting margins are cointegrated with annual Treasury yields.³ These studies generally fail to reject the null hypothesis that underwriting margins have a unit root using an augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979, 1981), without considering possible trend or mean and trend in the DGP. However, whether underwriting margins (and the other variables analyzed) are non-stationary has not been thoroughly explored.

The ADF test permits several alternative assumptions regarding deterministic components in the DGP for a given series and time period: (1) the DGP includes neither mean nor trend; (2) it includes a mean but no trend; (3) it includes both mean and trend; and (4) it includes linear and quadratic trend. West (1987) suggests that failure to consider trend could be problematic because unit root test power is greatly reduced when trend is incorrectly omitted from the model (also see DeJong, et al., 1992a). Conversely, incorrect inclusion of a deterministic trend also reduces power (Dickey, 1984).

More generally, unit root tests are known to have relatively low power, especially for samples with fewer than 100 observations (DeJong, et al., 1992a; Rudebusch, 1993; Elliot, et al., 1996; Hwang and Schmidt, 1996). Although Nelson and Plosser's (1982) results suggested that many macroeconomic time series had unit roots, subsequent studies often suggest that macroeconomic series are trend stationary, attributing Nelson and Plosser's results to low power tests (e.g., DeJong and Whiteman, 1991; DeJong, et al., 1992a; Rudebusch, 1993; Dieboldt and Senhadji, 1996). DeJong, et al. (1992a) show that tests for unit roots generally will have low power against near unit root alternatives and

³ With the exception of Haley's (1995) subsequent analysis of by-line underwriting results, cointegration analyses of underwriting margins suggest a long run relationship between underwriting margins and

vice versa. Elliott, et al. (1996) and Hwang and Schmidt (1996) show that standard ADF tests tend to have low power compared with tests with asymptotic power functions close to asymptotic power bound. They propose ADF tests based on generalized least squares demeaned and detrended data (GLS-ADF tests). Ayat and Burrige (2000) show that correctly including quadratic trend in the test equation can increase the power of unit root tests. Several sequential tests for unit roots have been proposed when deterministic components of the DGP are unknown (Perron, 1988; Doldado et al., 1990; Enders, 1995, and, using GLS-ADF tests, Ayat and Burrige, 2000), but there is no consensus concerning the most powerful unit root test or the suitability of sequential tests. The choice among different unit root tests remains an important empirical issue with critical implications for appropriate empirical models and estimation procedures.

We apply a battery of tests for unit roots in property-casualty insurance underwriting margins under different assumptions concerning deterministic components in the DGPs for the sample period. Our motivation is three-fold. First, intuition, theory, and stylized facts about soft and hard markets in property-casualty insurance provide relatively little indication that underwriting margins will be non-stationary after allowing for possible trend. They suggest that the effect of shocks will be temporary, which augurs against a unit root. If, for example, underwriting margins are trend stationary – they fluctuate around a deterministic trend – then the impact of shocks will disappear relatively quickly. If, on the other hand, underwriting margins are difference stationary – they have a unit root – then the effect of shocks is permanent.

Second, previous work on property-casualty insurance has not carefully considered the issues of power and inclusion of deterministic components in the DGP when testing

interest rates that is broadly consistent with basic theory and intuition.

for a unit root, especially whether underwriting margins may be trend stationary. Third, whether conventional regression methods can be appropriately used in analyses of underwriting margins is of considerable practical importance in testing hypotheses implied by developing theories on the causes of insurance price volatility.

In contrast with studies of underwriting margin studies that ignore possible deterministic components in the DGPs, we consider DGPs that include mean, linear trend, and/or quadratic trend. As DeJong, et al. (1992a, p. 923) note, a trend in a series “need not literally be part of the data generating process, but may be viewed as a substitute for a complicated and unknown function of population, capital accumulation, technological progress, etc.” Allowing for trends in underwriting margins is sensible because a variety of factors might produce trends in property-casualty underwriting margins during the latter half of the 20th century. Such factors include increased price competition in conjunction with the gradual breakdown of bureau rating systems under prior approval regulation, the long run growth of direct writers with lower underwriting expenses, gradual increases in the length of the claims tail, and changes in technology. At some risk of over-fitting, we consider DGPs with quadratic trend in addition to linear trend models. This choice reflects Ayat and Burrige’s (2000) findings concerning possible power increases if the true DGP includes quadratic trend and the possibility of diminishing trends in underwriting margins over time due, for example, to slower growth of direct writers.⁴

⁴ An alternative approach is to allow for regime shifts in DGP. Following Peron (1989), we applied tests that allowed for discrete regime shifts during the sample period and generally obtained results similar to those reported. Given the lack of an obvious break point or points for regime shifts, allowing for gradually changing trend with a quadratic specification is sensible and perhaps no more likely to result in data snooping bias than the regime shift approach.

We apply the unit root tests to loss ratios, expense ratios, combined ratios, and “economic loss ratios” (see, e.g., Winter, 1994) for nine property-casualty insurance lines and for all lines combined using industry-wide data from *Best’s Aggregates and Averages* for the period 1953-1998. When either linear or quadratic trends are included in the model, the null hypothesis that combined ratios and economic loss ratios have a unit root is rejected for most lines, and, perhaps more important, for all lines combined using both ADF tests and GLS-ADF tests. While tests that allow for linear trend only in the DGPs of conventional loss ratios and expense ratios often fail to reject the null hypothesis of a unit root, allowing for quadratic trend frequently causes rejection of the null hypothesis for those series.

We conduct a Monte Carlo simulation to provide evidence of test power in the specific context of underwriting margins during the sample period. Our goal is to shed additional light on whether the failure to reject the null hypothesis of a unit root for some of the historical series could plausibly reflect low power and on the relative power of possibly misspecified test equations. We first estimate for each data series AR(2) regression models that include mean, linear trend, and quadratic trend for the sample period. We next simulate 1000 samples for each series using the parameter estimates from those regressions and stationary disturbances. We then apply the unit root tests to the simulated series, which are stationary by design with estimated DGPs consistent with the historical data. Our simulations show test power is low for some lines and test equations. It generally is greatest when the ADF or GLS-ADF test includes either linear or quadratic trend, and it generally is negligible when neither mean nor trend are included.

