Forecasting Systematic Risk

Abstract

For over four decades researchers have been attempting to out-perform the constant beta model to forecast systematic risk for stocks. This paper contributes to the literature by achieving a dramatic reduction in forecast error by up to 40% over the constant model in an out-of-sample forecasting exercise. An autoregressive model with three or four lags and estimation based on the previous 80 quarters produces an overwhelming improvement over the benchmark constant beta model. Our findings have important implications in many areas of financial economics as precise beta measurement is often of crucial importance.

JEL Code: G0

Keywords: Portfolio Management, Realized Beta.

By

Vincent J. Hooper (v.hooper@unsw.edu.au)

Kevin Ng (kevin.ng@unsw.edu.au)

&

Jonathan J. Reeves (reeves@unsw.edu.au)

School of Banking and Finance
University of New South Wales, Sydney
Australia

Corresponding Author:

Jonathan J. Reeves
School of Banking and Finance
Faculty of Commerce and Economics
University of New South Wales, Sydney
Australia 2052

Email: reeves@unsw.edu.au.
Telephone +61 2 9385 5858. Fax +61 2 9385 6347.

Acknowledgements: We would like to thank John Maheu and Melissa Slavin for many helpful comments.

Forecasting Systematic Risk

Abstract

For over four decades researchers have been attempting to out-perform the constant beta model to forecast systematic risk for stocks. This paper contributes to the literature by achieving a dramatic reduction in forecast error by up to 40% over the constant model in an out-of-sample forecasting exercise. An autoregressive model with three or four lags and estimation based on the previous 80 quarters produces an overwhelming improvement over the benchmark constant beta model. Our findings have important implications in many areas of financial economics as precise beta measurement is often of crucial importance.

JEL Code: G0

Keywords: Portfolio Management, Realized Beta.

I Introduction

Asset pricing theory states that only systematic risk (beta) should be priced. Academics and practitioners alike typically use beta from the seminal contributions of Sharpe's (1964) and Lintner's (1965) Capital Asset Pricing Model (CAPM) as a measure of systematic risk. Jostova and Philipov (2006) stress that

"beta estimates are essential for many areas of modern finance including asset pricing, cash flow evaluation, risk management and performance valuation. The modelling and measurement of this unobservable parameter can have far reaching implications……. From a portfolio management perspective, betas are crucial for effective hedging and they underlie important performance measures. Therefore the precise measurement of latent betas is an issue of primary importance". This is also corroborated by Ghysels and Jacquier (2005) and Wang (2003).

In general, the forecast evaluation papers in the volatility literature produced only forecast error reductions of approximately 10%, relative to their GARCH benchmark. Our results achieve a much greater reduction in forecast error within this context as we achieved a 40% reduction for beta forecasts, relative to the constant model benchmark. For four decades, no one has been able to improve on the constant beta model until now.

Beta, defined as the ratio of the stock and market return covariance and the market variance, is acknowledged to be time-varying in nature [Hamada (1972), Ferson and Harvey (1991 and 1993), Ferson and Korajczyk (1995), Braun, Nelson and Sunier (1995), Berk, Green and Naik (1999), and Jacquier, Titman and Yalcin (2004)]. Despite the time-varying characteristic, the constant beta model has been the standard approach to forecast betas for over four decades and is known to have outperformed competing models [Ghysels (1998)].

In recent times, there has been an increasing focus on nonparametric volatility measurement [Andersen and Bollerslev (1998), Andersen, Bollerslev, Diebold, Labys (2001, 2003), Barndorff-Nielsen and Shephard (2002, 2004)]. Andersen, Bollerslev, Diebold and Wu (2006) were the first to study the dynamics of realized beta. This empirical study extends their work by examining the out-of-sample forecasting abilities using this innovative and growing measurement approach.

The efficacy of the realized approach to empirical finance with regard to the forecasting of betas is examined within the context of the Australian stock market. Australia offers a useful market to examine because quality data at many levels of frequency is available over a longer period of time than many other countries. In addition, the focus of Andersen, Bollerslev, Diebold and Wu (2006) was upon 25 Dow Jones stocks. We examine 26 Australian stocks and use a more comprehensive market index relative to the stocks being analysed.

In this paper, competing techniques used for forecasting betas are analysed. Specifically, three distinctive categories of models are inspected. These are the constant model, the autoregressive models and the random walk model. Various estimation in-sample sizes, 20, 40, 60 and 80, are also investigated. To enable the comparison of the various in-sample sizes and forecasting approaches, the out-of-sample beta forecasts are made over the identical period from the 2nd quarter 1994 through to the 2nd quarter 2005 for 26 companies. The forecasting abilities of each model are compared and a new dominant approach to forecast beta emerges. The AR(3) and AR(4) models computed on 80 quarterly realized betas produce the superior forecasts which are dramatic improvements over the traditional constant beta model forecasts. For stocks where data is not available for a long period of time, for example only 5 years, the AR(1) model is the most accurate forecaster.

This paper is organized as follows. Section II describes the stock return data. Section III describes beta measurement. Forecast evaluation is conducted in Section IV, followed by conclusions.

II Data

Daily security prices are collected from DataStream; prices are adjusted for dividends and market capitalization changes. The companies in the sample are selected based upon having a complete time series for a maximum time period available on DataStream and listed on the S&P/ASX200 Index. The

earliest recorded date for securities in Australia that were available on DataStream was the 2nd January 1973. Our sample extends from 2nd January 1973 through to 30th June 2005. The sample collected consists of 26 companies of which 19 of the 26 companies are in the ASX50.[1] This helps to ensure a reasonable degree of liquidity within the sample. Table 1 reports the sample of companies.

The Market Index is the All Ordinaries Index, which is Australia's premier market indicator. The All Ordinaries Index is based on the aggregate market value of 500 of the largest companies quoted on the Australian Stock Exchange (ASX). The Index represents 99% of the Australian Market[2].

III Measurement of Beta

Andersen, Bollerslev, Diebold and Wu (2006) provide a solid framework for computing realized betas. This approach is as follows:

The logarithmic $N \times 1$ vector price process, p_t, is assumed to follow a multivariate continuous-time stochastic volatility diffusion,

$$dp_t = \mu_t dt + \Omega_t dW_t \qquad (1)$$

where W_t is standard *N*-dimensional Brownian motion, Ω_t is the $N \times N$ positive definite diffusion matrix and μ_t is the *N*-dimensional instantaneous drift. Ω_t and μ_t are strictly stationary and jointly independent of W_t.

[1] At 30th June 2002.
[2] At 30th June 2002.

Defining the continuously compounded q-period return as $r_{i,t+q,q} \equiv p_{i,t+q} - p_{i,t}$ and following the theory of quadratic variation with the sampling frequency tending to infinity

$$\sum_{j=1,\ldots,[q/d]} r_{t+j.d,d} . r'_{t+j.d,d} - \int_0^q \Omega_{t+\tau} d\tau \to 0 \qquad (2)$$

For additional details refer to Andersen, Bollerslev, Diebold and Wu (2006).

