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Shi-Miin Liu, B. Wade Brorsen,
Charles Oellermann, and Paul Farris

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FORECASTING THE NEARBY BASIS OF LIVE BEEF CATTLE

Shi-Miin Liu, B. Wade Brorsen, Charles M. Oellermann, and Paul L. Farris*

Academic researchers have produced numerous articles providing statistical models of cash-futures basis for live cattle (e.g., Ehrich 1972; Ivy 1978; Erickson 1977; Leuthold 1979; Vaik and Leuthold 1988) and for other commodities (e.g., Trapp and Eilrich 1991; Tilley and Campbell 1988). Researchers have generally found it more difficult to model basis as the futures contract approaches maturity. A better understanding of basis as the futures nears the delivery period is needed. This seems especially true in view of the recent concerns about the delivery mechanism and lack of convergence revealed in studies by Peck and Williams (1991) and CBOT (1988), as well as interest in cash settlement (Kahl, et al. 1989; Kimle and Hayenga 1991).

This study seeks to forecast the live cattle basis during the month preceding contract delivery. Factors believed to be associated with changes in the nearby basis are identified, their relations to the basis examined, and forecasts performed based on these relations.

Past studies of the futures-cash price basis for live beef cattle have included several approaches and yielded varying results. Ehrich (1972) examined the basis during the two- or three-month period previous to the futures delivery month. He concluded that inventories play a key role. Ivy (1978) analyzed the basis between slaughter cattle cash prices at Guymon, Oklahoma, and the nearby live cattle futures contract price between 1973 and 1977. He found that the futures minus cash basis was related positively to the expected forward slaughter price and the supply of fed cattle in the Oklahoma region. His basis and price series, expressed in nominal terms, may have been positively associated partly because of an outside influence, inflation. Erickson (1977) developed two monthly models, one each for the nearby and four-month-lagged bases. He considered the effects of slaughter levels, feeder steer prices, one-month lagged cash price, cattle on feed, one-month lagged futures/cash price ratio, and seasonal dummy variables. His models, with price data expressed in nominal terms, provided moderate explanation of basis variability.

Leuthold (1979) employed a multiple regression model to explain variations in basis at various specified months prior to the futures contract delivery date. These were zero-to-one, two-to-three, four-to-five, and six-to-seven months preceding. His model related average monthly basis to monthly beef slaughter, price of corn, cash price of fed cattle, cash price of feeder cattle, cattle on feed in three weight categories, and seasonal dummy variables. For two to seven months prior to futures contract maturity, this model explained 78 to 90 percent of the variation in live cattle basis between 1965 and 1977. However, the model explained only 26 percent of the variation in the months previous to the delivery date. He concluded:

*Shi-Miin Liu is a postdoctoral researcher at Purdue University, B. Wade Brorsen is an associate professor at Oklahoma State University, Charles M. Oellermann is an attorney in Columbus, OH and former graduate student at Purdue University, and Paul L. Farris is professor emeritus at Purdue University.

"The nearby basis is more random and difficult to explain. During delivery, items traded in the cash and futures markets become nearly interchangeable at the delivery point, and the difference between the prices reflects short run conditions including liquidity of the market. ... Thus, it is not surprising that an economic model designed to depict shifting supply conditions cannot explain intertemporal price relationships during or very close to the delivery month." (p. 50)

In a later study, Naik and Leuthold (1988) found considerable variability among correlation coefficients between cash and futures prices of cattle at Omaha during maturity months. Significant factors explaining the basis in the Naik and Leuthold study were lagged values of the basis, per capita income and hog prices. They, along with added nonsignificant variables, accounted for 47% of the variation in the nearby basis.

An alternative to the cattle supply and demand variables and lagged basis used by Naik and Leuthold is considered in this study. We propose to use the spread between the nearby and deferred futures contracts as a measure of expected change in price. The spread variable is preferred over lagged basis because the spread is unaffected by spatial price differences. The proposed model is both simpler and easier to implement; in addition, it is based on readily available futures market prices.

