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6th April 2013

Our Reference: UE.SU.01

Dr Malcolm Roberts
Chairman
Queensland Competition Authority
G.P.O. Box 2257
BRISBANE QUEENSLAND 4001

BY EMAIL TO: research@qca.org.au

Dear Mr Roberts,

Cost of Capital Methodology Review, 2012-13

Please would you accept a submission by ESQUANT Statistical Consulting which has been prepared in response to the discussion paper, released by the Queensland Competition Authority (QCA), on the relationship between the risk-free rate and the market risk premium (MRP)[1]. The report authored by ESQUANT should accompany a recently lodged NERA report on the cost of equity for a regulated energy utility[2].

If the QCA has further questions about this submission, then please do not hesitate to contact Jeremy Rothfield, Network Regulation and Compliance Manager, on (03) 8846 9854.

Yours sincerely,

[redacted]

Jeremy Rothfield
Network Regulation and Compliance Manager

[1] QCA (2012), The Risk-free Rate and the Market Risk Premium, a discussion paper prepared by the Queensland Competition Authority, November 2012.

[2] NERA (2013), *The Cost of Equity for a Regulated Energy Utility: A Response to the QCA Discussion Paper on the Risk-Free Rate and the MRP*, prepared for United Energy and Multinet Gas by NERA Economic Consulting, March 2013.

ESQUANT
Statistical Consulting

A review of NERA's analysis of McKenzie and Partington's EGARCH analysis

A report for Multinet Gas

Neil Diamond, B.Sc.(Hons), Ph.D., A.Stat.

April 9, 2013

Contents

1 Terms of reference

Multinet Gas is seeking your expert assistance in respect of its proposed estimate of the cost of equity to be used in the calculation of the weighted average cost of capital. Multinet is also seeking your advice in relation to the approach taken by the AER to the estimation of the cost of equity (and the WACC more generally).

Specifically, your input is required in connection with a report prepared by NERA Economic Consulting, The Cost of Equity for a Regulated Energy Utility: A Response to the QCA Discussion Paper on the Risk-Free Rate and the MRP, a report for United Energy and Multinet Gas, March 2013. NERA has undertaken an analysis of the risk-free rate and the MRP, and has reviewed the following reports prepared for the AER:

- Review of regime switching framework and critique of survey evidence, Michael McKenzie and Graham Partington on behalf of the Securities Industry Research Centre of Asia-Pacific (SIRCA) Limited, report dated September 7th 2012.
- Review of NERA report on the Black CAPM, Michael McKenzie and Graham Partington on behalf of the Securities Industry Research Centre of Asia-Pacific (SIRCA) Limited, report dated August 24th 2012.
- Report to Corrs Chambers Westgarth, Equity Market Risk Premium, Michael McKenzie and Graham Partington on behalf of XTR Pty. Ltd., report dated December 21st 2011.
- Report to the AER, supplementary report on the equity market risk premium, Michael McKenzie and Graham Partington on behalf of the Securities Industry Research Centre of Asia-Pacific (SIRCA) Limited, report dated February 22nd, 2012.

You are asked to review the report prepared by NERA and to consider the questions presented below which are germane to sections 2.3 and 7.1 of the NERA document:

1. Is the EGARCH model prepared by McKenzie and Partington correctly specified?
2. What are the implications for the volatility of the excess returns to the market of the parameter estimates obtained by McKenzie and Partington?
3. Can you ascertain whether Figure 7 in the McKenzie and Partington review of the regime-switching framework report could reasonably have been produced using the parameter estimates obtained by the authors?

4. Can you derive, and report on, up-to-date parameter estimates for an EGARCH model that uses Handley's data updated to 2011? The relevant series that you will need to consider are: The grossed up series of with-credit returns to the Australian market portfolio, computed under the assumption that the market values a one-dollar credit at 35 cents (these data were not published in full by Handley but have been recreated); and, the bill return, which was calculated by rolling over three-month Treasury Notes.

5. What are the results for volatility from your amended EGARCH model?

6. Please assess the statement made by McKenzie and Partington that 'where the returns are skewed the [sample mean] will be biased'(paragraph 10 of the 21st December 2011 equity market risk premium report).