The beta of a security is the covariance of the security with the market divided by the variance of the market. The realized beta of a security is the realized covariance of the security and the market divided by the realized variance of the market. The realized covariance of the security *i* and the market *m* over a period *[t, t+q]* is the sum of the product of the returns of a security *i* and the market *M* for a period *d*, uniformly measured over the period *[t, t+q]*.

$$\hat{v}_{iM,t,t+q} = \sum_{j=1,\ldots,[q/d]} r_{i,t+j.d,d} . r_{M,t+j.d,d} \qquad (3)$$

The realized variance over a period [*t, t+q*] is the sum of the squared returns of the market *M* for a period *d* uniformly measured over the period *[t, t+q]*.

$$\hat{v}^2_{M,t,t+q} = \sum_{j=1,\ldots,[q/d]} r^2_{M,t+j.d,d} \qquad (4)$$

The realized beta is the realized covariance of the security and the market divided by the realized variance of the market, hence:

$$\hat{\beta}_{i,t,t+q} = \frac{\hat{v}_{iM,t,t+q}}{\hat{v}^2_{M,t,t+q}} = \frac{\sum_{j=1,\ldots,[q/d]} r_{i,t+j.d,d} . r_{M,t+j.d,d}}{\sum_{j=1,\ldots,[q/d]} r^2_{M,t+j.d,d}} \qquad (5)$$

In this study *q* will be quarterly and *d* will be daily, which follows a similar approach to that of French, Schwert and Stambaugh (1987) and Schwert (1989). Following Andersen, Bollerslev, Diebold and Wu (2006) the daily frequency is appropriate for quarterly beta measurement as it offers a balance between microstructure noise and a dense sampling frequency for the quarterly measure. In our study the computations are performed using the Ox programming language [Doornik (2001)].

Figure 1 presents the quarterly realized betas for Australian companies. The Autocorrelation Functions (ACFs) and Partial Autocorrelation Functions (PACFs) are contained in Figures 2 and 3 respectively, which suggest the appropriateness of low order autoregressive models, consistent with that of Andersen, Bollerslev, Diebold and Wu (2006), within the context of the US market.

IV Out-of-Sample Forecasting

The constant model is known to have outperformed more complicated models [Ghysels (1998)] and is thus used as a benchmark. An estimation in-sample size of 20, 15, 10 and 5 years assembled from 80, 60, 40 and 20 quarterly realized betas, respectively, is examined. The mean is then used as the one-quarter-ahead forecast, as shown in the following equation:

$$\beta_{t+1} = \frac{1}{n}\sum_{k=0}^{n-1}\beta_{t-k} \qquad (6)$$

Where *n* is the in-sample size of either 80, 60, 40 or 20.

To enable the comparison of the various in-sample lengths and forecasting approaches, the out-of-sample beta forecasts are made over an identical period from the 2nd Quarter 1994 through to the 2nd quarter 2005.

Secondly, autoregressive models are fitted on the time series of quarter realized betas. The coefficients are then used to forecast the next quarterly realized beta with the following equation:

$$\beta_{t+1} = \alpha_0 + \alpha_1\beta_t + \alpha_2\beta_{t-1} + ... + +\alpha_n\beta_{t-(p-1)} \tag{7}$$

Thirdly, a random walk model forecast, which is a variant of the constant beta model, is generated on the assumption that the previous quarter is the optimal predictor of the next period beta and is specified as follows:

$$\beta_{t+1} = \beta_t \tag{8}$$

To test the forecasting ability of each approach, the mean squared error (MSE) and mean absolute error (MAE) for each company is computed. The MSE and MAE are calculated as follows:

$$MSE = \frac{1}{m}\sum_{j=1}^{m}\left(\beta_j - \hat{\beta}_j\right)^2 \tag{9}$$

$$MAE = \frac{1}{m}\sum_{j=1}^{m}\left|\beta_j - \hat{\beta}_j\right| \tag{10}$$

where m is the number of quarters in the out-of-sample size, and β_j is the realized beta at quarter j and $\hat{\beta}_j$ is the corresponding forecast.

The MSE[3] and MAE[4] tables show the lowest error values in bold. The lowest MSE and MAE tend to be with the AR(3) and AR(4) models when the in-sample size is eighty or sixty quarterly realized betas, and the dominance tends to be with the AR(1) and AR(2) models, and constant model when the in-sample size is smaller, either forty or twenty quarters.

Observing specific companies, the autoregressive models often depict substantial reductions in MSE values. Ansell's MSE was reduced by 71.5%[5] when using the AR(3) over the constant model. When comparing the lowest MSE using the constant model for Ansell[6] with the AR(3), the AR(3) continues to dominate the constant model by reducing the MSE by 46.0%. Foster's MSE was reduced by 56.0%[7] when using the AR(3) over the constant model. Rio Tinto's MSE was reduced by 46.4%[8] when using the AR(3) over the constant model. James Hardie Industry's MSE was reduced by 33.8%[9] when using the AR(3) over the constant model. This shows that the constant model performs very poorly with some companies relative to the AR(3) model. There exist no incidents where the constant model dominates the autoregressive models.

To highlight how well the autoregressive models outperform the constant beta models, the average MSE and MAE values are recorded in Table

[3] Table 2, Table 4, Table 6 and Table 8.
[4] Table 3, Table 5, Table 7 and Table 9.
[5] Based on Table 2.
[6] From Table 8 where forecasts are based on the previous 20 Quarters.
[7] Based on Table 2.
[8] Based on Table 2.
[9] Based on Table 2.

10 and Table 11. These detail the average MSE and MAE values, over all stocks, for the various in-sample sizes and beta forecasting models. The results demonstrate that the autoregressive models are the superior method of beta forecasting. In particular the AR(3) and AR(4) based on the previous eighty quarterly realized betas achieves the lowest average value for both the MSE and MAE. Also to note the best in-sample size for the constant beta model is 20 quarters of 5 years, which is consistent with Fisher (1970) and Gonedes (1973). However, it must be stressed that the constant beta model is clearly inferior to the autoregressive model[10].

The beta forecasting abilities of the constant model is inversely related to the in-sample size the forecast is based upon, as opposed to the beta forecasting abilities of the autoregressive models which are proportionally related to the in-sample size. The random walk results are constant across the different in-sample sizes as the forecast is based solely upon the previous quarter. The superiority of autoregressive models remains robust even as the in-sample size decreases. From our results the most accurate method for producing one-quarter-ahead beta forecasts is to use an autoregressive model with three or four orders of lag based upon the previous eighty quarterly realized betas.

[10] Based on Table 10 and 11.