Theory

Because cattle are not storable, a standard model relating basis to storage costs, such as the one used by Tilley and Campbell (1988) is not applicable. A similar model, however, is applicable. Assuming an efficient market with no transaction costs, the current futures price equals the expected cash price at delivery. The basis (futures-cash) for a par delivery point with no transaction costs is then the expected change in cash price. Thus, where there are no transaction costs:

$$(1) \text{ Basis} = E(\Delta \text{ cash price}).$$

Because transaction costs do exist for both buyers and sellers, the basis, due to arbitrage, is restricted to a range of

$$(2) E(\Delta \text{ cash price}) + \text{cost of making delivery} \geq \text{Basis} \geq E(\Delta \text{ cash price}) - \text{cost of accepting delivery}$$

Thus, basis depends on both the expected change in cash price and cost associated with delivery

$$(3) \text{ Basis} = g(E(\Delta \text{ cash price}), \text{delivery costs})$$

Neither variable on the right side of the equation is directly measurable. Therefore, equation (3) must be estimated as

$$(4) \text{ Basis} = f(x, y, \epsilon)$$

where x is a set of variables used to predict $E(\Delta \text{ cash price})$, y is a set of variables used to predict delivery costs, and ϵ is the error term.

delivery costs, and ϵ is a random error variable. Naik and Leuthold's variables are one alternative to use for x . The other alternative considered here is to use the spread between the nearby and deferred futures to predict the expected change in cash price.

Factors Examined in This Study

In this study, the following regression model, which includes factors believed to be associated with the nearby basis, was specified:

$$(5) \quad \text{LGBAS} = f(\text{LGSLB}_{12}, \text{LGCCF}_{12}, \text{LGCHP}_{12}, \text{LGSHG}_{12}, \text{LGCPI}_{12}, \text{LLGSP}, \text{LGOI}_{12})$$

Where:

$\text{LGBAS} = \log(\text{FP}) - \log(\text{CP})$. FP is the average futures price during the month preceding contract maturity. CP is the mean Texas-Oklahoma cash price for average choice steers during that month.

Supply variables

$\text{LGSLB}_{12} = \log(\text{SLB}_1) - \log(\text{SLB}_2)$. SLB is the number of beef slaughtered commercially each month, United States, 1000 head. Subscripts 1 and 2 indicate lagged one and two months, respectively.

$\text{LGCCF}_{12} = \log(\text{CCF}_1) - \log(\text{CCF}_2)$. CCF is the number of cattle and calves on feed, 7 states, 1000 head. Subscripts 1 and 2 are indicators of the number of lagged months.

Demand variables

$\text{LGCHP}_{12} = \log(\text{CHP}_1) - \log(\text{CHP}_2)$. CHP is the monthly farm price of young chickens. Subscripts 1 and 2 are indicators of the number of lagged months.

$\text{LGSHG}_{12} = \log(\text{SHG}_1) - \log(\text{SHG}_2)$. SHG is the number of hogs slaughtered monthly, United States, 1000 head. Subscripts 1 and 2 are indicators of the number of lagged months.

Delivery cost variables

$\text{LGCPI}_{12} = \log(\text{CPI}_1) - \log(\text{CPI}_2)$. CPI is the monthly Consumer Price Index (1964 = 100). Subscripts 1 and 2 are indicators of the number of lagged months.

Futures market variables

$\text{LLGSP} =$ lagged LGSP. The lagged period is two months. $\text{LGSP} = \log(\text{DFP}) - \log(\text{FP})$, where DFP is the average price for the two-month-deferred futures contract. For example, if March is the observation month and April is the

nearby contract, then DFP is the price of the June contract observed in March. LLGSP is, thus, the April minus the preceding February spread observed in the preceding January.¹

$LGOI_{12} = \log(OI_1) - \log(OI_2)$. OI is the average monthly open interest of the nearby live cattle futures contract. Subscripts 1 and 2 are indicators of the number of lagged months.