Our overall results suggest that underwriting margins, especially combined ratios and economic loss ratios, generally are stationary around linear or quadratic trends. They provide support for using conventional least squares methods to estimate models of underwriting margins as a function of lagged underwriting margins, relevant deterministic regressors, and other stationary (or trend stationary) variables. They suggest that cointegration analysis may be neither relevant nor necessary. Indeed, our main results imply that combined ratios and economic loss ratios should not be cointegrated with anything.⁵

We emphasize that our findings do not imply that “anything goes” in regression model specification. Appropriate procedure will involve testing regressors for unit roots and will consider possible deterministic components in their DGPs. If underwriting margins are (trend) stationary, the inclusion of any non-stationary regressors would still make least squares regression nonsensical. A possible strategy in that event would be to include relevant deterministic components and transform (e.g., difference) the non-stationary regressors to achieve stationarity, assuming that the transformed regressors would still be consistent with the underlying theory used to motivate testable hypotheses.⁶

Section 2 describes the data and unit root tests. Section 3 reports results of the unit root tests. The power of different unit root tests for stationary series parameterized by the historical data is analyzed in Section 4. Section 5 concludes.

⁵ Note that if interest rates were non-stationary, basic insurance pricing theory implies that the loss ratio, expense ratio, and combined ratio would likely be non-stationary as well. However, Garcia and Perron (1996) and Malliaropoulos (2000) provide evidence that interest rates are trend stationary. We applied ADF and GLS-ADF tests to the nominal 3-month Treasury bill rate during our sample period allowing for quadratic trend. Both tests rejected the null hypothesis of a unit root at the 0.10 level.

2. Data and Methodology

We test the hypothesis of a unit root for loss ratios, expense ratios, combined ratios, and economic loss ratios for nine property-casualty insurance lines and all lines combined using annual industry-wide data during 1953-1998 from *Best's Aggregates and Averages*. The loss ratio is the ratio of losses and loss adjustment expenses incurred in a line to net premiums earned in that line. The expense ratio is the ratio of underwriting expenses to net premiums written. The combined ratio is the sum of the loss ratio and expense ratio.⁷ The economic loss ratio is an estimate of the present discounted value of incurred losses as a fraction of premiums net of expenses. Following Winter (1994), we calculate economic loss ratios as $D \times \text{loss ratio} / (1 - \text{expense ratio})$, where D is a line specific discount factor calculated with 5-year Treasury bond yields and claim payout factors estimated from Schedule P.⁸ Figure 1 plots the all lines expense ratio, loss ratio, combined ratio, and economic loss ratio during the sample period. It suggests an overall downward trend for the expense ratio and upward trends for the other variables.

Table 1 summarizes the individual lines analyzed. We include auto liability, auto physical damage, homeowners, commercial multi-peril, workers' compensation, and

⁶ Enders (1995, pp. 216-221) provides a succinct overview of the implications of non-stationary regressands or regressors for regression results. Chapter 5 of his book includes useful discussion of the short and long run dynamics of the regressand in a valid regression.

⁷ Because the combined ratio is the sum of the loss ratio and expense ratio, testing for a unit root in the combined ratio is equivalent to testing for cointegration of the loss and expense ratio with a restriction on the cointegrating vector. We thank Jan Breuer and an anonymous referee for pointing this out.

⁸ The discount factors used are listed in the Appendix. We use Winter's estimated payout factors for all lines combined. Data to estimate payout factors for individual lines were obtained from Schedule P, Part 3A of the 1990 issue of *Best's Aggregates and Averages*. We average the estimates for accident years 1980-1982. Five-year Treasury bond rates were obtained from the St. Louis Federal Reserve Bank's FRED database.

"other" liability (sometimes called general or miscellaneous liability).⁹ Because *Best's Aggregates and Averages* began reporting separate results for medical malpractice, private passenger auto liability, and private passenger auto physical damage in the 1970s, we created and analyzed three additional series: (1) other liability excluding medical malpractice after 1977, (2) private passenger auto liability including commercial auto liability prior to 1978, and (3) private passenger auto physical damage including commercial auto physical damage prior to 1978.

We apply seven unit root tests: (1) an ADF test with no mean or trend, (2) an ADF test with mean only, (3) an ADF test with mean and trend, (4) a GLS demeaned ADF test, (5) a GLS-ADF test with mean and trend, (6) an ADF test with quadratic trend, and (7) a GLS-ADF test with quadratic trend.¹⁰ Based on preliminary tests and prior evidence on cyclical patterns in underwriting margins, we apply the tests assuming that the underlying DGPs follow an AR(2) process.¹¹

Augmented Dickey-Fuller (ADF) Tests

To motivate the ADF test in the present context, consider the AR(2) process:

$$y_t = \rho_1 y_{t-1} + \rho_2 y_{t-2} + \varepsilon_t, \quad (1)$$

where the disturbance term, ε_t , is white noise, i.e., identically and independently with

⁹ Early editions of *Best's Aggregates and Averages* report underwriting experience for mutual insurers separately from stock insurers. We aggregated mutual and stock insurers' underwriting margins by taking an earned premium weighted-average.