V Conclusion

Within a wide range of contexts in finance, beta is a fundamental parameter that needs to be forecasted accurately. This paper evaluates competing models for forecasting beta, applied to the Australian stock market. Traditionally the constant beta model has been used as a benchmark. However, we discover that an autoregressive model with three or four lags, estimated on twenty years of quarterly realized betas gives rise to a substantial improvement over constant beta model forecasts. For some stocks the improvement is extraordinary. For example, Ansell's MSE is reduced by 46% when using the AR(3) model over the most accurate constant beta model. For stocks where data is not available for a long period of time, for example only 5 years, the AR(1) model is the most accurate forecaster. Our findings have wide ranging implications for finance as models are highly sensitive to forecast error in systematic risk.

References

Andersen, T.G. and T. Bollerslev, (1998), 'Answering the skeptics: yes, standard volatility models do provide accurate forecasts', *International Economic Review*, 39, 885-905.

Andersen, T.G., T. Bollerslev, F. X. Diebold and P.Labys, (2001), 'The distribution of exchange rate volatility', *Journal of the American Statistical Association*, 96, 42-55.

Andersen, T.G., T. Bollerslev, F. X. Diebold and P. Labys, (2003), 'Modelling and forecasting realized volatility', *Econometrica*, 71, 529-626.

Andersen, T.G., T. Bollerslev, F. X. Diebold and J. Wu, (2006), 'Realized beta: persistence and predictability', In T. Fomby and D. Terrell (eds.),

Advances in econometrics: econometric analysis of economic and financial times series in honour of R.F. Engle and C.W.J Granger, Volume B.

Barndorff-Nielsen, O.E. and N. Shephard, (2002), 'Estimating quadratic variation using realized variance', *Journal of Applied Econometrics*, 17, 457-477.

Barndorff-Nielsen, O.E. and N. Shephard, (2004), 'Econometric analysis of realized covariation: high frequency covariance, regression and correlation in financial economics', *Econometrica*, 72, 885-925.

Berk, J., R. Green and V. Naik, (1999), 'Optimal investment, growth options, and security returns', *Journal of Finance*, 54, 1553-1607.

Braun, P., D. Nelson and A. Sunier, (1995), 'Good news, bad news, volatility and betas', *Journal of Finance*, 50, 1575-1604.

Doornik, J.A., (2001), *Object-oriented matrix programming using Ox*,4th ed.. London: Timberlake Consultants Press.

Ferson, W. E. and C. R. Harvey, (1991), 'The time variation of economic risk premiums', *Journal of Political Economy*, 99, 385-415.

Ferson, W.E. and C. R. Harvey, (1993), 'The risk and predictability of international equity returns', *Review of Financial Studies*, 6, 107-131.

Ferson, W.E. and R. A. Korajczyk, (1995), 'Do arbitrage pricing models explain the predictability of stock returns?', *Journal of Business*, 68, 309-349.

Fisher, L., (1970), *The estimation of systematic risk: some new findings*, Proceeding of the Seminar on the Analysis of Security Prices, University of Chicago.

French, K. R., G. W. Schwert and R. F. Stambaugh, (1987), 'Expected stock returns and volatility', *Journal of Financial Economics*, 19, 3-29.

Ghysels, E., (1998), 'On stable factor structures in the pricing of risk: do time-varying betas help or hurt?', *Journal of Finance*, 53, 549-573.

Ghysels, E. and E. Jacquier, (2005), *Market beta dynamics and portfolio efficiency*, Working Paper, Department of Economics, University of North Carolina.

Gonedes, N. J., (1973), 'Properties of accounting numbers: models and tests', *Journal of Accounting Research*, 11, 212-237.

Hamada, R.S., (1972), 'The effects of the firm's capital structure on the systematic risk of common stocks', *Journal of Finance*, 27, 435-452.

Jostova, G. and A. Philipov (2006), 'Bayesian analysis of stochastic betas', *Journal of Financial and Quantitative Analysis*, 40, 747-778.

Lintner, J., (1965), 'The valuation of risky assets and the selection of risky investments in stock portfolios and capital budgets', *Review of Economics and Statistics*, 47, 13-37.

Schwert, G.W., (1989), 'Why does stock market volatility change over time?', *Journal of Finance*, 44, 1115-1153.

Sharpe, W.F., (1964), 'Capital asset prices: a theory of market equilibrium under conditions of risk', *Journal of Finance*, 19, 425-442.

Wang, K.Q., (2003), 'Asset pricing with conditioning information: a new test', *Journal of Finance*, 58, 161-196.

Table 1: Sample of Australian Companies

	Ticker	Company	Sector	Index
1	AGL	Australian Gas Light Company (The)	Utilities	ASX50
2	AMC	Amcor Limited	Materials	ASX50
3	AWC	Alumina Limited	Materials	ASX50
4	BHP	BHP Billiton Limited	Materials	ASX50
5	CCL	Coca-Cola Amatil Limited	Consumer Staples	ASX50
6	CML	Coles Myer Limited	Consumer Staples	ASX50
7	CSR	CSR Limited	Materials	ASX50
8	FGL	Foster's Group Limited	Consumer Staples	ASX50
9	GPT	GPT Group	Property Trusts	ASX50
10	JHX	James Hardie Industries N.V.	Materials	ASX50
11	LLC	Lend Lease Corporation Limited	Financial & Property Trusts	ASX50
12	MAY	Mayne Group Limited	Health Care	ASX50
13	NAB	National Australia Bank Limited	Financial & Property Trusts	ASX50
14	ORG	Origin Energy Limited	Energy	ASX50
15	ORI	Orica Limited	Materials	ASX50
16	RIO	Rio Tinto Limited	Materials	ASX50
17	STO	Santos Limited	Energy	ASX50
18	WBC	Westpac Banking Corporation	Financial & Property Trusts	ASX50
19	WPL	Woodside Petroleum Limited	Energy	ASX50
20	ANN	Ansell Limited	Health Care	ASX100
21	LEI	Leighton Holdings Limited	Industrials	ASX100
22	OSH	Oil Search Limited	Energy	ASX100
23	ADB	Adelaide Bank Limited	Financial & Property Trusts	ASX200
24	CRG	Crane Group Limited	Industrials	ASX200
25	GUD	GUD. Holdings Limited	Consumer Discretionary	ASX200
26	HIL	Hills Industries Limited	Industrials	ASX200

Table 2: MSE of One-Quarter-Ahead Forecast of Beta based on the previous 80 Quarters