There are six contract months (February, April, June, August, October, and December) traded for live beef cattle futures. The data for each contract month from 1970 to 1986 (102 observations) are used to build the models, and the data from 1987 to 1991 (30 observations) to perform the out-of-sample forecast. The futures price and open interest series are the daily opening price and open interest of the live cattle contract traded on the Chicago Mercantile Exchange (CME). The opening price was used because the futures market for live cattle opens at 9:05 a.m. and closes at 12:45 p.m. Thus, the opening price of futures contracts appears compatible with the price in the cash market.² Only three daily cash prices per week (Monday, Tuesday, and Wednesday) are included in calculating the monthly average since these are the most active trading days during the week. These series were obtained from the Dunn and Hargitt Commodity Data Bank, Lafayette, Indiana. Monthly data for other variables used in this study were provided by R. M. Leuthold (University of Illinois). They were collected from various publications by Leuthold.

Expected Directions of Influence

The spread variable LLGSP was included in the model specification to reflect the influence of intertemporal expectations in the futures market. According to Tomek and Gray (1970):

"The element of expectations is imparted to the whole temporal constellation of price quotations, and futures prices reflect essentially no prophecy that is not reflected in the cash price and is in that sense already fulfilled." (p. 373)

A lagged two-month-deferred futures price in excess of the lagged nearby futures price (i.e., a large value of LLGSP) means the future cash price would be expected to be above the current cash price, yielding an increased basis. If the lagged deferred contract price is below the lagged nearby futures price, a decreased basis would be expected. Therefore, a positive association between LGBAS and LLGSP is expected.

¹ Lagged one-month spread variable in this case, the June minus the April value observed in the preceding February, is considered to contain less information than the lagged two-month spread variable does because the two futures contracts involved in the calculation of one-month lagged spread variable are more distant to the observed month.

² The close prices of futures contracts were also employed, and the results showed little difference.

The lagged open interest variable can be influential in that increased holdings of futures contracts could be associated with expected lower future supplies, so that a positive change in open interest would be expected to be associated with positive changes in cash prices. Thus, a negative association between LGBAS and $LGOI_{12}$ is expected.

The effects of the beef supply variables might differ, depending on whether they influence future cash prices or more recent cash prices more. If increases in current U.S. beef slaughter were to dampen more recent cash prices more than prices in the future, the basis would widen and a positive association would be observed between changes in lagged beef supplies and the basis. However, if future cash prices were influenced relatively more than more recent cash prices, an increase in supply would narrow the basis and an inverse association would be observed. Cattle and calves on feed would be expected to have a greater influence on future cash prices and thus more cattle and calves on feed would lead to a lower basis.

Other things being equal, one would expect an increase in hog slaughter to dampen more recent cash beef prices and thus widen the basis. As chicken prices move higher, substitution of beef for chicken would be favored and more recent cash beef prices would tend to rise. Therefore, an inverse association between lagged changes in chicken prices and the basis would be expected.

Rising delivery costs associated with inflation would seem to have some influence on decisions to avoid delivery. As equation (2) shows, the effect of increasing delivery costs can be either positive or negative.

The supply and demand variables and the futures market variables are both measures of the expected change in cash price. Non-nested hypothesis tests are used to test the null hypothesis that the futures market variables provide the best prediction, versus the alternative hypothesis that the supply and demand variables provide the best prediction. The non-nested test used is the Wald test. It is the only non-nested test which has small sample properties. Other non-nested tests, such as the J-test (Davidson and Mackinnon 1981), have larger power, but are biased for small samples.

The Wald non-nested test of the null hypothesis that the futures market variables contain all the information in the supply and demand variables corresponds to the joint F-test that all the coefficients for the supply and demand variables in equation (5) are zero. Similarly, the null hypothesis that the supply and demand variables contain all the information in the futures market variables corresponds to the joint F-test that all the coefficients for the futures market variables in equation (5) are zero.