7. Please assess the statements made by McKenzie and Partington about the mean, median and mode: '[In] large samples . . . differences between the three measures of central tendency [will] be small' (paragraph 10 of the equity market risk premium report).

2 Specification of EGARCH Model given by McKenzie and Partington

The correct specification of the EGARCH(1,1) model, due to Nelson (1991), is:

$$r_t = \mu_t + h_t^{1/2} z_t,\ \ z_t \sim \text{i.i.d } N(0,1)$$
$$\log(h_t) = \mu_{\log(h)} + \beta(\log(h_{t-1}) - \mu_{\log(h)}) + g(z_{t-1})$$

where

$$g(z_{t-1}) = \theta z_{t-1} + \gamma(|z_{t-1}| - \sqrt{\frac{2}{\pi}})$$

and r_t is the return to the market portfolio in excess of the return to a bill, μ_t is the conditional mean of the excess return, h_t is the conditional variance of the excess return, and it is assumed that z_t follows a Normal distribution with mean 0 and standard deviation 1. The parameters of the model, to be estimated on the basis of the data, are μ_t, $\mu_{\log(h)}$, β, θ, and γ. Note that in principle μ_t can vary, but McKenzie and Partington assume that it is a constant, μ.

The specification given by McKenzie and Partington (2012) is incorrect. They give the second line above as:

$$\log(h_t) = \mu_{\log(h)} + \beta \log(h_{t-1} - \mu_{\log(h)}) + g(z_{t-1})$$

Additional concerns about the specification of the model are addressed in section 7.

Appendix A shows the equivalence of the EGARCH(1,1) model, as intended by McKenzie and Partington (2012), with the original specification given by Nelson (1991).

3 Implications for the volatility of the excess returns implied by McKenzie and Partington's Parameter Estimates

I have used the `rugarch` package (Ghalanos, 2012) in R (R Core Team, 2012). The specification used there is slightly different but equivalent, as shown in Appendix A. The corresponding specification for the EGARCH(1,1) model is

$$\log(\sigma_t^2) = \omega + \alpha_1 z_{t-1} + \gamma_1(|z_{t-1}| - E|z_{t-1}|)) + \beta_1 \log(\sigma_{t-1}^2)$$

and hence we have the following correspondences:

$$\begin{aligned} h_t &\equiv \sigma_t^2 \\ \mu_{\log(h)} &\equiv \frac{\omega}{1-\beta_1} \\ \theta &\equiv \alpha_1 \\ \beta &\equiv \beta_1 \\ \gamma &\equiv \gamma_1 \end{aligned}$$

Simulating 1,000,000 values of an EGARCH(1,1) process using the parameter estimates given by McKenzie and Partington (2012), gives a standard deviation of 0.426.

4 McKenzie and Partington's Figure 7

Figure 7 of McKenzie and Partington (2012) could not have been generated by an EGARCH model with the parameter estimates given in their Table 5. The average of $\log(\sigma_t^2)$ is given as -1.7393, implying the expected value of σ_t is at least 0.419. However, the maximum volatility shown in Figure 7 (based on digitising the graph using GetData Graph Digitizer 2.25, Federov, 2012) was 0.217.

5 Parameter estimates for an EGARCH model that uses Handley's data updated to 2011

Using Handley's data provided by NERA, (the relevant series that I used was, following the terms of reference, the grossed up series of with-credit returns to the Australian market portfolio, computed under the assumption that the market values a one-dollar credit at 35 cents [these data were not published in full by Handley but have been recreated]; and, the bill return, which was calculated by rolling over three-month Treasury Notes) the parameters of the EGARCH(1,1) model were estimated using the `rugarch` package in R. The estimated parameters are given in Table 1.

	Estimate	Std.Error	$t-$value	$p-$value
μ	0.066	0.011	5.910	0.000
ω	-0.851	0.579	-1.472	0.141
α_1	0.042	0.117	0.362	0.717
β_1	0.765	0.154	4.972	0.000
γ_1	0.674	0.272	2.479	0.013

Table 1: Estimated parameters for EGARCH(1,1) model.

In addition, robust standard errors are given in Table 2.

	Estimate	Std.Error	$t-$value	$p-$value
μ	0.066	0.014	4.807	0.000
ω	-0.851	1.271	-0.670	0.503
α_1	0.042	0.168	0.251	0.802
β_1	0.765	0.339	2.259	0.024
γ_1	0.674	0.564	1.195	0.232

Table 2: Estimated parameters for EGARCH(1,1) model with robust standard errors.