¹⁰ Tests within the Dickey-Fuller framework assume that errors are white noise (Dickey, 1976; Dickey and Fuller, 1979, 1981). Said and Dickey (1984) show that the ADF test can be used when the error process is a moving average. Phillips and Perron (1988) developed modified tests that allow for weak serial dependence among errors. Dufour and King (1991) and DeJong, et al. (1992b) investigate the impact of serial correlation in disturbances on the performance of ADF tests. We applied Phillips-Perron tests to the all lines combined ratio and rejected the null hypothesis of a unit root at the 0.10 level, compared with the 0.05 level for the tests reported below.

mean zero and finite variance ($\varepsilon_t \sim iid(0, \sigma_\varepsilon^2)$). Deducting y_{t-1} from both sides, this process can be rewritten as:

$$\Delta y_t = a_1 y_{t-1} + a_2 \Delta y_{t-1} + \varepsilon_t, \quad (2)$$

with $a_1 = \rho_1 + \rho_2 - 1$ and $a_2 = -\rho_2$.

Stationarity requires $\rho_1 + \rho_2 < 1$ (see Enders, 1995). The ADF test is a test of $H_0: a_1 = 0$ against the alternative $a_1 < 0$. Equation (2) illustrates that one lagged difference in y_t should be included in the ADF test equation for an AR(2) process. Allowing for mean, trend, and quadratic trend in the DGPs gives:

$$\Delta y_t = a_0 + a_1 y_{t-1} + a_2 \Delta y_{t-1} + \varepsilon_t \quad (3)$$

$$\Delta y_t = a_0 + a_1 y_{t-1} + a_2 \Delta y_{t-1} + a_3 t + \varepsilon_t \quad (4)$$

$$\Delta y_t = a_0 + a_1 y_{t-1} + a_2 \Delta y_{t-1} + a_3 t + a_4 t^2 + \varepsilon_t \quad (5)$$

As discussed above and emphasized in the literature on testing for unit roots, including irrelevant deterministic components or excluding relevant components reduces test power.¹²

¹¹ Preliminary tests based on the Schwartz criterion favored the AR(2) specification over AR(1) and AR(3) models. We conducted unit root tests assuming an AR(3) process in preliminary work and obtained similar results to those reported.

¹² We focus on tests of whether $a_1 = 0$. Dickey and Fuller (1981) provide F-statistics for testing the joint hypothesis that $a_0 = a_1 = a_3 = 0$. We tested this joint hypothesis for the underwriting margins for all lines combined. Broadly consistent with the results reported below, the null hypothesis was rejected for the combined ratio and the economic loss ratio but not for the loss ratio and expense ratio. As noted in the introduction, Doldado, et al. (1990) and others suggest sequential procedures to test for unit roots using ADF tests when the form of the DGP is unknown. (Ayat and Burrige (2000) suggest an alternative sequential method based on the GLS-ADF procedure.) Doldado, et al. (also see Enders, pp. 256-258) suggest applying the ADF test to the least restrictive model (i.e., the model with mean and trend) first. If the null hypothesis of a unit root is not rejected, testing proceeds to more restrictive models. They also argue that if the evidence suggests that the correct model includes a mean or trend component, the null hypothesis of a unit root can be tested using the standard normal distribution rather than applying the empirical cumulative distribution for the Dickey-Fuller test. Perron (1988), however, shows that the resulting test is inconsistent (its power does not approach one as the sample size increases). Given the lack of agreement about preferred sequential tests, we simply report results for each test equation. Note,

GLS-ADF Tests

Elliott, et al. (1996) and Hwang and Schmidt (1996) compare the asymptotic power function of the ADF test to that of the upper bound of the limiting power functions for the family of Neyman-Pearson tests. They find that powers of ADF tests are lower than those of the limiting power functions when deterministic components (mean or trend) are included in the DGP. These studies introduce a potentially more powerful unit root test: the “GLS” version of the ADF test.

Two steps are involved in a GLS-ADF test. The first step is to remove deterministic components from the DGP using a GLS regression to estimate the coefficients of the deterministic components. For a DGP with mean, the mean is removed using:

$$y_t^* = y_t - \hat{a}_0, \quad (6)$$

where \hat{a}_0 is the GLS estimated mean of the DGP. When both mean and trend are included in the DGP, they are removed using:

$$y_t^* = y_t - \hat{a}_0 - \hat{a}_3 t. \quad (7)$$

where \hat{a}_0 and \hat{a}_3 are the GLS estimates of the mean and trend coefficients. Similarly, mean, trend, and quadratic trend are removed using:

$$y_t^* = y_t - \hat{a}_0 - \hat{a}_3 t - \hat{a}_4 t^2. \quad (8)$$

The parameters of (6), (7) and (8) are estimated with GLS using weights designed to maximize the value of the power function of a unit root test (see the Appendix). The second step is to conduct an ADF test on the detrended and/or detrended series using the t statistic on the coefficient of y_{t-1}^* in the following ordinary least squares regression:

however, that the null hypothesis of a unit root in underwriting margins is often rejected for the least

$$\Delta y_t^* = a_1 y_{t-1}^* + a_2 \Delta y_{t-1}^* + \varepsilon_t \quad (9)$$

where $a_1 = \rho_1 + \rho_2 - 1$ and $a_2 = -\rho_2$.

3. Test Results

Table 2 reports t-statistics for the coefficients on the lagged underwriting margin from applying ADF and GLS-ADF tests to the loss ratio, expense ratio, combined ratio, and economic loss ratio under alternative assumptions regarding the underlying DGPs.¹³ The sample period is 1955-1998 (two years are lost given inclusion of the lagged margins in the test equations).

Panel 1 shows test statistics for loss ratios. For the test equation without mean or trend (column 1), the null hypothesis of a unit root in the loss ratio cannot be rejected for any line of business. Results when the assumed DGP for loss ratios includes a mean are reported in columns 2 and 3. The null hypothesis again is seldom rejected. The GLS-ADF results are similar to those for the ADF tests. Panel 1, columns (4) and (5) show test results for loss ratio models that include both mean and trend. Although the null hypothesis of a unit root in loss ratios is seldom rejected at the five-percent level, the null hypothesis of a unit root is rejected for all lines combined at the 0.10 level by both the ADF and GLS-ADF tests. It is rejected at either the 0.05 or 0.10 level for four lines using the ADF and ADF-GLS tests.¹⁴ Columns 6 and 7 in Panel 1 show test results for the loss ratio equation that allows for quadratic trend. The null hypothesis is rejected at

restrictive model.