Company	Constant	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	RW
ADEL.BRIGHTON	0.269	0.278	0.254	0.259	**0.253**	0.254	0.483
AUST.GAS LIGHT	0.165	0.138	0.117	0.117	**0.110**	0.112	0.196
AMCOR	0.077	0.068	0.066	0.061	0.061	**0.056**	0.104
ANSELL	0.516	0.174	0.161	**0.147**	0.148	0.148	0.181
ALUMINA	0.367	0.225	0.227	**0.223**	0.224	0.231	0.249
BHP BILLITON	0.301	0.173	0.144	0.147	**0.141**	0.144	0.175
COCA - COLA AMATIL	0.362	0.206	0.189	0.184	**0.170**	**0.170**	0.223
COLES MYER	**0.097**	0.106	0.109	0.111	0.110	0.109	0.161
CRANE GROUP	0.072	**0.071**	0.072	0.074	0.076	0.076	0.145
CSR	0.144	0.130	0.128	0.129	0.130	**0.125**	0.191
FOSTERS GROUP	0.168	0.080	**0.074**	**0.074**	0.075	0.076	0.086
GPT GROUP	0.091	0.077	0.074	0.074	**0.064**	0.066	0.113
GUD HOLDINGS	0.124	0.121	**0.120**	0.125	0.126	0.125	0.156
HILLS INDS.	**0.044**	**0.044**	**0.044**	0.045	0.046	0.046	0.100
JAMES HARDIE INDS.CDI.	0.225	0.168	**0.149**	**0.149**	0.163	0.162	0.182
LEIGHTON HOLDINGS	0.208	0.162	**0.155**	0.156	0.158	0.168	0.190
LEND LEASE	0.145	0.124	**0.112**	0.115	0.120	0.121	0.171
MAYNE GROUP	0.295	**0.266**	0.269	0.269	0.275	0.269	0.393
NATIONAL AUS.BANK	0.148	**0.115**	0.119	0.124	0.129	0.133	0.186
ORIGIN ENERGY (EX BORAL)	0.152	0.144	0.144	0.114	**0.113**	0.114	0.197
ORICA	0.165	0.112	0.092	**0.089**	**0.089**	0.092	0.130
OIL SEARCH	0.558	0.539	0.542	0.537	0.529	**0.526**	0.775
RIO TINTO	0.207	0.128	0.122	**0.111**	0.124	0.126	0.129
SANTOS	0.177	0.108	0.100	**0.094**	0.098	0.101	0.131
WESTPAC BANKING	0.100	0.082	0.081	0.082	**0.080**	0.082	0.114
WOODSIDE PETROLEUM	0.134	0.102	**0.090**	0.092	0.091	0.096	0.131

The forecast period covers the period from 1994:2 through 2005:2.

Table 3: MAE of One-Quarter-Ahead Forecast of Beta based on the previous 80 Quarters

Company	Constant	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	RW
ADEL.BRIGHTON	0.436	0.442	**0.414**	0.419	0.417	0.423	0.536
AUST.GAS LIGHT	0.341	0.307	0.285	0.285	**0.272**	0.273	0.367
AMCOR	0.204	0.187	0.188	0.179	0.178	**0.172**	0.235
ANSELL	0.649	0.333	0.318	0.294	0.286	**0.284**	0.332
ALUMINA	0.454	0.359	0.360	**0.353**	**0.353**	0.363	0.365
BHP BILLITON	0.424	0.334	0.296	0.298	**0.291**	0.294	0.326
COCA - COLA AMATIL	0.470	0.344	0.345	0.337	0.331	**0.330**	0.353
COLES MYER	**0.240**	0.250	0.251	0.260	0.252	0.252	0.303
CRANE GROUP	0.208	0.209	0.214	**0.210**	0.215	0.215	0.296
CSR	0.302	0.270	0.271	0.263	0.261	**0.258**	0.331
FOSTERS GROUP	0.329	0.236	**0.227**	0.230	0.231	0.232	0.217
GPT GROUP	0.244	0.230	0.217	0.220	0.211	**0.209**	0.257
GUD HOLDINGS	0.286	0.284	0.283	**0.279**	0.280	0.282	0.326
HILLS INDS.	0.176	**0.174**	0.176	0.176	0.177	0.177	0.253
JAMES HARDIE INDS.CDI.	0.400	0.351	0.339	**0.339**	0.351	0.347	0.338
LEIGHTON HOLDINGS	0.382	0.301	**0.294**	0.298	0.301	0.310	0.338
LEND LEASE	0.309	0.275	**0.247**	0.255	0.266	0.260	0.322
MAYNE GROUP	0.427	0.398	0.395	**0.387**	0.391	0.389	0.438
NATIONAL AUS.BANK	0.329	0.275	**0.266**	0.271	0.279	0.287	0.302
ORIGIN ENERGY (EX BORAL)	0.313	0.310	0.311	0.279	**0.277**	0.280	0.350
ORICA	0.330	0.274	0.253	0.252	**0.248**	0.253	0.293
OIL SEARCH	0.622	0.572	0.578	0.566	0.565	**0.539**	0.633
RIO TINTO	0.391	0.286	0.278	**0.270**	0.286	0.286	0.297
SANTOS	0.337	0.263	0.254	**0.246**	0.253	0.253	0.290
WESTPAC BANKING	0.257	0.240	0.228	0.228	**0.227**	0.228	0.267
WOODSIDE PETROLEUM	0.285	0.260	0.245	0.248	**0.244**	0.249	0.298

The forecast period covers the period from 1994:2 through 2005:2.

Table 4: MSE of One-Quarter-Ahead Forecast of Beta based on the previous 60 Quarters

Company	Constant	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	RW
ADEL.BRIGHTON	0.285	0.284	0.261	0.263	**0.257**	0.261	0.483
AUST.GAS LIGHT	0.145	0.135	0.119	0.125	**0.117**	0.122	0.196
AMCOR	0.078	0.070	0.070	0.069	0.068	**0.063**	0.104
ANSELL	0.556	0.182	0.173	0.160	**0.158**	0.163	0.181
ALUMINA	0.368	**0.229**	0.233	0.231	0.234	0.238	0.249
BHP BILLITON	0.289	0.167	0.144	0.151	**0.143**	0.144	0.175
COCA - COLA AMATIL	0.326	0.202	0.187	0.186	**0.172**	0.174	0.223
COLES MYER	**0.107**	0.111	0.112	0.114	0.113	0.115	0.161
CRANE GROUP	**0.069**	**0.069**	0.072	0.077	0.079	0.082	0.145
CSR	0.126	**0.122**	0.125	0.131	0.134	0.131	0.191
FOSTERS GROUP	0.226	0.102	0.093	0.088	0.090	0.092	**0.086**
GPT GROUP	0.083	0.075	0.074	0.074	**0.067**	0.068	0.113
GUD HOLDINGS	0.123	**0.116**	0.117	0.120	0.125	0.124	0.156
HILLS INDS.	0.123	0.116	0.117	0.120	0.125	0.124	**0.100**
JAMES HARDIE INDS.CDI.	0.190	0.158	**0.144**	**0.144**	0.150	0.154	0.182
LEIGHTON HOLDINGS	0.220	0.170	**0.164**	0.167	0.167	0.176	0.190
LEND LEASE	0.123	0.117	**0.111**	0.114	0.117	0.120	0.171
MAYNE GROUP	0.286	0.264	**0.264**	0.269	0.274	0.274	0.393
NATIONAL AUS.BANK	0.126	**0.115**	0.118	0.122	0.128	0.134	0.186
ORIGIN ENERGY (EX BORAL)	0.160	0.145	0.145	**0.124**	**0.124**	0.126	0.197
ORICA	0.166	0.120	0.100	0.095	**0.092**	0.098	0.130
OIL SEARCH	0.520	0.511	**0.504**	0.509	0.505	0.511	0.775
RIO TINTO	0.199	0.128	0.123	**0.110**	0.118	0.121	0.129
SANTOS	0.149	0.110	0.104	0.101	**0.098**	0.101	0.131
WESTPAC BANKING	0.112	**0.091**	**0.091**	0.093	**0.091**	0.094	0.114
WOODSIDE PETROLEUM	0.103	0.095	0.092	0.093	**0.091**	0.094	0.131

The forecast period covers the period from 1994:2 through 2005:2.