Out-of-Sample Forecast

Theil's (1966, pp. 26-29) inequality coefficient, U_2 , Ashley, Granger, and Schmalensee's (1980) statistical method (hereafter referred to as AGS test), and three market timing tests--enriksson and Merton's (1981), Cumby and Modest's (1987), and modified Cumby and Modest's (Jackson, et al. 1991) tests--are employed to examine the forecasting ability of our basis models. The procedures and characteristics of these tests are presented as follows.

The definition of Theil's inequality coefficient is:

$$U_2 = \frac{\sqrt{\frac{1}{T} \sum_{t=1}^T ((P_t - A_{t-1}) - (A_t - A_{t-1}))^2}}{\sqrt{\frac{1}{T} \sum_{t=1}^T (A_t - A_{t-1})^2}}$$

where P and A represent predictive and actual values, respectively. The possible values of U_2 extends from zero to infinity. If $P_t = A_t$ in all forecast periods, then a perfect model is found and $U_2 = 0$. When a no-change forecast model is used, $P_t = A_{t-1}$ for all periods and $U_2 = 1$. The naive no-change model, which predicts the next period using this period's actual observation, is often employed as a reference to make sure that the other built models perform equally or better than it. In other words, U_2 obtained from the out-of-sample prediction of a useful forecasting model is expected to range within the scope of 0 and 1.

Ashley, et al. developed a significance test to compare models' time series predictive ability by analyzing the mean-squared errors of post-sample forecasts. Suppose there are two forecasting models, I and II. For some time period t , let e_{1t} and e_{2t} be the forecast errors made by models I and II, and MSE , s^2 , and m denote out-of-sample mean-squared error, variance, and mean, respectively. Then,

$$(6) \quad MSE(e_1) - MSE(e_2) = [s^2(e_1) - s^2(e_2)] + [m(e_1)^2 - m(e_2)^2].$$

Both error means need to be positive, otherwise modification is required (i.e., multiply by -1). Let $\Delta_t = e_{1t} - e_{2t}$, and $\Sigma_t = e_{1t} + e_{2t}$, equation (6) can be re-written as follows:

$$(7) \quad MSE(e_1) - MSE(e_2) = [\text{cov}(\Delta, \Sigma)] + [m(e_1)^2 - m(e_2)^2],$$

where cov denotes the sample covariance over the out-of-sample period.

According to equation (7), model II would be concluded to outperform model I if the joint null hypothesis $\text{COV}(\Delta, \Sigma) = 0$ and $\mu(\Delta) = 0$ is rejected and the alternative hypothesis that both quantities are nonnegative and at least one is positive is favored, where COV and μ represent the population covariance and population mean, respectively. This is equivalent to testing the null hypothesis $\alpha = \beta = 0$ against the alternative that both are nonnegative and at least one is positive in the following equation.

$$(8) \quad \Delta_t = \alpha + \beta [\Sigma_t - m(\Sigma_t)] + u_t,$$

where u_t is an error term with mean zero and can be treated as independent of Σ_t . If either of the two least squares estimates for α and β is significantly negative, then models I and II show no significant difference in their forecasting ability. If one estimate is negative but not significant, the other estimate can be tested using a one-tailed t statistic. If both estimates are positive, the null hypothesis that both population values are zero should be tested by an F statistic and a

significance level equal to half that obtained from the tables of the F distribution.

Based on an equilibrium theory developed by Merton (1981), Henriksson and Merton propose a nonparametric statistic to measure models' market direction prediction ability. Assume M_t and Z_t are market direction and forecast direction variables at time period t , respectively. M_t equals 1 if $A_t > A_{t-1}$, and equals 0 otherwise. Z_t is equal to 1 if $P_t > A_{t-1}$ and equal to 0 if $P_t \leq A_{t-1}$. Breen, et al. (1989) show that the estimation of Henriksson and Merton's nonparametric statistic is equivalent to the estimation of β in the following regression:

$$(9) \quad Z_t = \alpha + \beta M_t + u_t$$

where u_t is the error term. If the estimate of β is significantly greater than zero then the market timing ability of the tested model is confirmed.

