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A Comparison of Marginal and Average Tobin's Q Ratios

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This study provides the foundation for analysis of average and marginal Tobin's Q ratios. Tobin's argument is based on marginal Q, but most studies use average Q as a proxy, many without mentioning they are using average Q for marginal analysis. Using superior replacement cost data and several parametric and nonparametric tests, we show that (1) average and marginal Q ratios are significantly different, and (2) using an average measure as a decision variable for capital investment leads firms to an incorrect investment decision approximately fifty percent of the time. In other words, the decision-makers of the firm would do as well flipping a coin. This casts doubt on the conclusions of many previous studies which use average Q as a proxy for marginal Q in determining capital investment opportunity.

I. INTRODUCTION

Tobin [21] suggests that the rate of investment is a function of Q, the ratio of the market value of new additional investment goods to their replacement cost. Tobin argues that firms have an incentive to invest

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when the marginal Q ratio is greater than one since capital equipment is worth more than it costs to replace. Firms should suspend investment when Q falls to one. A firm may not actually have positive net present value (NPV) projects, but a high market value is a sign that investors believe there are growth opportunities. Marginal Q may be used to capture the value of exercisable growth options.

Tobin's argument is based on marginal Q, but most studies use average Q as a proxy. Average Q ratios are preferred due to their comparative ease of computation. Average Q is easily observed, since it is the ratio of the market value of existing capital to its replacement cost. Many studies do not even mention they are using average Q for marginal analysis.[1]

Hayashi [7] derives conditions where average and marginal Q are directly related. If the firm is a price-taker with constant returns to scale in both production and installation of assets, then marginal and average Q ratios are equal. If the firm is a price-maker, then the average Q is higher than marginal Q by the monopoly rent. These conditions would be difficult to satisfy in empirical tests. Hayashi [8] also derives a relationship between optimal investment and Q. Most

recent empirical research on Tobin's Q has focused on a simplification of the average Q approximation rather than address the relationship between marginal and average Qs.[2]

Since average Tobin's Q is used so widely and diversely in empirical research, it is important to establish whether average Q is a useful proxy for marginal Q. Examples of the varied uses of Tobin's Q include the relationship between managerial equity ownership and firm value (Morck, Shleifer and Vishny [16] and McConnell and Servaes [15]), cross-sectional differences in investment and diversification decisions (Malkiel, Von Furstenberg and Watson [14] and Jose, Nichols and Stevens [10]), financing and compensation policies (Smith and Watts [20]), the relationship between cash flow and capital spending (Vogt [22] and Chen and Ho [3]), and the relationship between managerial performance and tender offer gains (Lang, Stulz and Walkling [11]).

Howe and Vogt [9] examine the relationship between marginal and average Qs and find a statistically significant relationship exists between their measures of marginal Q and average Q. They conclude that classifying firms according to average Q rather than marginal Q is

likely to result in misclassification. In fact, their results indicate that only slightly more than half of the firms in their sample are correctly classified when average Q is used as a proxy for marginal Q. Blose and Shieh [2] also examine the relationship between average and marginal Q and find them correlated, but that the relationship is "very complicated." They conclude, however, that average Q is an adequate proxy for marginal Q in determining captial investment opportunities.

We also seek to establish whether average Q is a useful proxy for marginal Q. This paper addresses two questions regarding the viability of average Q proxies. The first question utilizes Q as a descriptive statistic for the purpose of empirical research, and the second uses Q as a normative tool for the purpose of practical application. The first question is whether average Qs are unbiased estimates of marginal Qs; i.e. will average Q provide values that are, on average, near the average of marginal Q? The second question is whether average Q can be used as a tool for capital budgeting decisions.

This paper has two main contributions: like Howe and Vogt [9], we provide a way to estimate marginal Q strictly based on Tobin's definition, and we are able to provide an assessment of how well average Qs approximate marginal Qs. In addition, our source of

replacement cost data is superior to that used in most studies which use Tobin's Q. The following sections of this paper discuss the data collection process and the methodology. The results and conclusions follow.

II. DATA

Average Q is usually calculated as the ratio of the aggregate market value of the firm to replacement cost. The aggregate market value of each firm is the sum of the market values of equity and debt. The market value of equity is calculated as the product of the number of shares outstanding and the share price on the last day of the month preceding the capital investment announcement. The choice of that day is arbitrary; the purpose is to avoid including any trades, which incorporate the information in the announcement before the announcement is made. The market value of equity is calculated using the *University of Chicago's Center for Research in Security Prices* (CRSP) database.