Table 3 provides a comparison of the parameter estimates given by `rugarch` with those given by NERA (2013). There are only slight differences, due to the different optimisation methods used by `rugarch` and SAS.

	`rugarch` Estimate	NERA Estimate
μ	0.066	0.0660
ω	-0.851	-0.8356
α_1	0.042	0.0391
β_1	0.765	0.7707
γ_1	0.674	0.6501

Table 3: Comparison between Estimated parameters for EGARCH(1,1) model using `rugarch` and NERA (2013).

6 Volatility Results for Fitted Model

Using the estimated parameters, the calculated conditional standard deviation is plotted in Figure 1, together with the conditional standard deviations from the NERA (2013) report, based on the parameter estimates given in their report, and McKenzie and Partington's (2012) report, obtained by digitising the corresponding graph using GetData Graph Digitizer 2.25. The `rugarch` results are much more similar to the NERA results, and do not look at all like the McKenzie and Partington results. The differences between the rugarch results and the NERA results are very minor.

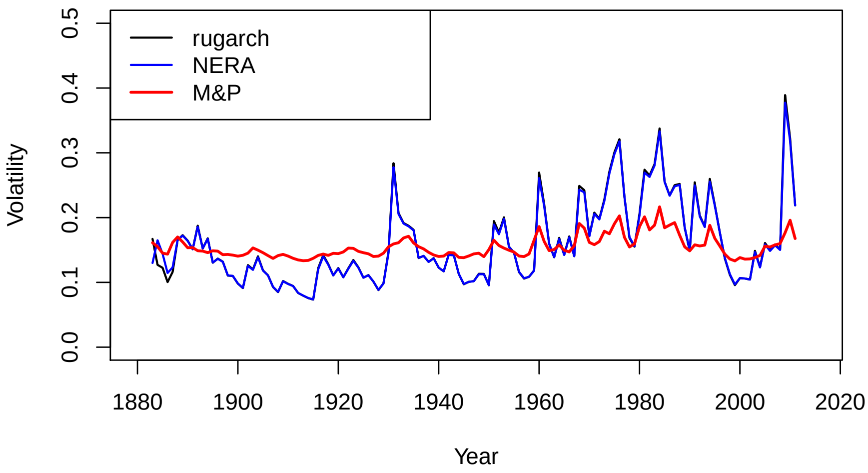

Figure 1: Comparison of volatility given by `rugarch`, that given by the NERA report and that given by McKenzie and Partington

7 Diagnostic Plots

Figure 2 gives a QQ (Quantile-Quantile) plot of the residuals from the fitted EGARCH model. If the model is correctly specified, then the residuals should fall on a straight line in the plot. This is not the case, indicating that the residuals are not normally distributed. A better model is obtained allowing the innovations to have a distribution with heavier tails such as a t-distribution. The best estimate of the degrees of freedom, ν, is 4.6, showing much heavier tails than for a normal distribution.

Figure 3 shows a Cumulative Sum graph of the mean-corrected Volatility. In this graph, changes in the slope correspond to shifts in the mean of the underlying process. The graph shows that just before 1960 the level of