By relaxing one critical assumption of Merton's theory that the conditional probability of a correct forecast is independent of the magnitude of subsequent realized returns, Cumby and Modest develop the following market timing test:

$$(10) \quad R_t = \alpha + \beta Z_t + u_t$$

where R_t denotes the return for a long position held from $t-1$ to t . The definitions of other symbols are the same as the above. If the return of a portfolio during forecasted up markets is significantly different from the return during forecasted down markets (i.e., $\beta > 0$) then the tested model has the market timing ability. In considering possibly different variances of the returns during predicted up and down markets, a heteroscedasticity-consistent covariance matrix estimator is needed in computing the t -statistics (White 1980). This estimation can be conducted using the software package SHAZAM (White, et al. 1988).

In contrast to the direction tests of Henriksson and Merton's and Cumby and Modest's methods, Jackson, et al. consider the size of forecasted changes and propose the modified Cumby and Modest test as follows:

$$(11) \quad R_t = \alpha + \beta F_t + u_t$$

where F_t is the forecasted return for a long position from period $t-1$ to period t (e.g., $\ln(P_t / A_{t-1})$). The market timing ability of the examined model is indicated by the significantly positive estimate for β . Since the error term, u_t , may also be heteroscedastic, a heteroscedasticity-consistent covariance matrix estimator is used to calculate the t -statistics.

Results

Table 1 shows the average basis by individual contract and for all contracts combined during pre-delivery months, 1970-1991. The averages for the June and August contracts were generally the lowest, the averages for April and December the highest. Considerable variability was apparent for all contracts. The basis was positive on average (implying futures is usually

higher), but was often negative.

Three regression models were employed in analyzing basis variations for all contracts combined (Table 2). Model 1, which includes the futures market variables but not the supply-and-demand variables, shows the high explanatory power of the spread variable. Also significant were the open interest and the delivery cost proxy, CPI. The results suggest that the basis decreases as delivery cost increases. In Model 2, which includes the supply-and-demand variables but not the futures market variables, cattle and calves on feed was the only significant supply variable and the measure of forthcoming supplies was inversely related to the basis. This finding is consistent with an increase in future expected supplies. For the demand side variables, chicken price was significantly associated with the nearby cattle basis while hog slaughtered was not. The signs suggest that both of the demand variables have more effect on prices for immediate delivery than prices for future delivery.

In Model 3, the spread and open interest variables are added to all other variables included in Model 2. The addition of the futures market variables increased the adjusted R^2 from .118 to .639. The spread variable was highly significant in Model 3, and the open interest variable was significant at the 5% level. The addition of the futures market variables also rendered insignificant the supply variable, cattle on feed, which showed the opposite in Model 2, but the demand variable, chicken price, still showed its significance.

From the converse view, the addition of the supply-and-demand variables to Model 1 only increased the adjusted R^2 from .623 to .639. This suggests that the supply-and-demand variables, as a whole, only slightly improved the overall explanatory power of the model.

The Wald non-nested tests reject the null hypothesis that the coefficients of the two futures market variables in Model 3 are zero (F -value = 69.68). The Wald non-nested tests, however, fail to reject the null hypothesis that the coefficients of the four supply and demand variables in Model 3 are zero (F -value = 2.14) at the 5% level. Thus, these results indicate that the two futures market variables contain all the information provided by the supply and demand variables. An additional advantage of the spread and open interest variables is that they are more readily available.