The market value of debt is defined as the sum of long term debt, short-term debt, and preferred stock. The value of preferred stock is approximated by preferred dividends divided by the estimated

preferred yield in the relevant year. Long term debt, short-term debt, and preferred dividends are obtained from the *Compustat* database.

Marginal Q is the change in market value of the firm relative to the change in replacement cost. This is calculated as the ratio of the abnormal return due to an investment announcement and the announced percentage change in investment plus one.[3] This calculation is based on Tobin's definition of Q and is superior to average Q: the value of the firm is calculated using current market information rather than historical replacement cost.

Replacement cost is defined as the sum of inventories and property, plant, and equipment. Many studies estimate replacement cost values using Compustat data. We obtain superior replacement cost values from the *FASB Statement 33 Data Bank*.[4] [5] *FASB 33* was issued in 1979 and became voluntary in 1986. The Financial Accounting Standards Board made available this data bank containing the supplementary disclosures of constant dollar and current cost amounts reported by firms in order to encourage research on the effect of changing prices. Companies included in the *Statement 33 Data Bank* have fiscal years that end between December 1979 and January 1984.

FASB 33 is the highest quality replacement cost data available during that time period.

The corporate investment announcements are taken from the *Wall Street Journal* beginning in 1982. There are few corporate investment announcements that are suitable for analysis. Data on replacement cost, investment announcements, market value, and abnormal returns are compiled for 1982 and 1983[6]. The time range is limited by the overlap of the data sources used.

FASB data on 1059 firms is provided in 1982 and 1983. Of these, 311 are deleted from the sample due to missing values, leaving 748 firms with complete replacement cost data for 1982 or 1983. The overlap between the *FASB 33* data, the investment announcement data, and CRSP is 107 firms. Forty-four firms were lost during the abnormal return calculations due to missing values, leaving a sample of 63 firms[7].

III. METHODOLOGY

To address the question of whether average Qs are unbiased estimates of marginal Qs, we perform three tests. The first test is a paired-difference t-test between marginal and average Qs. The second test, the Wilcoxon Signed-Rank test, is the nonparametric analog of the paired-difference t-test. The third test examines the coefficients of the

regression of marginal Q on average Q. These tests will examine whether average Q is an unbiased estimate of marginal Q. The first and third procedures test for unbiasedness in the means, and the second tests for unbiasedness in the slope. If average Q passes the test, i.e. we conclude that average Qs and marginal Qs are equal, then average Q may be used as a proxy for marginal Q. This result would validate the inferences of studies which use average Q as a proxy for marginal Q.

To address the question of whether average Q can be used as a tool for capital budgeting decisions, we construct a table classifying average Qs and marginal Qs by whether they exceed one and perform a Chi-square test of independence on the classifications. Tobin suggests that firms have an incentive to invest when marginal Q exceeds one. If a firm relies on average Q for investment decisions and average Q exceeds one when marginal Q does not, the firm will continue to invest beyond the point where capital equipment is worth more than it costs to replace. If average Q is less than one and marginal Q exceeds one, the firm will not invest when it should. If average Q

and marginal Q are shown to be dependent, average Q may be used for decisions on whether or not to continue investment.

IV. RESULTS

Table 1 shows the estimated average and marginal Q ratios and the announced percentage change in investment by firm. There are 63 observations in the sample. The average of the average Qs is 1.21, and the average of the marginal Qs is 1.05. Figure 1 shows the distribution of both average and marginal Qs in the sample. It is visually evident that marginal and average Qs are not distributed similarly in this sample.

Table 1

Estimated Tobin's Q Ratios and Announcements by Firm

Average Q is calculated as the ratio of the market value of the firm to replacement cost. Marginal Q is the ratio of the abnormal return due to an investment announcement and the announced percentage change in investment plus one.