¹³ Critical values were obtained from Fuller (1996).

¹⁴ We also rejected the hypothesis of a unit root for homeowners insurance when a dummy variable was included for 1992 to control the effects of Hurricane Andrew on the loss ratio, although conventional critical values for ADF tests may not be accurate when another regressor is included.

the 0.05 level for the all lines loss ratio with the ADF-GLS test and for six individual lines at the 0.05 or 0.10 level with that test.

Panel 2 of Table 2 reports test statistics for unit roots in expense ratios. The null hypothesis of a unit root generally cannot be rejected unless the test equation includes quadratic trend. When the test equation includes mean and linear trend, the null hypothesis is rejected only for commercial multi-peril insurance. When quadratic trend is included, however, the null hypothesis is rejected at the 0.05 level for all lines combined and for five individual lines. The ADF and GLS-ADF tests yield similar results.

Test results for combined ratios are reported in Panel 3 of Table 2. When a mean component is included in the DGP, the null hypothesis of a unit root is rejected at the 0.05 level for four lines and at the 0.10 level for another three lines and all lines combined. Moreover, when both mean and trend are included, the null hypothesis is rejected at the 0.10 level in all cases and at the 0.05 level for five lines (four lines with the ADF test) and all lines combined.¹⁵ The null hypothesis is rejected for fewer individual lines when quadratic trend is included in the combined ratio test equation. A possible explanation is that any quadratic components in loss ratios and expense ratios are partially offsetting and that inclusion of quadratic trend reduces power when it has little explanatory power.¹⁶ The test results for economic loss ratios (Panel 4) are similar to those for combined ratios.

¹⁵ Again, when a dummy variable was included for year 1992, we rejected the null hypothesis of a unit root in the combined ratio for homeowners insurance.

¹⁶ The possibility that loss and expense ratios could have unit roots but be cointegrated, so that the combined ratio is stationary, is inconsistent with the evidence that loss and expense ratios for many of the series do not have unit roots. That the null hypothesis of a unit root is rejected for the combined ratio and either the loss or expense ratio but not both for a series may not be surprising given possibly low power, sampling error, and the large number of tests conducted. For example, the null is rejected for the AL expense ratio and combined ratio for at least one specification but not for the AL loss ratio. The simulation analysis suggests that power is low for the AL loss ratio (see Table 4).

4. Test Power

This section describes and presents results of simulations to provide evidence of unit root test power for underwriting margins during the sample period. Our goal is to shed additional light on whether the failure to reject the null hypothesis of a unit root for some of the historical series could plausibly reflect low power and on the relative power of possibly misspecified test equations.

We first estimate parameters of a DGP that allows for possible mean, linear trend, and quadratic trend for each data series:

$$y_t = a_0 + \rho_1 y_{t-1} + \rho_2 y_{t-2} + a_3 t + a_4 t^2 + \varepsilon_t. \quad (10)$$

Table 3 shows the results. The estimates of ρ_1 are positive, while the estimates of ρ_2 are negative (with the exception of homeowners). The sum of the estimates is less than one for each series. The estimated coefficients for trend in the loss ratio equations (Panel 1) are positive and significant for five of the 10 series, including all lines combined. The coefficients for the quadratic trend term are negative and not infrequently significant, consistent with a diminishing trend in loss ratios over time. The estimated trend coefficients for expense ratios (Panel 2) are generally negative whereas the estimated coefficients for quadratic trend are positive. Thus, there is some evidence of a diminishing downward trend in expense ratios. The opposite signs compared with the loss ratio equations are not surprising given that equilibrium loss ratios should be negatively related to expense ratios.

The estimated coefficients for linear and quadratic trend for the combined ratios (Panel 3) are insignificant for most lines and all lines combined. However, equations with linear but not quadratic trend (not reported) generally yielded positive and

significant coefficients for trend. The results therefore suggest that any quadratic trends in loss and expense ratios tended to offset and that the inclusion of quadratic trend in the combined ratio equations makes it difficult to distinguish between trend and quadratic trend (t and t^2 are very highly correlated) and plausibly reduces power when quadratic trend is included in the unit root test equations (recall Panel 3 of Table 2). The results of estimating equation (10) with economic loss ratios (Table 3, Panel 4) are similar to those for combined ratios.

We then simulated 1000 samples for each series using:

$$y_t = \hat{y}_t + v_t, \quad (11)$$

where \hat{y}_t is the predicted value from equation (10) and v_t is drawn from a normal distribution with mean zero and standard deviation equal to the estimate of $\hat{\sigma}_\varepsilon$ from equation (10). Forty-four observations are included in each simulated series. The initial two values of the disturbance used to generate the lagged underwriting margins for the first observation (corresponding to 1955) were drawn from a normal distribution with mean equal to the average value of the first five observations in the historical data series and standard deviation given by (see Hamilton, 1994):¹⁷

$$\sigma_u^2 = \frac{\hat{\sigma}_\varepsilon^2}{1 - \rho_1^2 - \rho_2^2 - 2\rho_1^2\rho_2\left(\frac{1}{1 - \rho_2}\right)} \quad (12)$$

Given that the sum of the estimated autocorrelation coefficients for equation (10) was less than 1 for each series and that the simulated disturbances are stationary, each simulated series is stationary with a DGP that reflects the parameter estimates using the

¹⁷ These two initial observations (y_{-2} and y_{-1}) are used to simulate the remaining data during the sample period. They are not included in the unit root tests. The 44-year sample period for the unit root tests corresponds to the number of observations in the historical data.

historical data. We can therefore apply the unit root tests to each series to examine the empirical power of each test to reject the null hypothesis of a unit root when it is false. Note that each test equation except the quadratic is misspecified, with the degree of misspecification depending on the true unknown parameters and sampling error in the estimates of equation (10). The procedure therefore provides evidence of the power of different, potentially misspecified tests to reject the null hypothesis of a unit root for known stationary series with characteristics similar to the historical underwriting margins and the extent to which any of the tests have reasonable power for a given series.¹⁸