Table 5: MAE of One-Quarter-Ahead Forecast of Beta based on the previous 60 Quarters

Company	Constant	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	RW
ADEL.BRIGHTON	0.452	0.447	0.418	0.421	**0.415**	0.425	0.536
AUST.GAS LIGHT	0.323	0.303	**0.282**	0.292	0.283	0.287	0.367
AMCOR	0.201	0.182	0.182	0.179	0.178	**0.171**	0.235
ANSELL	0.657	0.342	0.327	0.303	**0.294**	0.297	0.332
ALUMINA	0.455	0.364	0.369	0.363	**0.362**	0.367	0.365
BHP BILLITON	0.417	0.334	0.301	0.304	**0.291**	0.295	0.326
COCA - COLA AMATIL	0.463	0.344	0.347	0.336	**0.335**	0.337	0.353
COLES MYER	0.257	0.256	**0.253**	0.263	0.260	0.262	0.303
CRANE GROUP	**0.206**	0.207	0.211	0.218	0.224	0.227	0.296
CSR	0.278	**0.255**	0.260	0.261	0.263	0.260	0.331
FOSTERS GROUP	0.388	0.256	0.250	0.244	0.247	0.250	**0.217**
GPT GROUP	0.235	0.229	0.223	0.226	**0.214**	0.215	0.257
GUD HOLDINGS	0.285	**0.275**	0.280	0.277	0.281	0.284	0.326
HILLS INDS.	0.285	0.275	0.280	0.277	0.281	0.284	**0.253**
JAMES HARDIE INDS.CDI.	0.368	0.344	**0.333**	0.334	0.341	0.346	0.338
LEIGHTON HOLDINGS	0.391	0.307	**0.299**	0.305	0.303	0.311	0.338
LEND LEASE	0.275	0.266	**0.244**	0.248	0.256	0.256	0.322
MAYNE GROUP	0.416	0.393	**0.389**	0.392	0.396	0.402	0.438
NATIONAL AUS.BANK	0.299	0.264	**0.260**	0.261	0.267	0.270	0.302
ORIGIN ENERGY (EX BORAL)	0.313	0.304	0.304	**0.279**	0.280	0.286	0.350
ORICA	0.341	0.284	0.261	0.257	**0.248**	0.254	0.293
OIL SEARCH	0.591	0.545	0.545	0.547	0.543	**0.534**	0.633
RIO TINTO	0.378	0.283	0.281	**0.272**	0.281	0.282	0.297
SANTOS	0.316	0.264	0.257	0.250	**0.249**	0.254	0.290
WESTPAC BANKING	0.268	0.250	**0.243**	0.247	**0.243**	0.252	0.267
WOODSIDE PETROLEUM	0.256	0.260	0.253	0.256	**0.252**	0.254	0.298

The forecast period covers the period from 1994:2 through 2005:2.

Table 6: MSE of One-Quarter-Ahead Forecast of Beta based on the previous 40 Quarters

Company	Constant	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	RW
ADEL.BRIGHTON	0.291	0.299	**0.277**	0.281	0.280	0.282	0.483
AUST.GAS LIGHT	0.145	0.137	0.119	0.123	**0.116**	**0.116**	0.196
AMCOR	**0.071**	**0.071**	0.077	0.076	0.076	0.074	0.104
ANSELL	0.475	0.188	0.187	**0.175**	0.176	0.185	0.181
ALUMINA	0.334	**0.220**	0.229	0.228	0.232	0.236	0.249
BHP BILLITON	0.301	0.171	**0.154**	0.163	0.163	0.172	0.175
COCA - COLA AMATIL	0.304	0.206	0.196	0.194	**0.188**	0.191	0.223
COLES MYER	**0.112**	0.113	0.114	0.114	0.114	0.117	0.161
CRANE GROUP	**0.068**	**0.068**	0.071	0.073	0.077	0.081	0.145
CSR	**0.115**	0.116	0.125	0.135	0.142	0.142	0.191
FOSTERS GROUP	0.219	0.092	0.087	**0.086**	0.087	0.091	0.086
GPT GROUP	0.079	0.076	0.079	0.082	**0.073**	0.077	0.113
GUD HOLDINGS	0.116	**0.111**	0.116	0.122	0.123	0.123	0.156
HILLS INDS.	**0.045**	0.047	0.048	0.050	0.054	0.055	0.100
JAMES HARDIE INDS.CDI.	0.163	0.152	**0.148**	0.150	0.152	0.159	0.182
LEIGHTON HOLDINGS	0.211	0.168	**0.165**	0.174	0.183	0.179	0.190
LEND LEASE	**0.113**	0.125	0.120	0.122	0.124	0.129	0.171
MAYNE GROUP	0.278	**0.276**	0.278	0.288	0.295	0.300	0.393
NATIONAL AUS.BANK	**0.111**	0.117	0.126	0.134	0.146	0.154	0.186
ORIGIN ENERGY (EX BORAL)	0.153	0.147	0.154	**0.139**	0.147	0.150	0.197
ORICA	0.158	0.120	**0.104**	0.110	0.108	0.118	0.130
OIL SEARCH	**0.475**	0.486	0.483	0.489	0.496	0.514	0.775
RIO TINTO	0.196	0.128	0.125	**0.112**	0.120	0.123	0.129
SANTOS	0.140	0.102	0.099	0.096	**0.095**	0.099	0.131
WESTPAC BANKING	0.108	0.097	**0.094**	0.098	0.098	0.102	0.114
WOODSIDE PETROLEUM	0.133	0.107	**0.101**	0.102	0.104	0.108	0.131

The forecast period covers the period from 1994:2 through 2005:2.

