Section A: Project Overview

- Start Date: 1 May 2014
- Completion Date: 30 April 2014

1. Project Name

Systemic risk and contagion effects on risk margins for interrelated financial institutions and sectors

2. Project Summary

The proposed project deals with measuring and quantifying systemic risk, contagion effects and exposure in risk margins for interrelated financial institutions and sectors, and linking the same to external economic shocks. The proposal addresses the issue of assessing the effectiveness of stress testing in group structures as a means of enhancing the resilience of the group, and entities within the group, to financial and economic shocks and limiting intra-group contagion. The project and methodological developments have implications of how APRA and industry can enhance their stress testing procedures and learn more from the results of this testing.

3. Project Team

First Name	Surname	Position	Institution	Team Position	Email
Piet	De Jong	Professor of Actuarial Studies	FBE Macquarie University	Leader	piet.dejong @mq.edu.au
Geoff	Loudon	Associate Professor	FBE Macquarie University	Investigator	geoff.loudon @mq.edu.au
Weihao	Choo	Senior Actuarial Executive	MSIG Holdings (Asia)	Investigator	chooweihao @gmail.com

4. Budget (cash request only):

Year 1 (Total)	
CIFR	Member
$100,000	–

5. Relevant CIFR Key Area of Interest

- Systemic risk

Assessing and the level systemic risk in Australia demands a coherent methodology to measure the same and implement them in the Australian financial system context. A number of methodologies have recently been proposed to assess systemic risk (see references later). The current project aims to critique, improve upon and test these methodologies and apply and implement such improved technologies in the Australian context.

Present regulations are based on standard approaches such as VaR_q. Such regulations and capital requirements are mainly "standalone" where individual industries are analysed on a standalone basis using similar stress scenarios. Non–standalone approaches implicit in systemic risk calculations may lead to different margins, uncover systematic biases or tighter or amplify confidence intervals around margins in line with economic cycle. Both over and underestimation of capital margins impose costs on the economy.

6. Research Proposal of interest to: APRA, RB

The current proposal arises out of the following target areas identified by CIFR and drawn to my attention by Professor David Gallagher:

- Assess the level of systemic risk in the Australian economy and in the ADI, insurance and superannuation industries, and identify potential domestic and external shocks to the Australian economy, and potential methods to protect against or remediate these shocks.
- Assess the effectiveness of stress testing in group structures as a means of enhancing the resilience of the group, and entities within the group, to financial and economic shocks and limiting intra-group contagion.
- Consider how APRA and industry could enhance their stress testing procedures and learn more from the results of this testing.

Contact with other individuals

- APRA – Charles Littrell. On 4 March 2014 the Team Research Leader met the Mr Charles Littrell of APRA to discuss the CIFR target research areas. The discussion ranged over a number of topics related to the same and the attitude APRA may take to any proposals. The discussion also canvassed the need to design appropriate quantitative methodologies and data bases for any empirical assessments.

- RBA – no contact.

7. Capability

- Piet de Jong

Forty years' experience in the quantitative modelling uncertainty and risk including risks arising in insurance (general and mortality), time series dynamics, finance, capital allocation, health economics.

- Geoff Loudon

Extensive experience in conducting and supervising empirical research in finance. Research area includes financial risk management and security pricing, modelling inter-relations among risks, returns and underlying factors, especially during times of market crisis. Expertise in financial econometrics including application of regime-switching models; multivariate GARCH style models; stochastic volatility estimation; etc.

- Weihao Choo

Fully qualified actuary (FIAA) with extensive industry experience in stress testing and capital modelling, liability valuation, portfolio monitoring and pricing, investment modelling, and business planning. Academic research expertise as evidenced in two publications in international journals (exceptional for someone his age). Presently finishing PhD while working in industry. PhD research relates to risk and risk measurement and capital modelling and allocation.