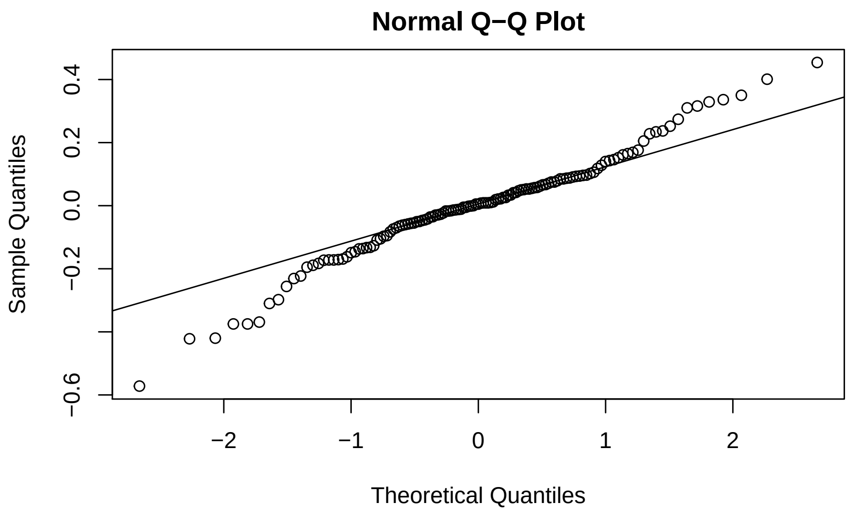

Figure 2: QQ plot of residuals for the EGARCH(1,1) model

volatility increased. However, in the specified EGARCH model, the volatility, although autocorrelated, is assumed to be stationary.

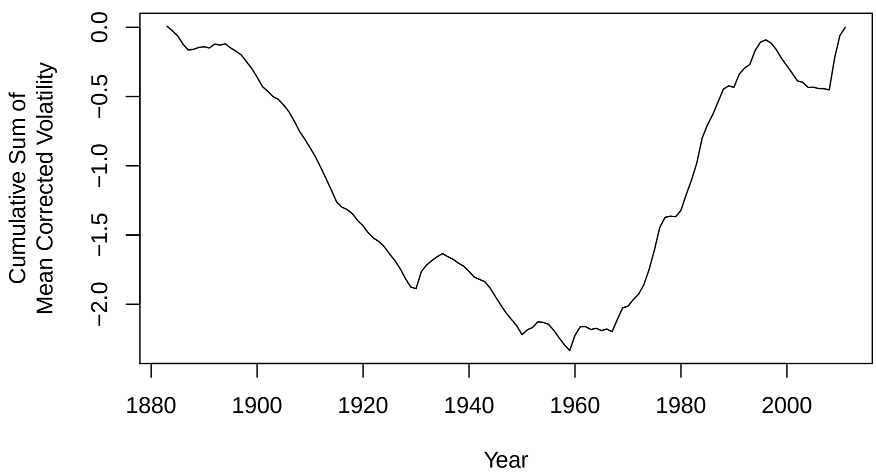

Figure 3: Cumulative Sum graph of the mean-corrected volatility

8 Possible Bias of Sample Mean for Skewed Distributions

McKenzie and Partington state in Paragraph 10 of their December 2011 equity market risk premium report that "when the returns are skewed the sample mean will be biased". This is not correct. The sample mean is an unbiased estimator of the population mean, as long as the population mean exists, irrespective of whether the distribution is skewed or not.

If the distribution is symmetric, the population mean and the population median are identical. Although the sample mean is a more efficient estimator than the sample median, the sample median is a more resistant estimator in the presence of outliers.

The situation is more complicated when the distribution is skewed. Generally, but not universally, when the distribution is positively skewed the following inequalities hold:

$$\text{Population Mode} < \text{Population Median} < \text{Population Mean}$$

The implication is that there is a bias using the sample median to estimate the population mean.

9 Differences between Measures of Central Tendency

McKenzie and Partington make the following statement about the mean, median and mode: '[In] large samples ... differences between the three measures of central tendency [will] be small' (paragraph 10 of the equity market risk premium report). This would only be correct for symmetric distributions. For non-symmetric distributions, the statement is not correct.

Consider a lognormal distribution (see, for example, Forbes et al. 2011, pp 131-134.) with parameters μ and σ, the mean and standard deviation of the logarithm of the data values. Then we have the following:

$$\begin{aligned} \text{Mean} &= \exp\left(\mu + \frac{1}{2}\sigma^2\right) \\ \text{Median} &= \exp(\mu) \\ \text{Mode} &= \exp(\mu)/\exp\left(\sigma^2\right) \end{aligned}$$

Clearly, no matter the size of the sample, the three population parameters will remain different. Figure 4 shows a simulation for 100,000 samples of size 200, where the log returns of an asset are independent and identically distributed as normal with mean 8% and standard deviation 20%, with the mode being estimated using kernal density methods. Note how both the distributions of the sample mode and sample median are shifted to the left relative to the distribution of the sample mean. The difference between the mean and the median of the simple returns is, on average, 2.2% which relative to the population mean of the excess returns to the market portfolio is obviously economically significant.