Table 7: MAE of One-Quarter-Ahead Forecast of Beta based on the previous 40 Quarters

Company	Constant	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	RW
ADEL.BRIGHTON	0.457	0.454	**0.431**	0.434	0.435	0.452	0.536
AUST.GAS LIGHT	0.326	0.314	0.289	0.297	0.285	**0.282**	0.367
AMCOR	**0.184**	0.186	0.192	0.186	0.190	0.191	0.235
ANSELL	0.580	0.340	0.341	0.319	**0.313**	0.323	0.332
ALUMINA	0.431	0.355	0.363	**0.354**	0.361	0.364	0.365
BHP BILLITON	0.427	0.334	**0.313**	0.321	0.318	0.327	0.326
COCA - COLA AMATIL	0.458	0.365	0.366	**0.353**	0.355	**0.353**	**0.353**
COLES MYER	0.269	**0.256**	**0.256**	0.264	0.264	0.268	0.303
CRANE GROUP	**0.200**	0.202	0.206	0.208	0.218	0.226	0.296
CSR	**0.247**	**0.247**	0.260	0.269	0.278	0.283	0.331
FOSTERS GROUP	0.388	0.250	0.237	0.230	0.232	0.236	**0.217**
GPT GROUP	0.229	0.225	0.229	0.234	**0.221**	0.225	0.257
GUD HOLDINGS	0.280	**0.265**	0.274	0.275	0.280	0.283	0.326
HILLS INDS.	**0.178**	0.180	0.186	0.188	0.194	0.199	0.253
JAMES HARDIE INDS.CDI.	0.340	0.326	0.331	0.332	**0.325**	0.340	0.338
LEIGHTON HOLDINGS	0.370	0.304	**0.300**	**0.300**	0.310	0.306	0.338
LEND LEASE	0.259	0.269	**0.247**	0.253	0.263	0.269	0.322
MAYNE GROUP	0.402	0.401	**0.399**	0.405	0.413	0.423	0.438
NATIONAL AUS.BANK	**0.256**	0.259	0.264	0.272	0.279	0.288	0.302
ORIGIN ENERGY (EX BORAL)	0.298	0.299	0.307	**0.290**	0.296	0.304	0.350
ORICA	0.333	0.283	**0.263**	0.273	0.269	0.277	0.293
OIL SEARCH	0.547	0.519	0.517	**0.509**	0.514	0.510	0.633
RIO TINTO	0.366	0.280	0.273	**0.271**	0.274	0.276	0.297
SANTOS	0.309	0.256	0.253	0.250	**0.247**	0.249	0.290
WESTPAC BANKING	0.251	0.254	**0.248**	0.251	0.249	0.252	0.267
WOODSIDE PETROLEUM	0.292	**0.269**	**0.269**	0.273	0.277	0.277	0.298

The forecast period covers the period from 1994:2 through 2005:2.

Table 8: MSE of One-Quarter-Ahead Forecast of Beta based on the previous 20 Quarters

Company	Constant	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	RW
ADEL.BRIGHTON	**0.279**	0.284	0.301	0.328	0.352	0.370	0.483
AUST.GAS LIGHT	0.143	0.139	**0.136**	0.146	0.150	0.163	0.196
AMCOR	**0.074**	0.085	0.097	0.091	0.101	0.106	0.104
ANSELL	0.274	**0.126**	0.141	0.148	0.173	0.198	0.181
ALUMINA	0.392	0.279	0.333	0.357	0.412	0.442	**0.249**
BHP BILLITON	0.298	0.177	**0.169**	0.184	0.201	0.220	0.175
COCA - COLA AMATIL	0.231	**0.202**	0.223	0.231	0.238	0.260	0.223
COLES MYER	**0.101**	0.105	0.110	0.112	0.118	0.128	0.161
CRANE GROUP	**0.066**	0.069	0.080	0.088	0.093	0.106	0.145
CSR	**0.121**	0.126	0.137	0.156	0.171	0.183	0.191
FOSTERS GROUP	0.148	0.104	0.103	0.108	0.116	0.127	**0.086**
GPT GROUP	**0.069**	0.070	0.080	0.081	0.082	0.088	0.113
GUD HOLDINGS	**0.100**	0.104	0.109	0.122	0.126	0.132	0.156
HILLS INDS.	**0.046**	0.048	0.050	0.053	0.058	0.064	0.100
JAMES HARDIE INDS.CDI.	0.178	**0.155**	0.165	0.173	0.210	0.230	0.182
LEIGHTON HOLDINGS	0.186	0.188	0.184	**0.181**	0.206	0.230	0.190
LEND LEASE	**0.120**	0.127	0.132	0.145	0.148	0.169	0.171
MAYNE GROUP	0.270	**0.266**	0.267	0.283	0.293	0.338	0.393
NATIONAL AUS.BANK	**0.109**	0.115	0.125	0.138	0.147	0.153	0.186
ORIGIN ENERGY (EX BORAL)	**0.128**	0.149	0.167	0.160	0.170	0.181	0.197
ORICA	0.171	0.121	**0.114**	0.130	0.134	0.123	0.130
OIL SEARCH	**0.421**	0.436	0.453	0.449	0.475	0.562	0.775
RIO TINTO	0.183	**0.122**	0.133	0.156	0.164	0.173	0.129
SANTOS	0.141	0.118	0.118	**0.113**	0.117	0.115	0.131
WESTPAC BANKING	**0.095**	0.096	0.107	0.114	0.122	0.133	0.114
WOODSIDE PETROLEUM	0.130	0.109	**0.104**	0.117	0.123	0.133	0.131

The forecast period covers the period from 1994:2 through 2005:2.

Table 9: MAE of One-Quarter-Ahead Forecast of Beta based on the previous 20 Quarters

Company	Constant	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	RW
ADEL.BRIGHTON	0.443	**0.441**	0.455	0.480	0.490	0.514	0.536
AUST.GAS LIGHT	0.324	**0.312**	0.316	0.320	0.321	0.326	0.367
AMCOR	**0.182**	0.201	0.216	0.213	0.231	0.244	0.235
ANSELL	0.407	**0.267**	0.288	0.299	0.311	0.345	0.332
ALUMINA	0.470	**0.401**	0.449	0.469	0.513	0.515	0.365
BHP BILLITON	0.418	**0.321**	0.322	0.339	0.352	0.371	0.326
COCA - COLA AMATIL	0.404	0.366	0.382	0.376	0.378	0.400	**0.353**
COLES MYER	0.245	**0.238**	0.242	0.246	0.245	0.252	0.303
CRANE GROUP	**0.188**	0.199	0.212	0.224	0.229	0.250	0.296
CSR	**0.248**	0.256	0.272	0.290	0.300	0.315	0.331
FOSTERS GROUP	0.322	0.258	0.241	0.245	0.259	0.277	**0.217**
GPT GROUP	**0.212**	0.214	0.223	0.227	0.227	0.233	0.257
GUD HOLDINGS	0.265	**0.263**	0.275	0.282	0.287	0.302	0.326
HILLS INDS.	**0.177**	0.183	0.195	0.200	0.210	0.216	0.253
JAMES HARDIE INDS.CDI.	0.345	**0.328**	0.349	0.354	0.355	0.361	0.338
LEIGHTON HOLDINGS	**0.299**	0.304	0.318	0.305	0.331	0.352	0.338
LEND LEASE	**0.260**	0.270	0.273	0.296	0.299	0.312	0.322
MAYNE GROUP	**0.375**	0.385	0.393	0.406	0.417	0.447	0.438
NATIONAL AUS.BANK	**0.245**	0.255	0.263	0.275	0.276	0.282	0.302
ORIGIN ENERGY (EX BORAL)	**0.283**	0.310	0.333	0.325	0.329	0.339	0.350
ORICA	0.340	0.281	**0.277**	0.301	0.312	0.303	0.293
OIL SEARCH	0.484	**0.482**	0.499	0.484	0.498	0.524	0.633
RIO TINTO	0.327	**0.265**	0.281	0.293	0.309	0.322	0.297
SANTOS	0.303	0.269	**0.267**	0.271	0.274	0.268	0.290
WESTPAC BANKING	**0.250**	0.254	0.261	0.266	0.274	0.282	0.267
WOODSIDE PETROLEUM	0.295	0.274	**0.272**	0.289	0.289	0.296	0.298

The forecast period covers the period from 1994:2 through 2005:2.