Table 4 shows the empirical rejection rates of each test at the 0.05 test size (significance level) for 1,000 samples of each series. ADF tests assuming no mean or trend in the DGP for underwriting margins have little power, which may account for the failure of earlier studies to reject the null hypothesis and therefore assume that underwriting margins have unit roots. Power increases substantially when the model allows for a non-zero mean and increases further when both mean and trend are included. The ADF and GLS-ADF tests have similar power. For the equations that allow for linear but not quadratic trend, test power is relatively high for combined ratios (less so for economic loss ratios), but low for loss ratios and especially expense ratios. When quadratic trend is included, test power is often much higher for loss ratios and especially expense ratios compared with the linear trend equations. Power is low, however, for some lines, regardless of the test equations.

¹⁸ Rudebusch (1993) uses a similar approach to examine the power of unit root tests that are consistent with the assumed DGP. Also see Dieboldt and Senhadji (1996).

5. Conclusions

Our overall results provide evidence that property-casualty underwriting margins are stationary and imply that researchers might fail to reject the null hypothesis of a unit root if they do not allow for deterministic components in the DGP. When mean and trend are included in the assumed DGP, the null hypothesis that combined ratios and economic loss ratios have a unit root during 1953-1998 is rejected for most of the business lines analyzed and for all lines combined using both ADF and GLS-ADF tests. Including quadratic trend in the assumed DGP frequently leads to the rejection of the null hypothesis for loss ratios and expense ratios as well. Our Monte Carlo simulations indicate that test power is relatively low for some lines of business and generally very low when neither mean nor trend are included in the test equation.

Our findings suggest that it is neither necessary nor appropriate in empirical work to assume that underwriting margins are difference stationary or to employ cointegration analysis. They suggest instead that conventional regression methods can be used to estimate econometric models of the determinants of underwriting margins in levels, allowing for possible linear and quadratic trend, and provided that the relevant explanatory variables are stationary (or trend stationary). Appropriate methodology will involve testing regressors for unit roots and will consider possible deterministic components in their DGPs. We emphasize that our findings do not imply that “anything goes” in model specification. Inclusion of non-stationary regressors will produce meaningless results even if underwriting margins are (trend) stationary. If an explanatory variable is not stationary, it may be possible achieve stationarity by differencing without violating the underlying theory used to generate testable hypotheses.

Appendix

Claims Payout Factors. The estimated claims payout factors used to calculate the economic loss ratios are shown below (see Table 1 for line definitions):

<u>Line</u>	<u>Year 1</u>	<u>Year 2</u>	<u>Year 3</u>	<u>Year 4</u>	<u>Year 5</u>	<u>Year 6</u>	<u>Year 7</u>	<u>Year 8</u>
ALL	0.435	0.266	0.107	0.055	0.034	0.034	0.034	0.034
AL	0.255	0.260	0.182	0.130	0.089	0.038	0.029	0.016
PPAL	0.366	0.317	0.148	0.083	0.044	0.023	0.012	0.006
HO	0.695	0.219	0.031	0.021	0.015	0.010	0.006	0.005
CMP	0.408	0.244	0.090	0.081	0.068	0.051	0.034	0.024
WC	0.280	0.283	0.159	0.099	0.065	0.046	0.041	0.028
OL	0.069	0.124	0.162	0.171	0.154	0.136	0.104	0.079
OLMM	0.084	0.139	0.171	0.166	0.145	0.127	0.095	0.074

The factors for all lines combined (ALL) are those reported in Winter (1994). The individual lines' factors are three-year averages of factors estimated for accident years 1980-1982 from Schedule P, Part 3A, as reported in the 1990 issue of *Best's Aggregates and Averages*.

The GLS-ADF Test. Based on Elliott, et al (1996), the GLS estimator for \hat{a}_0 , in equation (8) is obtained by regressing the vector,

$$\left[y_1, y_2 - \rho_0 y_1, \dots, y_T - \rho_0 y_{T-1} \right]' \text{ on the vector, } \left[1, 1 - \rho_0, \dots, 1 - \rho_0 \right]', \text{ where}$$

$\rho_0 = 1 - 7.0 / T$ and T is the number of observations used for the unit root test. The asymptotic power functions under this test are close to upper bound of all possible power functions (the power envelope). Specifically, At this point, the asymptotic power function of the GLS-ADF test is tangent to its power envelope at a power of 50 percent when the size is set at a 5 percent level. King (1988) suggests that a test's power function is close to the power envelope over a considerable range under this setup.

When both mean and trend components are both included in the DGP, $[\hat{a}_0, \hat{a}_3]'$ in equation (9) are estimated by regressing, $[y_1, y_2 - \rho_0 y_1, \dots, y_T - \rho_0 y_{T-1}]'$ on the matrix

$\begin{bmatrix} 1, & 1-\rho_0, & \dots, & 1-\rho_0 \\ 1, & 2-\rho_0, & \dots, & T-(T-1)\rho_0 \end{bmatrix}'$, where ρ_0 equals $1 - 13.5 / T$. When a quadratic trend is

included in the DGP, $[\hat{a}_0, \hat{a}_3, \hat{a}_4]'$ in equation (10) are estimated by regressing,

$[y_1, y_2 - \rho_0 y_1, \dots, y_T - \rho_0 y_{T-1}]'$ on the matrix $\begin{bmatrix} 1, & 1-\rho_0, & \dots, & 1-\rho_0 \\ 1, & 2-\rho_0, & \dots, & T-(T-1)\rho_0 \\ 1, & 4-\rho_0, & \dots, & T^2-(T-1)^2\rho_0 \end{bmatrix}'$, where ρ_0

equals $1 - 18.5 / T$.