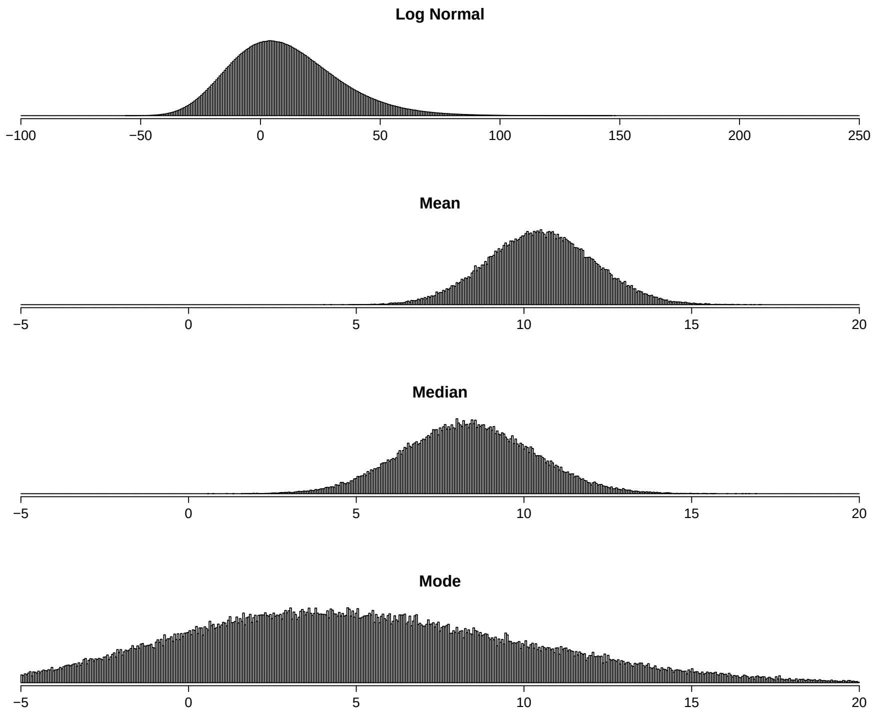

Figure 4: Simulated lognormal data and distributions of means, medians and modes of simple returns. Note that a different scale has been used for the individual results in the top panel, compared to the bottom three panels.

10 Conclusions

Based on my review I make the following conclusions:

- The specification given by McKenzie and Partington (2012) is not correct. In addition, residuals from the model are clearly non-normal, and the volatility seems to have undergone a step change just prior to 1960.
- The average volatility based on McKenzie and Partington's parameter estimates is approximately 0.427.

- Figure 7 of McKenzie and Partington (2012) does not match the parameter estimates given in their Table 5.
- I have used `rugarch` to provide updated parameter estimates for the EGARCH(1,1) model. These parameter estimates give volatility results very similar to those given by NERA (2013), but not at all similar to the McKenzie and Partington (2012) results.
- The sample mean is unbiased for the population mean, as long as the population mean exists, irrespective of the skewness of the population.
- There is no reason for the mean, median and mode to be the same for large samples if the distribution is skewed.

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Nelson, D.B. (1991). "Conditional heteroskedasticity in asset returns: A new approach". *Econometrica* **59**: 347-370.

R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, http://www.R-project.org/.

Wheatley, S. and Quach, B. (March, 2013). "The Cost of Equity for a Regulated Energy Utility: A Response to the QCA Discussion Paper on the Risk-Free Rate and the MRP, a report for United Energy and Multinet Gas". NERA Economic Consulting.

A A comparison of EGARCH specifications

Following Engle (1982), for each time period let ξ_t be the model's prediction error and σ_t^2 be the variance of ξ_t given information at time t. Engle's ARCH model is given by

$$\xi_t = \sigma_t z_t$$

where z_t is idependent and identically distributed with mean zero and standard deviation 1.

Nelson (1991) introduced the EGARCH model. His equations were:

2.1

$$\ln(\sigma_t^2) = \alpha_t + \sum_{k=1}^{\infty} \beta_k g(z_{t-k})$$

2.2

$$g(z_t) = \theta z_t + \gamma(|z_t| - E(|z_t|))$$

and a more parsimonious model than **2.1**:

2.3

$$\ln(\sigma_t^2) = \alpha_t + \frac{(1 + \psi_1 L + \ldots \psi_q L^q)}{(1 - \Delta_1 L - \ldots \Delta_p L^p)} g(z_{t-k})$$

where L is the backshift operator

$$L z_t = z_{t-1} \quad L^q z_t = z_{t-q}$$

with q a positive integer.