Company	Estimated Average Q	Estimated Marginal Q	Announces % Change in Investment
Abbot Laboratories	2.33	1.09	20.0
American Hospital Supply	1.67	1.04	20.0
American Motors Corp	1.22	1.79	-25.4
Anheuser-Busch Cos Inc	1.41	.84	19.0
Armco Inc	.78	.68	-24.0
Bethlehem Steel Corp	1.05	.97	-30.9
CPC International Inc	1.23	1.04	50.0
Carlisle Cos Inc	1.65	1.46	16.0
Caterpillar Inc	1.01	.98	-12.0
Celanese Corp	.88	.81	-31.3
Chromalloy American	.87	.91	-50.0
Chrysler Corp	1.33	1.23	23.0*
Cincinnati Milacron Inc	1.37	.79	12.0
Coastal Corp	1.04	.97	-68.0
Columbia Gas System	.96	1.06	-10.0
Connecticut Natural Gas	1.03	.45	15.7
Consolidated Natural Gas	.94	1.82	9.7
Crown Zellerbach	.95	1.65	-5.0
Cummings Engine	1.20	.99	-44.7
Dow Chemical	1.00	.10	-36.0
Eaton Corp	1.06	1.30	-12.0
Emerson Electric Co	1.80	.95	-18.0
Ex-Cell-O Corp	.95	.88	-3.0
Federal-Mogul Corp	1.20	.96	-28.0
Fort Howard Corp	2.29	1.53	-13.0
General Mills Inc	1.50	.78	20.0
Goodrich (B.F.) Co	.84	1.22	-19.0
Goodyear Tire & Rubber	1.03	1.07	32.5
Halliburton Co	1.12	.99	-22.7

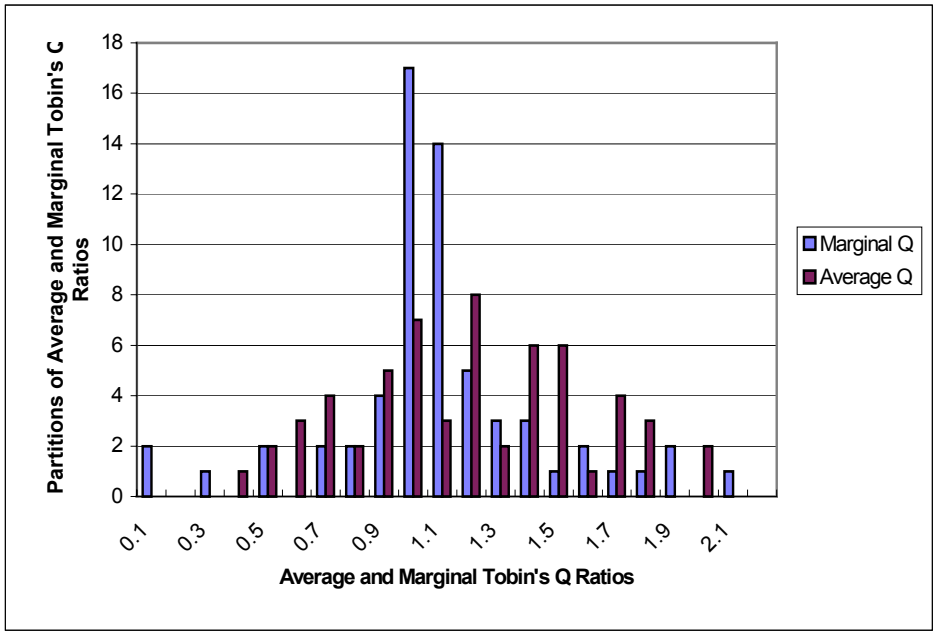
Heinz (H.J.) Co	1.54	.94	15.0

Table 1 (Continued)