Models 1 and 2 and a no-change model are employed and compared in the out-of-sample forecast for the period 1987-1991. The effect of the lagged basis variable is captured by the no-change model. The observed and predicted log bases from Models 1 and 2 for this period are presented in Table 3. Following the above findings, Model 1 is anticipated to surpass the other two models in the out-of-sample forecast. As judged by the U_2 values obtained, Model 1 ($U_2 = 0.89978$) indeed outperforms both Model 2 ($U_2 = 1.18773$) and the no-change model ($U_2 = 1$). It is no surprise that Model 2 performs worse than the no-change model because the prediction of the no-change model is based on the lagged one-month basis variable.

Table 4 includes the results of AGS tests and the three market timing tests. With respect to AGS test, equations (1), (2), and (3) compare Model 1 and the no-change model, Model 2 and the no-change model, and Models 1 and 2, respectively. In equation (1), the negative estimate for α is not significant, and the one-tailed t test for β shows significance at the 10% level. It means

that Model 1 forecasts better than the solely employed lagged basis variable. Since the estimated coefficient for α is significantly negative in equation (2), Model 2 does not outperform the no-change model in terms of its forecasting ability as indicated by the U_2 coefficient. Because the estimates for both α and β in equation (3) are positive, the F-test was conducted. The result rejects the null hypothesis that forecast errors generated by Models 1 and 2 are the same. In other words, the forecasting performance of Model 1 is better than that of Model 2 according to the AGS test. By contrast, the market timing ability of both Model 1 and Model 2 is confirmed as judged by the significantly positive β estimates in the three market timing tests.³ The forecasting competence of Models 1 and 2 is not distinguishable according to these tests.

Conclusions

The lagged spread between nearby and distant contracts was shown to provide strong explanatory power in regressions of the nearby basis for live cattle. Similar variables may prove useful in studies of basis for other commodities. The results of this analysis indicate that the variables from the futures market (intertemporal spreads and open interest) contain all the information contained in a set of supply and demand variables, and can perform reasonably good forecasting function as judged by Theil's inequality coefficient, the AGS test, and the three market timing tests employed in this study.

³ Since our dependent variable, the basis, is already in logarithmic form, the returns needed in the Cumby and Modest's and modified Cumby and Modest's tests are simply defined as changes of log bases.

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Table 1. Average Nearby Basis and Variability for Individual Live Cattle Contracts, 1970-91.

Contract Month	Number of Observations	Average	Standard Deviation	Range	
				Minimum	Maximum
----dollars per hundred weight----					
February	22	0.258	1.505	-2.350	3.710
April	22	1.027	1.333	-2.100	3.550
June	22	-0.355	2.389	-4.360	5.090
August	22	-0.605	1.953	-4.250	2.800
October	22	0.285	1.576	-2.120	3.580
December	22	0.910	1.724	-2.710	3.700
All	132	0.253	1.846	-4.360	5.090

Table 2. Results of Nearby Cattle Basis (Futures-Cash) Regression Models, All Contracts Combined, 1970-1986.

Explanatory Variables	Model 1	Model 2	Model 3
Coefficients and t values			
Intercept	0.028*** (6.85)	0.012** (2.17)	0.025*** (5.92)
LLGSP	0.706*** (12.59)		0.681*** (11.39)
LGOI ₁₂	-0.024** (-2.56)		-0.021 (-2.24)**
LGCPI ₁₂	-2.099*** (-3.95)	-0.654 (-0.78)	-1.868*** (-3.44)
LGS LB ₁₂		-0.102 (-1.62)	0.034 (0.80)
LGCCF ₁₂		-0.161** (-2.19)	-0.063 (-1.30)
LGCHP ₁₂		-0.142*** (-3.00)	-0.076** (-2.46)
LGS HG ₁₂		0.031 (0.58)	-0.037 (-1.07)
Observations	102	102	102
F Value	55.97***	3.68***	26.33***
Adjusted R ²	0.623	0.118	0.639

*** indicates significance at 1% level
 ** indicates significance at 5% level
 * indicates significance at 10% level

Table 3. Observed and Predicted Log Bases Generated by Models 1 and 2, 1987-1991.