The EGARCH(1,1) model corresponds to $\alpha_t \equiv \alpha$ and $q = 0$ and $p = 1$ and hence Equation 2.3 becomes:

$$\begin{aligned}
\ln(\sigma_t^2) &= \alpha + \frac{1}{(1 - \Delta_1 L)} g(z_{t-1}) \\
\Rightarrow (1 - \Delta_1 L) \ln(\sigma_t^2) &= (1 - \Delta_1 L)\alpha + g(z_{t-1}) \\
\Rightarrow \ln(\sigma_t^2) - \Delta_1 \ln(\sigma_{t-1}^2) &= (1 - \Delta_1)\alpha + g(z_{t-1}) \\
\Rightarrow \ln(\sigma_t^2) &= (1 - \Delta_1)\alpha + g(z_{t-1}) + \Delta_1 \ln(\sigma_{t-1}^2) \\
&= (1 - \Delta_1)\alpha + \theta z_{t-1} + \gamma(|z_{t-1}| - E(|z_{t-1}|) + \Delta_1 \ln(\sigma_{t-1}^2)
\end{aligned}$$

The `rugarch` model has the general specification (Ghalonas, 2012b):

$$\ln(\sigma_t^2) = \left(\omega + \sum_{j=1}^{m} \zeta_j v_{jt}\right) + \sum_{j=1}^{q} (\alpha_j z_{t-j} + \gamma_j (|z_{t-j}| - E(|z_{t-j}|))) + \sum_{j=1}^{p} \beta_j \ln(\sigma_{t-j}^2)$$

where v_j's are external regressors. In the EGARCH(1,1) model there are no external regressors and $q = 1$ and $p = 1$, leading to the equation

$$\ln(\sigma_t^2) = \omega + \alpha_1 z_{t-1} + \gamma_1(|z_{t-1}| - E(|z_{t-1}|)) + \beta_1 \ln(\sigma_{t-1}^2)$$

and hence the Nelson EGARCH(1,1) model and the `rugarch` specification are identical where

$$\begin{aligned}
(1-\Delta_1)\alpha &\equiv \omega \\
\theta &\equiv \alpha_1 \\
\gamma &\equiv \gamma_1 \\
\Delta_1 &\equiv \beta_1
\end{aligned}$$

The corrected version of the specification provided incorrectly by McKenzie and Partington is

$$r_t = \mu_t + h_t^{1/2} z_t, \;\; z_t \sim \text{i.i.d } N(0,1)$$

$$\log(h_t) = \mu_{\log(h)} + \beta(\log(h_{t-1}) - \mu_{\log(h)}) + g(z_{t-1})$$

where

$$g(z_{t-1}) = \theta z_{t-1} + \gamma(|z_{t-1}| - \sqrt{\frac{2}{\pi}})$$

This can be rewritten as

$$\begin{aligned}
\log(h_t) &= \mu_{\log(h)} - \beta\mu_{\log(h)} + \beta\log(h_{t-1}) + \theta z_{t-1} + \gamma(|z_{t-1}| - \sqrt{\frac{2}{\pi}}) \\
&= \mu_{\log(h)}(1-\beta) + \beta\log(h_{t-1}) + \theta z_{t-1} + \gamma(|z_{t-1}| - E(|z_{t-1}|))
\end{aligned}$$

since

$$E(|z_{t-1}|) = \sqrt{\frac{2}{\pi}}$$

when z_t follows a standard normal distribution. Again, this is equivalent to the Nelson EGARCH(1,1) model where

$$\begin{aligned}
(1-\Delta_1)\alpha &\equiv \mu_{\log(h)}(1-\beta) \\
\theta &\equiv \theta \\
\gamma &\equiv \gamma \\
\Delta_1 &\equiv \beta
\end{aligned}$$

Finally, the equivalence between the corrected specification due to McKenzie and Partington (2012) and the rugarch specification is given by

$$\begin{aligned}
\mu_{\log h} &\equiv \frac{\omega}{1-\beta} \\
\theta &\equiv \alpha_1 \\
\beta &\equiv \beta_1 \\
\gamma &\equiv \gamma_1
\end{aligned}$$