8. Certifications

Certification by Team Leader

I, Piet de Jong, certify that:

- All the details on this FP are true and complete;
- I have notified CIFR of any actual or potential conflicts of interest I may have in relation to the FP and I undertake that, if the FP is successful, I will notify CIFR of any conflicts of interest which arise subsequent to the submission of the FP;
- I will notify CIFR if there are any changes in my circumstances which may impact on my eligibility to participate in, or ability to perform, the project subsequent to the submission of this FP;
- In participating in this FP, I consent to CIFR copying, disclosing and otherwise dealing with information contained in the Proposal, for the purpose of considering this proposal and making decisions as to the funding round;
- All information contained in the FP is both current and accurate;
- The work proposed in this project is not funded elsewhere;
- The work proposed is unique and that it has not been fully or partially completed elsewhere; and
- All named researchers have agreed to participate and agree to an immediate CIFR announcement should funding be approved.

Signature	Name	Position	Date
	Piet de Jong	Professor and Team Leader	03 March 2014

Certification by Organisations contributing to the project

I certify that:

- My organisation supports the FP and will contribute the resources outlined in the FP.
- If teaching relief is requested in the FP the Organisation approves the relief.

Signature	Name	Position	Date

Section B: Project Objectives, Significance and Policy Implications

Our starting point for the proposed research is the recent literature and the CIFR targeted areas and APRA aims and functions. This recent literature includes Adrian and Brunnermeier (2011) Acharya et al. (2012) Acharya et al. (2012) and Brownlees and Engle (2010). The proposed research aims to extend and apply these techniques particularly in relation to the entities regulated by APRA. Thus our broad aim is to develop, implement and bring to bear recent developments in stress testing on the aims of APRA in general and the CIFR targeted research areas detailed above.

Improved measures of contagion and systematic risk

CoVaR_q as proposed in Adrian and Brunnermeier (2011) suffers from a number of difficulties:

- Couched in terms of VaR_q which contains the scale of the original measurements. It is worthwhile to have a scale independent measures.
- Conditioning on $\text{VaR}_{0.5}$ is undesirable and relatively intractable. In our proposed we reference stress with respect to the unconditional VaR_q. This permits a more transparent analysis and estimation.
- Our approach will separate out the effect of marginal distributions and interdependence and econometrically relate these these structures separately to external variables including shocks and drivers of systemic risk.

Significance of the project and policy implications

Understanding the impact of external shocks and how they propagate within the financial system is vital for managing and remediating systemic risk. Effective regulation is dependent upon the development of a robust and reliable set of appropriate risk measures. We propose new measures of systemic risk that relate marginal and joint distributions separately to external drivers. This allows for more cogent and coherent stress testing as it includes the estimation of contagion effects, exposure effects and systemic risk across related entities and different financial sectors. Improved stress testing, estimation of risk effects and transmission of shocks through the financial system will make for more cogent prudential policy, prudential margin setting and better identify sources of risk to the financial system.

Section C: Data, Method and Outputs

Data

Advice and cooperation is requested from appropriate research personal within APRA to assist in both development and implementation. We anticipate that APRA is able to provide additional relevant data that will enhance the practical usefulness of our empirical measures of systemic risk, contagion and its drivers.

Method

Technical background and path to improved stress testing in the context of contagion and external shocks

Our developments will be based on the following definition and econometric implementation:

$$\mathrm{CoV_q}(x,y) \equiv \mathrm{VaR_q}(x|y>q) - \mathrm{VaR_q}(x) \ , \qquad \mathrm{CoV_q}(x) \equiv \mathrm{CoV_q}(x,x) \ . \quad (1)$$

It is shown that (1) is a more robust and extensible definition than has been proposed in the literature and more readily amenable and useful to empirical work.