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Figure 1
 All lines Loss Ratios, Expense Ratios, Combined Ratios,
 and Economic Loss Ratios (1953-1998)

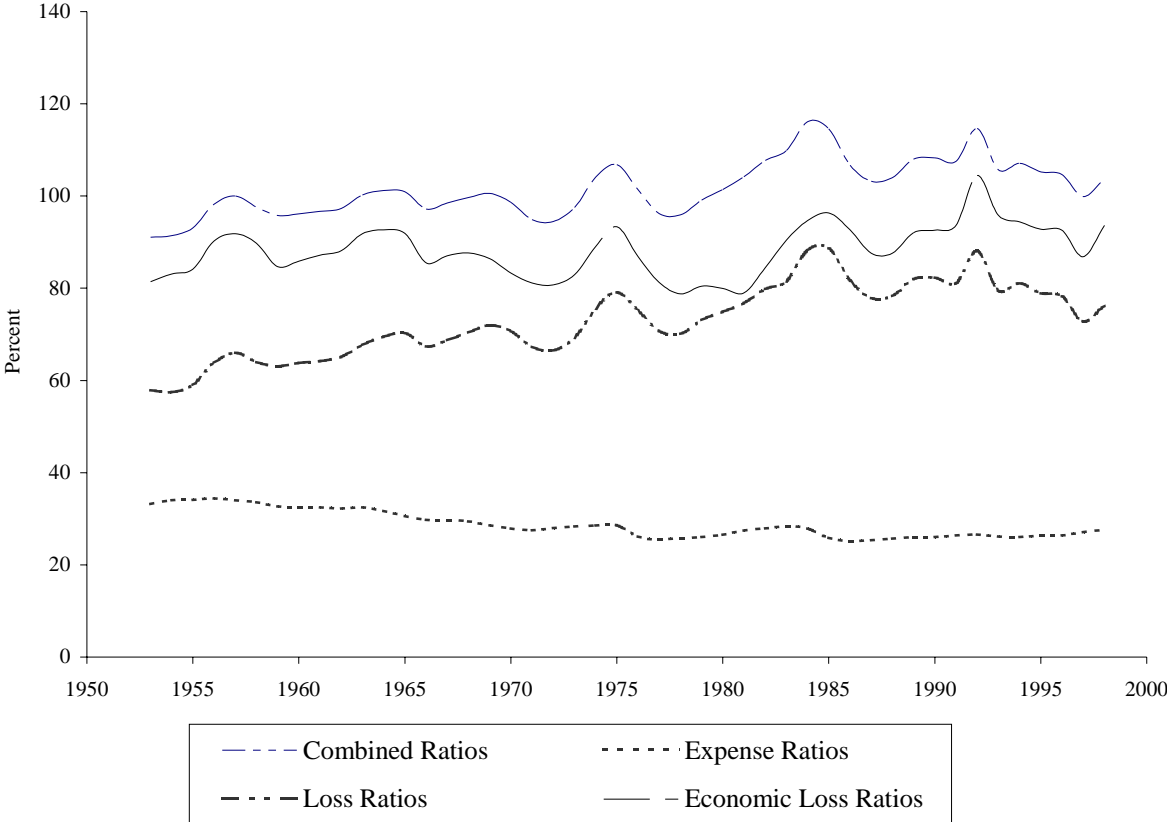


Table 1
Lines of Business Analyzed

Variable	Description	Sample Period	Note
ALL	All lines combined	1953-1998	
AL	Auto liability	1953-1998	
APD	Auto physical damage	1953-1998	
PPAL	Private passenger auto liability	1953-1998	Includes commercial auto liability prior to 1978
PPAPD	Private passenger auto physical damage	1953-1998	Includes commercial auto physical damage prior to 1978
HO	Homeowners	1954-1998	
CMP	Commercial multiple peril	1955-1998	
WC	Workers' compensation	1953-1998	
OL	Other liability	1953-1998	Includes medical malpractice prior to 1978
OLMM	Other liability and medical malpractice	1953-1998	