Table 10: Average MSE of One-Quarter-Ahead Forecast of Beta
Australian Companies

In-Sample Size	Constant	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	RW
80	0.204	0.152	0.144	**0.142**	**0.142**	0.143	0.204
60	0.202	0.154	0.148	0.148	0.148	0.150	0.204
40	0.189	0.152	0.149	0.151	0.153	0.157	0.204
20	0.172	0.151	0.159	0.168	0.181	0.197	0.204

Values are computed by taking the mean of the 26 Australian company's MSE values in each of the various in-sample sizes and for each model. The minimum value is indicated in bold.

Table 11: Average MAE of One-Quarter-Ahead Forecast of Beta
Australian Companies

In-Sample Size	Constant	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	RW
80	0.352	0.299	0.290	**0.286**	**0.286**	**0.286**	0.333
60	0.351	0.301	0.294	0.293	0.292	0.295	0.333
40	0.334	0.296	0.293	0.293	0.295	0.299	0.333
20	0.312	0.292	0.303	0.311	0.320	0.333	0.333

Values are computed by taking the mean of the 26 Australian company's MAE values in each of the various in-sample sizes and for each model. The minimum value is indicated in bold.

Figure 1: Quarterly Realized Betas for Australian Companies

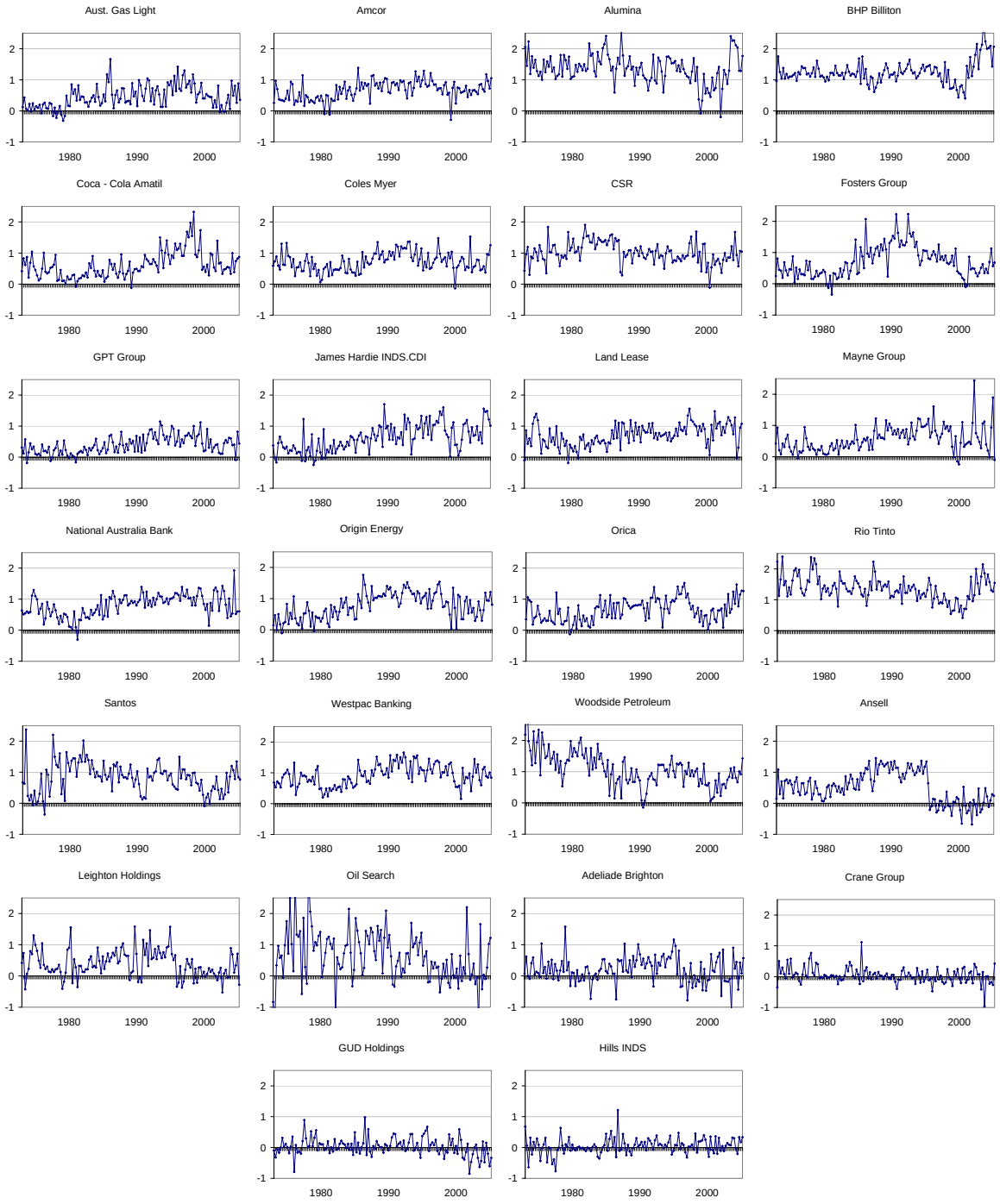

Figure 1: The sample covers from the 2nd January 1973 to the 30th June 2005. The sample size is 130.

Figure 2: Autocorrelation Functions - Quarterly Realized Betas for Australian Companies