The proposed research agenda of this project begins by initially considering u and v uniform random variables on $[0,1]$. Then obviously $\mathrm{VaR_q}(u) = \mathrm{VaR_q}(v) = q$. Define $u^+ \equiv \mathrm{VaR_q}(u|v>q)$ as the VaR_q of u given v exceeds its VaR_q:

$$\mathrm{P}(u \le u^+ | v > q) = q \ , \qquad 0 < q < 1 \ . \quad (2)$$

The left hand side equals

$$\frac{\mathrm{P}(u \le u^+, v > q)}{1-q} = \frac{u^+ - C(u^+, q)}{1-q} \ ,$$

where $C(u,v)$ is the joint distribution (copula) of u and v. Rearranging yields

$$u^+ \equiv \mathrm{VaR_q}(u|v>q) = q(1-q) + C(u^+, q) \ . \quad (3)$$

If u and v are independent then $C(u,v) = uv$ and $u^+ = q$. If $u = v$ then $u^+ = q + q(1-q) = 2q - q^2$ and $u^+ - q = q(1-q)$. Thus if u and v are non–negatively related, $0 \le u^+ - q \le q(1-q)$.

- Note $u^+_{t+1} = q(1-q) + C(u^+_t, q)$. Iterate this equation and make C a function of forcing variables. e.g. a Clayton copula where the parameter is a function of forcing variables.

- If u and v are negatively dependent then define

$$\mathrm{CoV_q}(u,v) \equiv -\mathrm{CoV_q}(u, 1-v)$$

In terms of $u^+ \equiv \mathrm{VaR_q}(u|v > q)$, define the contagion effect of v on u as

$$\beta_{uv} \equiv \frac{u^+ - q}{q(1-q)} = \frac{\mathrm{CoV_q}(u,v)}{\mathrm{CoV_q}(v)} \ . \tag{4}$$

Thus β_{uv} is the change in VaR_q of u given v becomes q–stressed as a proportion of the change if $u = v$. For positively dependent random variables $0 < \beta_{uv} \leq 1$ with the lower and upper limits attained under independence and perfect dependence, respectively. If u and v are negatively dependent then $1-1/(1-q) \leq \beta_{uv} < 0$. Negative dependence is not be studied in great detail in this project. Note $\beta_{uv} \neq \beta_{vu}$.

Furthermore we may define quantities such as $u^- \equiv \mathrm{VaR}_q(u|v \leq q)$ measuring the impact of a non distressed state in v. For brevity we do not dwell on these constructs in this writeup although the ramifications and potential uses of these constructs will be investigated in the research.

Contagious stress effects for financial variables and the contagion matrix

We now discuss actual variables on actual scales. Suppose F_x and F_y are the marginal distributions of x and y with $x = F_x^-(u)$ and $y = F_y^-(v)$. Then the contagion effect of y on x is defined as the change in $\mathrm{VaR}_q(x)$ when y becomes q–distressed is equal to

$$\mathrm{CoVaR}_q(x,y) \equiv \mathrm{VaR_q}\{x|y > \mathrm{VaR_q}(y)\} - \mathrm{VaR_q}(x) \tag{5}$$

$$= F_x^-\{q + \beta_{uv} q(1-q)\} - F_x^-(q) \approx \frac{q\beta_{uv}}{\lambda} = \frac{\mathrm{CoV_q}(u,v)}{q'} \ , \tag{6}$$

where $'$ denotes differentiation and λ is the hazard of x at $x = \mathrm{VaR}_q(x)$. If F_x is linear then the approximation is exact. Hence it is appropriate to scale x such that F_x^- is linear in the tail. Rescaling has no effect on the copulas connecting variables.

If x is vector then $\mathrm{CoV_q}(x)$ is the (non–symmetric) matrix with entries $\mathrm{CoV_q}(x_i, x_j)$ and

$$R \equiv \mathrm{CoV_q}(x) = D^{-1} \times \mathrm{CoV_q}(u) \ , \qquad D = \mathrm{diag}\,(q_1', \ldots, q_m') \ ,$$

where m is the number of components in x.

Econometric implementation

The above development provides a framework for linking bivariate copulas and marginals to external variables and shocks study the impact of the same on stresses within the system and the contagious effects of crises. Proposed econometric analysis will be extend upon Brownlees and Engle (2010).