Table 2
Unit Root Test Statistics for Alternative DGPs

	No Mean or		Mean Only		Mean and Trend		Quadratic Trend	
	Trend							
	ADF	ADF	GLS- ADF	ADF	GLS- ADF	ADF	GLS- ADF	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
<i>Panel 1: Loss Ratios</i>								
ALL	0.24	-2.59	-1.60	-3.19**	-3.25**	-3.66**	-3.87*	
AL	-0.17	-2.36	-1.51	-2.55	-2.54	-3.02	-3.06	
APD	-1.01	-4.26*	-2.89**	-4.15*	-4.09*	-5.74*	-5.89*	
PPAL	0.28	-2.85**	-1.77	-2.91	-3.04	-2.62	-2.72	
PPAPD	0.28	-4.51*	-2.79**	-4.39*	-4.12*	6.29*	-6.47*	
HO	0.11	-2.44	-1.89	-3.30**	-3.38**	-3.49	-3.96*	
CMP	-0.37	-2.50	-2.30	-4.20*	-3.17	-3.93*	-3.89*	
WC	0.13	-2.72**	-2.25	-2.69	-2.52	-3.13	-3.22	
OL	-0.01	-1.91	-1.60	-2.26	-2.58	-3.48	-3.57**	
OLMM	-0.18	-2.84**	-1.73	-3.11	-3.22**	-3.23	-3.55**	
<i>Panel 2: Expense Ratios</i>								
ALL	-1.02	-1.93	-2.29	-1.62	-2.37	-4.61*	-4.49*	
AL	-1.03	-2.34	-2.37	-2.49	-3.16	-5.37*	-5.34*	
APD	-1.79**	-2.23	-2.43	-1.42	-1.66	-3.41	-2.86	
PPAL	-1.42	-2.00	-2.45	-2.44	-2.85	-5.27*	-5.11*	
PPAPD	-1.98*	-1.85	-2.41	-1.23	-1.53	-3.34	-2.64	
HO	-2.72*	-2.30	-3.02*	-0.69	-1.59	-3.37	-2.32	
CMP	-0.38	-3.37*	-3.38*	-3.82*	-4.44*	-3.89*	-4.11*	
WC	0.11	-2.22	-2.25	-1.51	-1.74	-3.27	-3.36	
OL	-0.83	-1.84	-1.92	-2.36	-2.34	-4.32*	-4.25*	
OLMM	-0.75	-2.29	-2.39	-2.53	-1.26	-3.96*	-3.80**	
<i>Panel 3: Combined Ratio</i>								
ALL	0.21	-2.81**	-2.83**	-4.24*	-4.22*	-3.91*	-3.79**	
AL	0.17	-3.27*	-3.30*	-3.38**	-3.51*	-3.36	-3.33	
APD	0.17	-4.19*	-4.30*	-4.36*	-4.47*	-6.02*	-6.02*	
PPAL	0.11	-3.18*	3.21*	-3.05	-3.33**	-3.04	-3.03	
PPAPD	0.12	-4.38*	-4.47*	-4.45*	-4.33*	-6.42*	-6.40*	
HO	0.08	-2.72**	-2.70**	-3.20**	-3.24**	-3.28	-3.42	
CMP	-0.21	-2.71**	-2.78**	-4.19*	-4.01*	-3.94*	-4.01*	
WC	0.23	-2.66**	-2.79**	-3.25**	-3.23**	-3.22	-3.33	
OL	-0.34	-2.39	-1.85	-3.30**	-3.27**	-3.67**	-3.79*	
OLMM	-0.31	-2.41	-1.86	-3.58*	-3.71*	-3.46	-3.54**	
<i>Panel 4: Economic Loss Ratios</i>								
ALL	0.18	-3.02*	-1.62**	-3.40**	-3.57*	-4.08*	-3.80**	
AL	-0.22	-3.10*	-2.93*	-3.06	-3.35**	-4.02*	-3.70**	
PPAL	-0.27	-3.09*	-2.99*	-3.05	-3.39**	-3.56**	-3.52	
HO	0.12	-2.30	-2.44	-2.71	-2.25	-3.10	-3.18	
CMP	-0.39	-2.42	-1.87	-3.34**	-4.21*	-4.43*	-4.62*	
WC	0.27	-3.25*	-3.47*	-3.56*	-3.66*	-3.86*	-4.02*	
OL	-0.08	-2.59**	-2.76**	-3.46**	-3.73*	-3.61**	-3.86*	
OLMM	-0.06	-2.72**	-2.54	-3.58*	-3.50*	-3.66**	-3.88*	

See Table 1 for line descriptions. The estimation period is 1955-1998. Values reported are t-statistics for the lagged underwriting margin. From Fuller (1996), the .05 and .10 critical values (with 50 observations) are: neither mean nor trend, -1.95 and -1.61; mean only, -2.93 and -2.60; linear trend, -3.50 and -3.18; and quadratic trend, -3.85 and -3.54.

* Significant at 0.05 level.

** Significant at 0.10 level.

Table 3
 Estimated Parameters and Residual Standard Deviations for AR(2) Model of
 Underwriting Margins (in percent) with Mean, Linear, and Quadratic Trend:

$$y_t = a_0 + \rho_1 y_{t-1} + \rho_2 y_{t-2} + a_3 t + a_4 t^2 + \varepsilon_t$$

	\hat{a}_0	\hat{a}_3	\hat{a}_4	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\sigma}_\varepsilon$
<i>Panel 1: Loss Ratios</i>						
ALL	30.85*	0.52*	-0.006**	0.79*	-0.32**	3.01
	3.70	2.50	-1.87	5.19	-1.94	
AL	17.81*	0.19	-0.002	1.22*	-0.48*	2.62
	3.17	1.19	-0.81	8.71	-3.25	
APD	43.79*	0.74*	-0.012*	0.77*	-0.53*	3.92
	6.94	2.81	-2.40	5.94	-4.01	
PPAL	15.64*	0.17	-0.002	1.21*	-0.43*	2.76
	2.76	1.03	-0.77	8.36	-2.80	
PPAPD	48.36*	0.91*	-0.014*	0.70*	-0.55**	3.78
	6.47	3.46	-2.94	5.45	-4.27	
HO	40.42*	0.32	0.003	0.25	0.05	9.63
	2.96	0.58	0.28	1.52	0.26	
CMP	28.80*	-0.17	0.011	0.83*	-0.31*	6.52
	2.92	-0.39	1.63	5.60	-2.06	
WC	15.76*	0.24	-0.003	1.31*	-0.55*	3.46
	3.15	1.21	-0.86	9.32	-3.78	
OL	16.98*	1.02*	-0.010	0.97*	-0.37*	7.57
	2.60	2.31	-1.74	6.55	-2.47	
OLMM	13.50*	1.06*	-0.010*	0.99*	-0.34*	7.54
	2.27	2.32	-1.96	6.59	-2.22	
<i>Panel 2: Expense Ratios</i>						
ALL	16.39*	-0.25*	0.004*	1.05*	-0.51*	0.50
	4.54	-4.28	4.10	7.93	-4.19	
AL	15.32*	-0.20*	0.003*	1.17*	-0.66*	0.39
	5.30	-4.74	4.23	9.90	-5.70	
APD	15.05*	-0.23*	0.003*	0.72*	-0.16	0.61
	3.36	-3.31	3.14	4.51	-1.18	
PPAL	17.79*	-0.24*	0.003*	1.06*	-0.62*	0.39
	5.22	-4.99	4.45	8.32	-5.05	
PPAPD	15.90*	-0.26*	0.003*	0.65*	-0.12	0.59
	3.31	-3.46	3.42	3.95	-0.86	
HO	26.17*	-0.43*	0.006*	0.33*	0.05	0.58
	3.69	-3.60	3.62	2.07	0.51	
CMP	15.16*	-0.07	-0.002	1.07*	-0.49*	1.03
	3.71	-1.00	1.07	7.89	-3.70	
WC	4.86*	-0.12*	0.003*	1.47*	-0.66*	0.57
	3.19	-2.69	2.90	12.28	-5.52	
OL	15.17*	-0.32*	0.005*	1.23*	-0.60*	1.24
	4.27	-3.59	3.09	9.64	-4.79	
OLMM	13.25*	-0.31*	0.004*	1.26*	-0.57*	1.05
	3.95	-3.68	3.22	9.72	-4.56	