Hercules Inc	1.28	.29	-7.5
Idaho Power	.99	.10	-73.0*
Jewel Cos Inc	1.01	1.18	10.0*
K Mart Corp	1.09	1.07	45.0
Kimberly-Clark Corp	1.09	.98	-12.0
Lubrizol Corp	1.42	1.16	-26.0
Mobil Corp	.88	.48	11.0
Montana Power Co	.98	1.02	29.0
Murphy Oil Corp	1.03	.65	8.0
Nabisco Brands Inc	1.20	1.06	9.0
National Semiconductor	1.69	1.88	-5.0
Niagra Mohawk Power	.95	1.10	17.4
Nicor Inc	.94	.99	-35.0
Olin Corp	.94	.94	14.0
Payless Cashways	2.51	1.11	45.0
Pennzoil	1.19	1.59	-10.0
Phelps Dodge Corp	.82	.98	-22.0
Potlach Corp	1.02	1.32	-27.0
Robins (A.H.) Co	1.24	.89	-29.0
Smith International Inc	.98	1.14	-20.0
S. Indiana Gas & Elec	1.00	1.05	88.0
Southwest Forest Ind.	.92	1.11	75.0
Standard Oil Co	1.10	1.01	-13.0
Texas Instruments Inc	1.69	1.35	11.0
Timken Co	.79	1.10	-17.0
Transco Energy Co	1.02	.91	-20.0
Union Camp Corp	1.34	.99	85.0
Union Carbide Corp	.86	1.07	-23.3
Union Pacific Corp	1.15	.92	-15.0
U S Shoe Corp	1.44	1.08	47.0
Upjohn Co	1.21	1.34	-18.2
Westinghouse Electric	1.03	.98	33.0
Weyerhaeuser Co	1.26	1.03	-35.0

* multi-year investment announcement

Figure 1. Distribution of Average and Marginal Tobin's Q Ratios

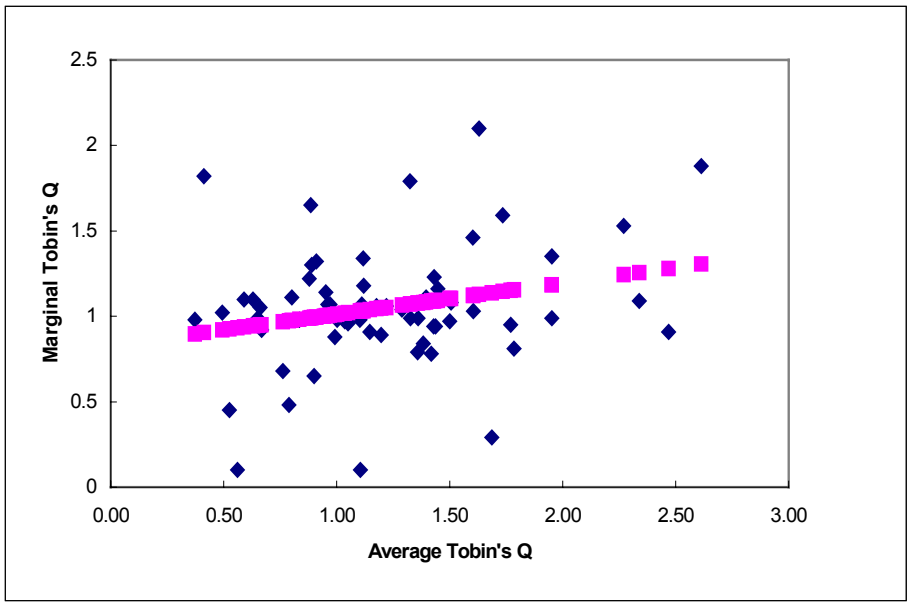


The first test of whether average Qs are unbiased estimates of marginal Qs is the paired-difference t-test between marginal and average Qs. The hypothesis that average Q and marginal Q are equal is rejected with a p-value of 0.02. The result of the equivalent

nonparametric test, the Wilcoxon Signed-Rank test, is consistent. This test also indicates that average Q is not equal to marginal Q.

Marginal Q is then regressed on average Q; the joint null hypothesis of this test is that the intercept is zero and the slope is one. If the null is not rejected, we may conclude that average Q is an unbiased estimate of marginal Q. This regression yields an intercept of 0.83 and a slope of 0.18 (the regression plot is shown in Figure 2). A t-test on the slope shows that the slope is significantly different from one, which indicates that average Q is not an unbiased estimate of marginal Q. In addition, the explanatory power of the regression is very low. The R^2 is 0.06, which indicates that average Q is only explaining 6% of the variation in marginal Q. The results of these three tests suggest that average Qs are not unbiased estimates of marginal Qs, which casts doubt on the inferences of studies using average Q.[8]

Figure 2. Regression Plot of Marginal Q on Average Q



The Chi-square test of independence is used to address the question of whether average Q can be used as a decision-making tool to decide whether to continue investment. Taking the customary $Q \geq 1$ as the cut-off point (NPV ≥ 0), Table 2 shows the extent of agreement between marginal and average Qs when categorized by whether they exceed one, the cut-off for investment decisions. Average Qs yield the correct investment decision, i.e. agree with marginal Q, in 48% of the

cases. In particular, reliance on average Q will lead to over-investment in 30% of the cases and under-investment in 22% of the cases. The null hypothesis of the Chi-square test of independence, that average Qs and marginal Qs are independent, is not rejected; the p-value is 0.64. The result of this test suggests that average Q is not a reliable predictor of whether marginal Q exceeds one and therefore is not a useful proxy. One could do just as well flipping a coin.