Expected outputs

- Preparation of an industry style report for APRA and other interested regulatory bodies.
- Seminar presentations of report to APRA and other interested regulatory bodies.
- Preparation of academic papers to be presented at relevant conferences and submitted to high ranked, peer-reviewed, international journals.

Bibliography

Acharya, V., R. Engle, and M. Richardson (2012). Capital shortfall: A new approach to ranking and regulating systemic risks. *The American Economic Review 102*(3), 59–64.

Acharya, V., L. Pedersen, T. Philippon, and M. Richardson (2012). Measuring systemic risk.

Adrian, T. and M. K. Brunnermeier (2011). Covar. Technical report, National Bureau of Economic Research.

Brownlees, C. T. and R. Engle (2010). Volatility, correlation and tails for systemic risk measurement. *New York University, mimeo*.

Timetable for the delivery of Outputs

Date	Output	Details (of proposed Output)

Section D: Research Record and References

1. Research Record

- Piet de Jong, Team Leader.

  The following selected publications (in no particular order) detail expertise in designing and, where appropriate, implementing tools to quantify, assess and model uncertainty related to finance, demographics and economics.

  De Jong, P. (2012). Modeling dependence between loss triangles. *North American Actuarial Journal 16*(1), 74–86.

  De Jong, P. (2006). Forecasting Runoff Triangles. *North American Actuarial Journal 10*(2), 28.

  De Jong, P. (1989). Smoothing and interpolation with the state-space model. *Journal of the American Statistical Association 84*(408), 1085–1088.

  De Jong, P. (1991). The diffuse Kalman filter. *Annals of Statistics 19*(2), 1073–1083.

  De Jong, P. and P. Boyle (1983). Monitoring mortality: a state-space approach. *Journal of Econometrics 23*, 131–146.

  De Jong, P. and Chu-Chun-Lin S. (2003). Smoothing with an unknown initial condition. *Journal of Time Series Analysis 24*(2), 141–148.

  De Jong, P. and S. Ferris (2006). Adverse selection spirals. *Astin Bulletin 36*(2), 589–628.

  De Jong, P. and G. Heller (2008). *Generalized Linear Models for Insurance Data*. Cambridge University Press.

  De Jong, P. and C. Marshall (2007). Mortality projection based on the Wang transform. *ASTIN Bulletin* (1), 149–162.

  De Jong, P. and J. R. Penzer (1998). Diagnosing shocks in time series. *Journal of the American Statistical Association 93*(442), 796–806.

  De Jong, P. and N. Shephard (1995). The simulation smoother for time series models. *Biometrika 82*, 339–350.

  De Jong, P. and B. Zehnwirth (1983b). Claims reserving, state-space models and the Kalman filter. *Journal of the Institute of Actuaries 110*, 157–181.

- Geoff Loudon, Principal Researcher

  The following papers detail expertise in econometric and time series analysis in finance and financial risk and regulation.

Liu, J., Loudon, G., Milunovich G., Linkages between international REITs: the role of economic factors, *Journal of Property Investment & Finance, 30*(5), 2012, 473–492.

Dean, W., Faff, R., Loudon, G., Asymmetry in return and volatility spillover between equity and bond markets in Australia, *Pacific–Basin Finance Journal, 18*(3), 2010, 272–289.

Hobbes, G., Lam, F., Loudon, G., Regime shifts in the stock–bond relation in Australia, *Review of Pacific Basin Financial Markets and Policies, 10*(1), 2007, 81–99.

Loudon, G., Okunev, J., White, D., Hedge fund risk factors and the Value–at–Risk of fixed income trading strategies, *The Journal of Fixed Income 16*(2), 2006, 46–61.

Loudon, G., Is the risk–return relation positive? Further evidence from a stochastic volatility in mean approach, *Applied Financial Economics 16*(13), 2006, 981–992.

Loudon, G., Financial risk exposures in the airline industry: evidence from Australia and New Zealand, *Australian Journal of Management 29*(2), 2004, 295–316.

Loudon, G., Watt, W., Yadav, P., An empirical analysis of alternative parametric ARCH models, *Journal of Applied Econometrics 15*(2), 2000, 117–136.