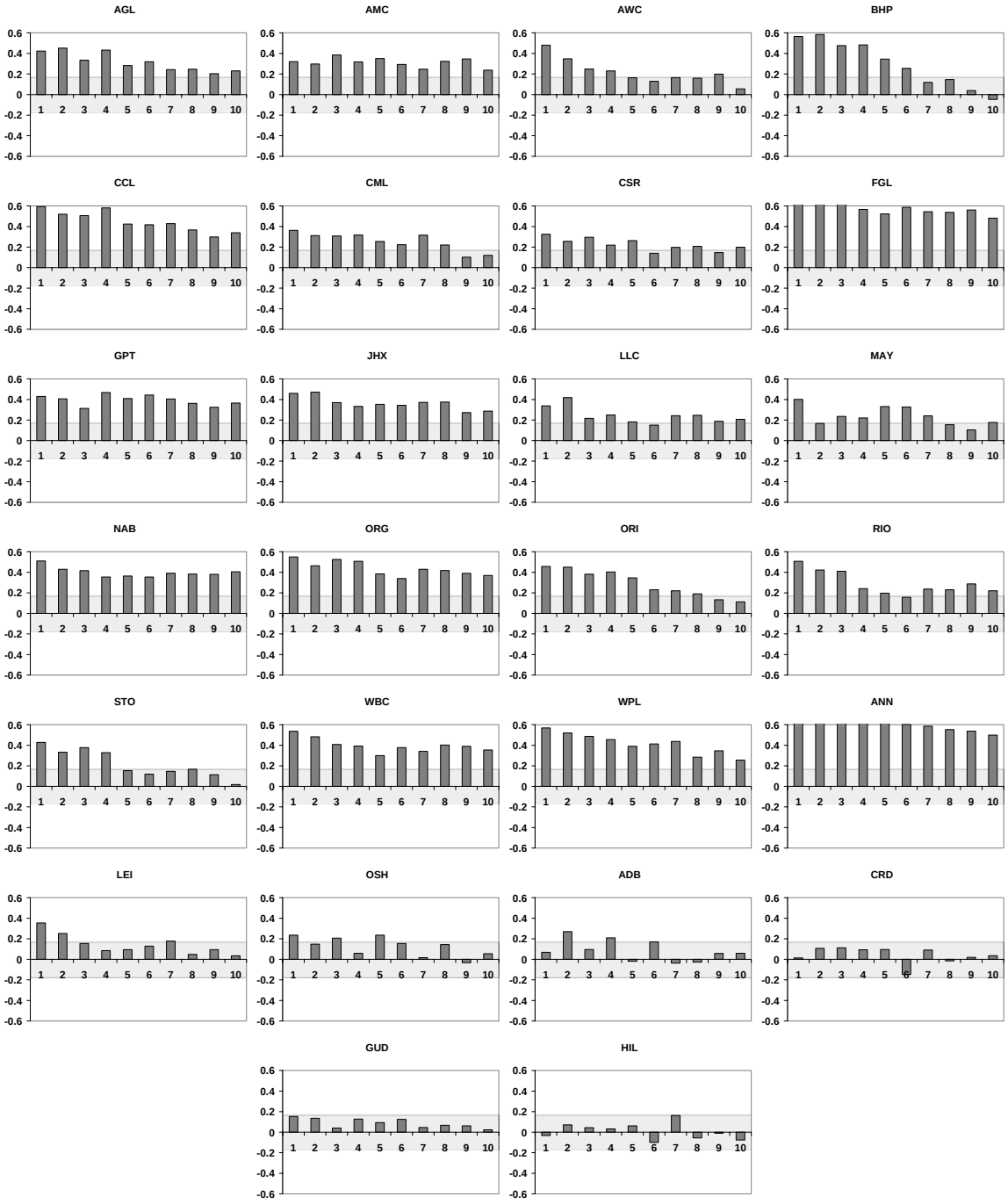

Figure 2: The sample covers from the 2nd January 1973 to the 30th June 2005. The sample size is 130. The graphs include a 95% significance interval band.

Figure 3: Partial Autocorrelation Functions - Quarterly Realized Betas for Australian Companies

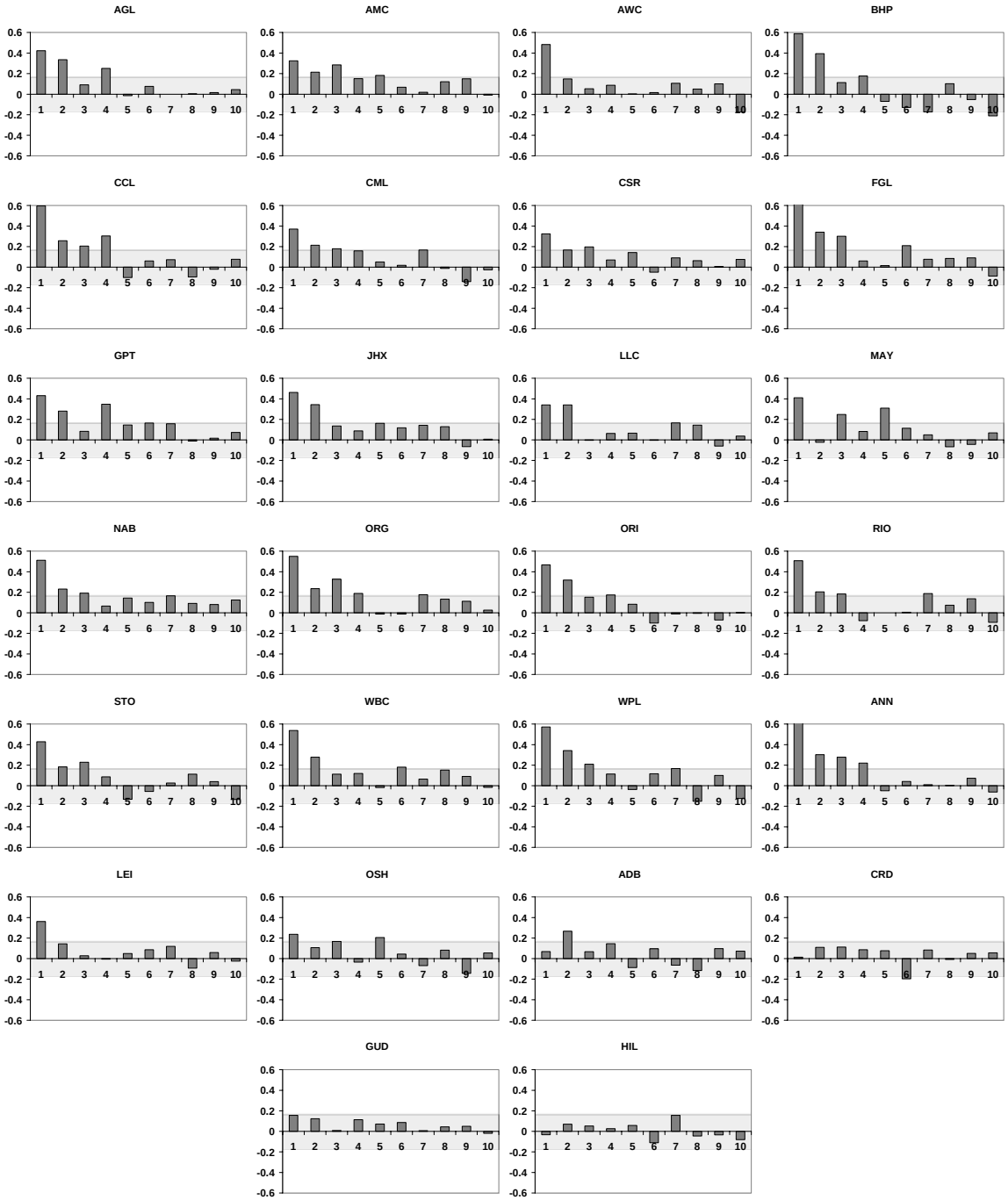

Figure 3: The sample covers from the 2nd January 1973 to the 30th June 2005. The sample size is 130. The graphs include a 95% significance interval band.