Table 2

Classifications of Marginal and Average Tobin's Qs

Marginal and average Qs in the sample are grouped by whether they exceed one.

	Marginal Q greater than one	Marginal Q less than or equal to one
Average Q greater than one	23	20
Average Q less than or equal to one	10	10

Since the average Qs perform so poorly, we recalculate average Qs using replacement cost values from the *Compustat* database. This source yields similar average Qs. The average of the average Qs using *Compustat* data is 1.19. Appendix B shows average Qs calculated using both *FASB* and *Compustat* data. A paired-difference t-test between average Qs based on *FASB* data and average Qs based on *Compustat* data indicates that they are not significantly different.

The results of the parametric and nonparametric tests are similar using average Qs based on *Compustat* data. The regression of marginal Q on average Q yields an intercept of 0.72 and a slope of 0.28. The R^2 is only 0.08, which indicates that average Q is only explaining 8% of the variation in marginal Q. Both the paired-difference t-test and the Wilcoxon Signed-Rank test between marginal and average Q indicate that average Q is not equal to marginal Q. Classification of average and marginal Qs by whether they exceed one suggests that the correct investment decision will be reached only 52% of the time when average Qs are used rather than marginal Qs. The firm will over-invest 32% of the time, and under-invest 16% of the time. The Chi-square test of independence indicates that marginal Q and average Q are

independent. This test fails to reject the null hypothesis of independence with a p-value of 0.79.

Thus, using another source of replacement cost data for average Qs does not improve the performance of average Qs.

V. CONCLUSIONS

This study provides a way to estimate marginal Q strictly based on Tobin's definition and provides an assessment of how well average Qs approximate marginal Qs. We conclude that, on average, the marginal and average Tobin's Q ratios differ for firms in the sample. Parametric and nonparametric tests using superior replacement cost data indicate that average Qs are not unbiased estimates of marginal Qs and that average Qs are not useful for estimating whether marginal Qs exceed one.

These results cast doubt on the results of the many studies which use average Q as a proxy for marginal Q, since a firm's incentive to invest may not be accurately reflected by average Q. Average Qs do contain information regarding investment opportunities; the usefulness may depend on the application.

NOTES

1. Exceptions to this oversight include Abel [1], Chirinko [4,5], Schankerman and Nadiri [19], Osterberg [17], and Yoon [23].
2. Examples include Perfect and Wiles [18], Chung and Pruitt [6], and Lewellen and Badrinath [12].
3. Appendix A provides a detailed explanation of the calculation of marginal Q.
4. There is a sample bias towards large firms, since only larger firms are required by *FASB 33* to report replacement cost data. This should only bias the results if large firms are more (or less) likely to have profitable investment opportunities.
5. Replacement costs calculated using the *Compustat* data base yield similar average Qs. Appendix B shows average Qs calculated using both *FASB* and *Compustat* data.
6. If 1982 and 1983 are unusual for any of the data items, the conclusions of this study may not be generalizable. Also, if firms tend to announce only limited types of announcements such as good news or bad news, the results would be biased.

7. Please see Appendix A for a discussion of abnormal return calculations.
8. Like Blose and Shieh [2], we also examine quadratic, exponential, and log regressions of marginal Q on average Q. There is no theoretical support for these relationships and the results are even worse than those for the linear model.