B Neil Diamond CV

Curriculum Vitae
Neil Diamond December 2012

Full Name:	Neil Thomas Diamond
Academic Qualifications:	B.Sc (Hons) (Monash), Ph.D. (Melbourne), A.Stat

Career History

1977-78	Statistician, ICI Explosives Factory, Deer Park
1979-86	Research Officer, Research Scientist, Senior Research Scientist And Statistics and Computing Team Leader, ICI Central Research Laboratories, Ascot Vale
1987-1989	Lecturer, Department of Mathematics, Computing and Operations Research, Footscray Institute of Technology
(1989)	Visiting Scientist, Center for Quality and Productivity Improvement, University of Wisconsin-Madison, USA.
1990-2003	Senior Lecturer, Department of Computer and Mathematical Sciences, Victoria University of Technology
(1995)	Visiting Fellow, Center for Quality and Productivity Improvement, University of Wisconsin-Madison, USA.
2003-2004	Senior Statistician, Insureware
2004-2006	Senior Lecturer and Deputy Director of Consulting, Department of Econometrics and Business Statistics, Monash University.
2007- 2012	Senior Lecturer and Director of Consulting, Department of Econometrics and Business Statistics, Monash University.
2011- 2012	Associate Professor and Co-ordinator of Statistical Support, Victoria University.
2012-	Director, ESQUANT Statistical Consulting

Research and Consulting Experience

- A Ph.D. from the University of Melbourne entitled “Two-factor interactions in non-regular foldover designs.”

- Ten years with ICI Australia as an industrial statistician initially with the Explosives group and eventually with the research group.

- Two six month periods (Professional Experience Program and Outside Studies Program) at the Center for Quality and Productivity Improvement, at the University of Wisconsin-Madison. The Center, founded and directed by Professor George Box, conducts innovative practical research in modern methods of quality improvement and is an internationally recognised forum for the exchange of ideas between experts in various disciplines, from industry and government as well as academia.

- Extensive consulting and training on behalf of the Centre for Applied Computing and Decision Analysis based at VUT for the following companies:

Data Sciences	Initiating Explosives Systems
Analytical Science Consultants	Saftec
Glaxo Australia	Datacraft Australia
Enterprise Australia	ICI Australia
The LEK partnership	Kaolin Australia
BP Australia	AMCOR
Melbourne Water	Kinhill Group
Australian Pulp and Paper Institute	

- Operated the Statistical Consulting Service at Victoria University of Technology from 1992-2003.

- From 2003-2004 worked as a Senior Statistician with Insureware on the analysis of long-tailed liability data.

- From December 2004 to December 2006 Deputy Director of Consulting of Monash University Statistical Consulting Service based in the Department of Econometrics and Business Statistics.

- From January 2007 Director of Consulting of Monash University Statistical Consulting Service based in the Department of Econometrics and Business Statistics.

- Extensive consulting and training on behalf of the Monash University Statistical Consulting Service for the following companies and organisations:

Australian Tax Office	Department of Human Services
J D McDonald	IMI Research
Port of Melbourne Corporation	Incitec Pivot
Agricola, Wunderlich & Associates	Parks Victoria
Australian College of Consultant Physicians	ANZ
Department of Justice	CRF(Colac Otway)
Australian Football League Players' Association	United Energy
ETSA	ENA

Postgraduate Supervision

Principal Supervisor

Gregory Simmons (1994-1997). M.Sc. completed. "Properties of some minimum run resolution IV designs."

Tony Sahama (1995-2003). Ph.D. completed. "Some practical issues in the design and analysis of computer experiments."

Ewa Sztendur (1999-2005). Ph.D. completed. "Precision of the path of steepest ascent in response surface methodology." [As a result of this thesis, Ewa was awarded the 2006 Victoria University Vice-Chancellor's Peak Award for Research and Research Training-Research Degree Graduate.]

Co-supervisor

Keith Hart (1996-1997). M.Sc. completed. "Mean reversion in asset prices and asset allocations in funds management."

Jyoti Behera (1999-2000). M.Eng. completed. "Simulation of container terminals."

Ray Summit (2001-2004). Ph.D. completed. "Analysis of warranty data for automobile data."