Loudon, G., Foreign exchange exposure and the pricing of currency risk in equity returns: Some Australian evidence, *Pacific–Basin Finance Journal 1*(4), 1993, 335–354.

Loudon, G., The foreign exchange operating exposure of Australian stocks, *Accounting and Finance 33*(1), 1993, 19–32.

Loudon, G., American put pricing: Australian evidence, *Journal of Business Finance and Accounting 17*(2), 1990, 297–321.

- Weihao Choo, Principal Researcher

  An early career researcher with demonstrated capabilities

  Choo, W. and P. De Jong (2009). Loss reserving using loss aversion functions. *Insurance Mathematics and Economics 45*(2), 271–277.

  Choo, W. and P. De Jong (2010). Determining and Allocating Diversification Benefits for a Portfolio of Risks. *Astin Bulletin 40*(1), 257–269.

2. Grants

- Piet de Jong, Team Leader

  Most of my research requires limited money – just lots of time and concentration. Despite this I have held a number of research grants mainly to facilitate my ongoing research program:

  - While at the University of British Columbia from 1982–2001 (Professor of Statistics) I held NSERC operating grants to facilitate my ongoing research program. These are equivalent to ARC discovery grants except that the grant is based on performance rather than detailed aspirations to research one or other issue. The individual research program and operating grant led to many highly cited publications in A* international academic journals.
  - While at the University of Amsterdam (Visiting Research Fellow) in 1987 I was funded under the Dutch government's ZWO initiative. This led to a number of world class highly cited academic publications.
  - While at the London School of Economics (Reader in Statistics) from 1995-1998. I held NSERC operating grants. Again this led to a number of highly cited A* international academic publications.
  - While at Macquarie University 2003-2014 (Professor of Actuarial Studies) I have held grants from Macquarie University (jointly funded with APRA) and the Institute of Actuaries. Again this has led to my more recent A* international publications including a jointly authored book published by Cambridge University Press.

- Geoff Loudon, Principal Researcher

  No recent grants

- Weihao Choo, Principal Researcher

  Early stage researcher. Just now finishing PhD.

Section E: Detailed Budget and Justifications

Expenditure	Year 1 – Total			
	Cash (CIFR)	Cash (Member)	In Kind	Other
Staff – Teaching relief for De Jong for 2 months, 28% for oncosts & 30% infrastructure: $172,363 \times 1.28 \times 2/12 \times 1.3$ – Teaching relief for Loudon for 1 month1, 28% for oncosts & 30% infrastructure: $135,000 \times 1.28 \times 1/12 \times 1.3$			47,802 18,720	
Equipment Computer and related items	2,500	2,500		
Data				
Travel 2 researchers x 2 conferences	10,000	10,000		
Fellowships Weihao Choo	25,000	25,000		
Scholarships				
Research Assistant Cash: RA, top of Level 6 band grossed up by on costs, 3 days pw: $66487 \times 1.28 \times 0.6$ In kind: Infrastructure @ 30% : $51,062.02 \times 0.3$	25,531	25,531	15,319	
Other costs				
Total				

Basis for teaching-relief request

De Jong requests funding for two months teaching relief, during the second half of 2014. The purpose is to give effective direction to the project for a period without the burden of teaching and convening courses.

Loudon requests funding for one month of teaching relief, during the second half of 2014. This will free up additional time for him to be more fully involved in the project.

Basis for RA request

A research assistant at the top of the Level 6 band is required for data analysis and assistance with programming. His or her tasks will be supervised by the researchers, and the appointment would be for 3 days per week for the

duration of the project. The tasks are twofold. The first is to gather appropriate data and secondly to program methods in R.

Basis for Fellowship request

The fellowship will facilitate one of the researchers (Weihao Choo) to devote appropriate time to the project.

Basis for Travel request

Present research at two international conference. Note that workshopping the paper with industry practitioners and researchers at one international conference is required to maximise the impact of this research.