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Appendix A

Calculation of Marginal Q

Marginal Q is calculated as the change in market value over the change in capital investment. This is estimated by one plus the ratio of the cumulative abnormal return to the percentage change in investment. Abnormal returns are estimated by a market model using daily stock returns. The three-day announcement period contains the day before, the day of, and the day after the announcement of the capital investment. A three-day standardized abnormal return is used rather than a one-day return since dissemination of the announcement may extend over three days. The estimation period is calculated from days -231 to -30, where day 0 is the day of the investment announcement in the *Wall Street Journal*. The market model parameters are estimated as:

$$R_{it} = a_i + b_i R_{mt}, \qquad (1)$$

where R_{it} is the return on security i on day t, R_{mt} is the return on the value-weighted market index on day t, and a_i and b_i are the estimated intercept and slope for security i. The abnormal returns are calculated as:

$$AR_{it} = R_{it} - (a_i + b_i R_{mt}), \quad (2)$$

where AR_{it} is the abnormal return on day t for security i. If two or more consecutive returns are missing, the missing days are deleted from the estimation period. If only one return is missing, a compounded return is calculated over the two days. The average abnormal return for a given day t, $\overline{AR_t}$, is the equally-weighted average of the individual securities' abnormal returns,

$$\overline{AR}_t = \frac{1}{N}\sum_{i=1}^{N} AR_{it}, \quad (3)$$

where N is the number of securities. A cumulative average abnormal return, CAR_{t_1, t_2}, is the sum of average abnormal returns over days t_1 through t_2, t_1

$$CAR_{t_1, t_2} = \frac{1}{N}\sum_{i=1}^{N} \sum_{t=t_{1i}}^{t_{2i}} AR_{it}, \quad (4)$$

where t_{1i} and t_{2i} are trading days in relation to the investment announcement date.

The estimation procedure assumes that the announced investments have the same risk as the firm and that undertaking the

project will not change the capital structure of the firm. It is also assumed that the market prices new projects correctly.

Appendix B

Alternative calculations for Average Tobin's Q

Average Q is calculated as the ratio of the market value of the firm to replacement cost. *FASB* average Qs use *FASB 33* data for replacement cost, Compustat average Qs use *Compustat* data.

Company	Estimated average Q using FASB data	Estimated average Q using compustat data
Abbot Laboratories	2.05	2.04
American Hospital Supply	2.10	2.18
American Motors Corp	.28	.25
Anheuser-Busch Cos Inc	.45	.45
Armco Inc	.28	.29
Bethlehem Steel Corp	.14	.12
CPC International Inc	.78	.74
Carlisle Cos Inc	.85	.88
Caterpillar Inc	.45	.53
Celanese Corp	.25	.17
Chromalloy American Corp	.32	.25
Chrysler Corp	.52	.48
Cincinnati Milacron Inc	1.04	1.05
Coastal Corp	.15	.15
Columbia Gas System	.22	.18
Connecticut Natural Gas Corp	.14	.26
Consolidated Natural Gas Co	.12	.25
Crown Zellerbach	.24	.25
Cummings Engine	.47	.41
Dow Chemical	.37	.34
Eaton Corp	.38	.47
Emerson Electric Co	1.41	1.43
Ex-Cell-O Corp	.72	.67
Federal-Mogul Corp	.42	.49
Fort Howard Corp	.48	1.49
General Mills Inc	.84	.90
Goodrich (B.F.) Co	.14	.14
Goodyear Tire and Rubber Co	.36	.34
Halliburton Co	.86	.71
Heinz (H.J.) Co	.77	.84

Hercules Inc	.93	.70
Idaho Power	.14	.23

Appendix B (Continued)

Jewel Cos Inc	.31	.30
K Mart Corp	.26	.30
Kimberly-Clark Corp	.47	.47
Lubrizol Corp	1.14	1.12
Mobil Corp	.23	.26
Montana Power Co	.11	.22
Murphy Oil Corp	.26	.29
Nabisco Brands Inc	.73	.75
National Semiconductor Corp	.80	.53
Niagra Mohawk Power	.16	.24
Nicor Inc	.15	.21
Olin Corp	.48	.35
Payless Cashways	.39	.71
Pennzoil	.46	.36
Phelps Dodge Corp	.12	.23
Potlach Corp	.27	.30
Robins (A.H.) Co	1.27	1.37
Smith International Inc	.62	.64
Southern Indiana Gas & Elec	.15	.22
Southwest Forest Industries	.16	.18
Standard Oil Co	.19	.22
Texas Instruments Inc	.89	.76
Timken Co	.37	.43
Transco Energy Co	.21	.12
Union Camp Corp	.77	.58
Union Carbide Corp	.33	.30
Union Pacific Corp	.21	.37
U S Shoe	1.44	
Upjohn Co	.96	1.08
Westinghouse Electric Corp	.33	.34
Weyerhaeuser Co	.58	.47