Rob Moore (2001-2007). Ph.D. completed. "Computer recognition of musical instruments.

M.Sc. Minor Theses

Milena Shtifelman (1999). Completed. (Monash University Accident Research Centre). "Modelling interactions of factors influencing road trauma trends in Victoria."

Rohan Weliwita (2002). Completed. "Modelling road accident trauma data."

Theses Examination

One M.Sc. major thesis (University of Melbourne) and one M.Sc minor thesis (Victoria University).

Workshops

Victoria University

- Experimental Design.
- Longitudinal Data Analysis.
- Statistics for Biological Sciences.
- Introductory Statistics for Research.
- Software Packages for Statistics.
- Design and Analysis of Questionnaires and Sample Surveys.
- Introductory SPSS.
- Statistics for Biological Sciences using R.
- Statistics for Biological Sciences using SPSS.
- Research Design and Statistics.

Monash University

- Expert Stats Seminars for higher degree research students on Software Packages for Statistics, Questionnaire Design, Analysis of Survey Data, and Multivariate Statistics.
- Introduction to Statistics for Pharmacy (5 hours).

Other

- Design of Experiments for ICI Australia (One day course).
- Design of Experiments for Quality Assurance-including Taguchi Methods. A 2-day professional development short course on behalf of the Centre for Manufacturing Advanced Engineering Centre.
- Design of Experiments for the Australian Pulp and Paper Institute.
- Statistical Methods for ANZ Analytics.

Teaching Experience

Monash University

- Business Statistics (First Year), Marketing Research Analysis (Second Year), Survey Data Analysis (Third Year-Clayton and Caulfield).

Victoria University of Technology

- Applied Statistics (First Year), Linear Statistical Models, Sampling and Data Analysis (Second Year), Experimental Design (Third Year).
- Statistics for Engineers, Statistics for Nurses, Statistics for Occupational Health.
- Forecasting (Graduate Diploma in Business Science)

Sessional Teaching

- RMIT (1991, 1996-2002) Design of Experiments for Masters in Quality Management.
- AGSM (1993-1997): Total Quality Management for Graduate Management Qualification.
- Various other: The University of Melbourne, Enterprise Australia, Swinburne Institute of Technology.

Industry Projects

Over 30 projects for the following companies and organisations:

Gas and Fuel Corporation	Ford Australia
Mobil Australia	Fibremakers
ICI Australia	Western General Hospital
Data Sciences	Keilor City Council
AMCOR	Composite Buyers
Davids	Email Westinghouse
Craft Coverings	Australian Wheat Board
CSL	Holding Rubber
Viplas Olympic	Melbourne Water
Federal Airports Corporation	

Publications

Chapters in Books

1. Sztendur, E.M. and Diamond, N.T., (2001). "Inequalities for the precision of the path of steepest ascent in response surface methodology," in Cho, Y.J, Kim, J.K., and Dragomir, S.S. (eds.) *Inequality Theory and Applications Volume 1*, Nova Publications.

Journal Articles

1. Diamond, N.T., (1991). "Two visits to Wisconsin," *Quality Australia*, **7**, 30-31.
2 Diamond, N.T., (1991). "The use of a class of foldover designs as search designs," *Austral. J. Statist*, **33**, 159-166.
3 Diamond, N.T., (1995). "Some properties of a foldover design," *Austral. J. Statist*, **37**, 345-352.
4 Watson, D.E.R., Hallett, R.F., and Diamond, N.T., (1995). "Promoting a collegial approach in a multidisciplinary environment for a total quality improvement process in higher education, " *Assessment & Evaluation in Higher Education*, **20**, 77–88.
5 Van Matre, J. and Diamond, N.T., (1996). "Team work and design of experiments," Quality Engineering, 9, 343–348.
6 Diamond, N.T., (1999). "Overlap probabilities and delay detonators," *Teaching Statistics*, **21**, 52–53. Also published in "Getting the Best from Teaching Statistics", one of the best 50 articles from volumes 15 to 21 of *Teaching Statistics*.
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Professional Service

- President, Victorian Branch, Statistical Society of Australia, 2001-2002.
  - Terms as Council Member, Vice-President, and Past President.
- Referee: *Australian and New Zealand Journal of Statistics*, *Biometrika*, *Journal of Statistical Software*