Month/Year	Observed	Predicted (Model 1)	Predicted (Model 2)
1 1987	-0.005432	-0.009894	0.018216
3 1987	0.044159	0.007092	0.036464
5 1987	-0.054710	-0.022864	0.001249
7 1987	-0.066095	-0.037400	0.009075
9 1987	0.014427	-0.005292	0.004934
11 1987	-0.035359	0.023902	0.012593
1 1988	-0.009104	-0.014334	0.018351
3 1988	0.012756	0.022742	0.024155
5 1988	-0.045462	-0.014273	0.002817
7 1988	-0.026216	-0.019623	-0.016781
9 1988	0.003563	0.027135	0.015965
11 1988	-0.005587	0.030114	0.016041
1 1989	-0.012966	0.021403	0.007674
3 1989	-0.013890	0.023133	0.016582
5 1989	-0.059345	-0.020386	0.004636
7 1989	0.000981	-0.010046	0.022485
9 1989	0.033299	0.046660	0.030549
11 1989	-0.006779	0.027544	0.021816
1 1990	-0.013749	0.013606	0.007014
3 1990	-0.026842	-0.005397	0.001818
5 1990	-0.055096	-0.019110	0.023971
7 1990	-0.001193	0.004209	0.017329
9 1990	0.005617	0.013209	0.029516
11 1990	-0.033953	-0.004871	0.010722
1 1991	-0.030063	0.001208	0.010056
3 1991	0.001605	0.005623	0.027798
5 1991	-0.035662	-0.008547	0.003004
7 1991	0.010059	0.008367	0.011432
9 1991	0.038895	0.029324	0.022272
11 1991	0.027979	0.050293	0.008614

Table 4. Results of AGS and Three Market Timing Tests for Out-of-Sample Forecasts^a

A. AGS test [equation (8)]:

(1) Model 1 and the no-change model are compared:

$$\Delta_t = -0.0043 + 0.4815 [\Sigma_t - m(\Sigma_t)] \quad F\text{-value} = 1.46$$

(-0.59) (1.61)

(2) Model 2 and the no-change model are compared:

$$\Delta_t = -0.0129 + 0.0884 [\Sigma_t - m(\Sigma_t)] \quad F\text{-value} = 2.14$$

(-2.00) (0.52)

(3) Models 1 and 2 are compared:

$$\Delta_t = 0.0086 + 0.1005 [\Sigma_t - m(\Sigma_t)] \quad F\text{-value} = 3.45^*$$

(2.37)* (1.13)

B. Henriksson and Merton's test [equation (9)]:

$$(1) \text{ Model 1: } Z_t = 0.6667 + 0.2857 \cdot M_t$$

(6.16)* (2.21)*

$$(2) \text{ Model 2: } Z_t = 0.5556 + 0.4444 \cdot M_t$$

(5.92)* (3.96)*

C. Cumby and Modest's test [equation (10)]:^b

$$(1) \text{ Model 1: } RBAS_t = -0.0185 + 0.0359 \cdot Z_t$$

(-1.57) (2.82)*

$$(2) \text{ Model 2: } RBAS_t = -0.0295 + 0.0485 \cdot Z_t$$

(-4.79)* (6.43)*

D. Modified Cumby and Modest's test [equation (11)]:^c

$$(1) \text{ Model 1: } RBAS_t = -0.0093 + 0.7408 \cdot FBAS_t$$

(-1.38) (4.63)*

$$(2) \text{ Model 2: } RBAS_t = -0.0081 + 0.5442 \cdot FBAS_t$$

(-2.09)* (7.45)*

- a. t-values are in the parentheses, and * denote significance at the 5% level for the two-tail test.
 b. RBAS = LGBAS - lagged LGBAS.
 c. FBAS = forecasted LGBAS - lagged LGBAS.