Table 3 – Continued

	\hat{a}_0	\hat{a}_3	\hat{a}_4	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\sigma}_\varepsilon$
<i>Panel 3: Combined Ratios</i>						
ALL	49.05*	0.21	-0.001	0.86*	-0.37*	3.16
	3.93	1.21	-0.34	5.73	-2.40	
AL	26.92*	0.082	-0.001	1.28*	-0.55	2.63
	3.45	0.59	-0.29	9.49	-3.91	
APD	70.30*	0.38	-0.008**	0.80*	-0.57*	3.89
	6.18	1.70	-1.85	6.23	-4.37	
PPAL	24.88*	0.07	-0.001	1.26*	-0.51*	2.73
	3.12	0.50	-0.32	9.06	-3.48	
PPAPD	76.20*	0.47	-0.010*	0.74*	-0.58*	3.78
	6.57	2.11	-2.11	5.83	-4.52	
HO	69.29*	-0.18	0.010	0.27	0.04	9.70
	3.14	-0.31	0.83	1.63	0.24	
CMP	44.58*	-0.25	0.013	0.90*	-0.37*	6.88
	3.26	-0.55	1.21	6.30	-2.49	
WC	25.64*	0.14	-0.001	1.20*	-0.49*	3.49
	3.28	0.71	-0.19	8.27	-3.24	
OL	36.67*	0.69	-0.007	0.96*	-0.40*	7.93
	3.31	1.62	-0.79	6.51	-2.61	
OLMM	31.32*	0.76**	-0.010	0.99*	-0.37*	7.76
	3.09	1.76	-1.15	6.65	-2.48	
<i>Panel 4: Economic Loss Ratios</i>						
ALL	47.70*	-0.32	0.008*	0.83*	-0.36*	3.56
	4.10	-1.71	2.12	5.56	-2.36	
AL	33.27*	-0.35*	0.007*	1.18*	-0.52*	2.99
	4.00	-2.15	2.14	8.66	-3.75	
PPAL	30.20*	-0.25	0.005	1.20*	-0.50*	3.27
	3.63	-1.49	1.45	8.67	-3.54	
HO	60.62*	-0.70	0.020	0.32*	0.07	13.18
	2.85	-0.87	1.19	1.96	0.43	
CMP	57.28*	-1.83*	0.050*	0.78*	-0.37*	7.25
	3.66	-2.57	2.97	5.59	-2.56	
WC	30.17*	-0.24	0.007	1.20*	-0.59*	4.18
	3.85	-1.12	1.48	8.63	-3.90	
OL	37.36*	-0.09	0.009	0.84*	-0.32*	8.40
	3.18	-0.22	0.90	5.51	-2.02	
OLMM	35.97*	0.01	0.005	0.85*	-0.32*	7.68
	3.26	0.03	0.62	5.58	-2.06	

See Table 1 for line descriptions; t-statistics are reported below the estimated coefficients. The estimation period is 1955-1998.

* Significant at 0.05 level.

** Significant at 0.10 level.

Table 4
Simulated Powers of Unit Root Tests at 0.05 Test Size

	No Mean or Trend		Mean Only		Mean and Trend		Quadratic Trend	
	ADF	ADF	GLS-ADF	ADF	GLS-ADF	ADF	GLS-ADF	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
<i>Panel 1: Loss Ratios</i>								
ALL	0%	10%	0%	66%	62%	74%	77%	
AL	0	35	21	58	57	56	58	
APD	0	88	90	95	94	100	100	
PPAL	0	29	21	32	29	33	34	
PPAPD	0	85	83	97	94	100	100	
HO	0	18	4	74	71	72	75	
CMP	0	17	7	45	51	57	54	
WC	0	34	47	50	59	82	79	
OL	0	12	10	42	33	60	60	
OLMM	0	12	8	33	38	68	67	
<i>Panel 2: Expense Ratios</i>								
ALL	3	3	4	10	3	93	91	
AL	8	5	2	22	12	94	95	
APD	44	0	1	9	5	55	57	
PPAL	2	0	2	23	30	96	98	
PPAPD	37	10	2	2	1	52	55	
HO	100	0	1	37	29	37	45	
CMP	0	30	28	10	12	50	55	
WC	0	54	47	13	1	82	90	
OL	1	22	28	60	61	71	77	
OLMM	0	52	50	63	64	66	78	
<i>Panel 3: Combined Ratios</i>								
ALL	0	45	44	92	93	84	82	
AL	0	52	46	85	70	79	68	
APD	0	100	97	100	100	100	100	
PPAL	0	62	58	54	53	78	70	
PPAPD	0	99	95	100	100	100	100	
HO	0	58	43	68	48	69	66	
CMP	0	13	15	45	45	93	88	
WC	0	38	25	64	62	50	52	
OL	0	33	27	48	31	65	70	
OLMM	0	35	39	45	63	74	74	
<i>Panel 4: Economic Loss Ratios</i>								
ALL	0	64	33	66	42	85	82	
AL	0	99	74	82	68	86	94	
PPAL	0	75	68	52	51	60	62	
HO	0	32	34	47	29	52	52	
CMP	0	45	41	50	42	84	85	
WC	0	65	72	70	74	82	84	
OL	0	42	31	75	76	71	74	
OLMM	0	68	53	68	53	75	68	

See Table 1 for line descriptions. Values shown are percentages of 1000 stationary samples of 44 observations where the null hypothesis of unit root is rejected.