

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

An Examination of Bank Risk Measures and their Relationship to Systemic Risk Measurement

A dissertation presented in partial fulfilment of the requirements

for the Degree of

Doctoral of Philosophy

in

Finance

at Massey University, Manawatu (Turitea),

New Zealand

Xiping Li

2018

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

Abstract

This research explores ways of measuring bank risk, both individual bank risk and systemic risk, with the main focus on z-score. Z-score is a popular indicator of individual bank risk-taking. Despite its popularity among academics, there is a lack of consensus on a standard way to construct a time-varying z-score measure. Meanwhile, in the post-GFC period, increasing attention has been given to macro-prudential policy and its role in mitigating systemic risk.

This research discusses major challenges in existing approaches to the construction of time-varying z-score measure. It empirically compares these approaches using quarterly data of New Zealand banks. Both conceptual discussions and empirical analyses support the use of a rolling window in the computation of time-varying z-score, which is consistent with changing bank risk profiles through time. This research is also the first study to propose a risk-weighted z-score measure.

This research further proposes a new systemic risk measure based on z-score, which is developed on the concept of Leave-One-Out (LOO) approach. The systemic risk contribution of an individual bank can be captured by the variation of risk-taking of a banking system when excluding the particular bank. The LOO z-score measure can be computed using accounting information only, and is therefore applicable to both listed and unlisted banks. Empirical analysis on the LOO z-score measure in assessing banks' systemic risk contribution is first applied to the New Zealand and Australian markets, and then extended to an international sample including 17 countries. The LOO z-score measure is proved to be useful for assessing banks' systemic risk contribution, with a positive rank correlation with Marginal Expected Shortfall (MES) and Delta Conditional Value-at-Risk (ΔCoVaR).

The LOO z-score measure provides a new approach to assess systemic risk contribution using accounting data, which can be used as a complement to market-based approaches. This measure is especially useful for systemic risk analyses of banks with limited or even no share market data at all, which is the key advantage. The ability to include both listed and unlisted banks in the evaluation of systemic risk is fundamental in macro-prudential policy frameworks.

Acknowledgement

I wish to acknowledge all the people who have supported and assisted me in getting this research completed.

First of all, I would like to express my most sincere gratitude to my family, especially my parents and my beloved daughter, without whose love and support, I could not have completed the work. Words cannot fully express my gratitude to my parents, and I would like to dedicate this thesis to my parents for their consistent and unconditional love and support.

My particular thanks go to my supervisors Associate Professor David Tripe, Dr David Smith, and Dr Chris Malone for their invaluable guidance, encouragement and patience throughout my PhD journey. I am especially grateful for their always prompt responses to my questions and timely feedback on my work. It is due to their guidance that I have been able to complete my PhD qualification in time. I am extremely thankful to my main supervisor Associate Professor David Tripe for his expert guidance since my Masters study. David is so knowledgeable about all banking and financial stability related research, and has always given me useful comments and suggestions, which help me a lot to complete this research. Thank you, David!

I would also like to express my thanks to all my teachers who have taught me in schools and universities in China and New Zealand. They all play an important role that teaches me to be a good person and makes me capable of completing this ambitious project.

I am also grateful to School of Economics and Finance at Massey University for providing a wonderful place to study and for funding me to attend several local and overseas conferences. Thanks also go to Head of School, Professor Martin Young, and all the staff of the School, particularly Fong Mee Chin, Cameron Rhodes, Sue Edwards, Maryke Bublitz, and Mui Kuen Yuen for providing data source, technical and administrative support.

I would like to acknowledge Markus Brunnermeier, Thorsten Beck, Jonathan Batten, Prasanna Gai, David Mayes, Kent Matthews, Alistair Milne, Martien Lubberink, Shams

Pathan, Mamiza Haq, and Shrimal Perera for their valuable comments and suggestions on the thesis. I also owe thanks to the discussants and participants at the 2016 29th *Australasian Finance & Banking Conference*, the 2017 21st *New Zealand Finance Colloquium*, the 2017 *European Financial Management Symposium on Finance and Real Economy*, the 2017 8th *Conference on Financial Markets and Corporate Governance*, and the 2017 7th *International Conference of the Financial Engineering and Banking Society*, the 2017 7th *Auckland Finance Meeting*, and the seminar participants at Reserve Bank of New Zealand, who provided comments and suggestions on the thesis.

Finally, I would like to thank all my PhD fellows, particularly Bilal Hafeez, Feng (Jennifer) Xie, and Khairul Zharif Zaharudin. I am grateful to Jennifer for her company throughout my PhD journey. Special thanks go to Bilal, Zharif, as well as Zharif's wife Nor Elliany Hawa Ibrahim, for long discussions not only on research problems but also on attitudes towards life. Their company makes my final year PhD unforgettable. I also appreciate all my friends in China, who, despite long distance, consistently encourage me to accomplish this PhD project.

Table of Contents

Abstract.....	i
Acknowledgement	ii
List of Tables	vii
List of Figures	ix
Chapter One: Introduction.....	1
1.1 Background	1
1.2 The problems	2
1.3 Aim and objectives of this research.....	4
1.4 Contributions of this research	5
1.5 An outline of the dissertation	6
Chapter Two: Literature review	7
2.1 Studies on individual bank risk	7
2.1.1 Measurement of bank risk at individual bank level.....	7
2.1.2 Measurement of bank credit risk and market risk	8
2.2 Studies on z-score	10
2.3 Studies on systemic risk	13
2.3.1 Sources of systemic risk	13
2.3.2 Measurement of systemic risk.....	16
2.3.2.1 Regulatory data-based approaches	16
2.3.2.2 Share market data-based approaches.....	17
Chapter Three: Time-varying z-score, aggregate z-score and Leave-One-Out z-score measures.....	25
3.1 Challenges with the time-varying z-score measure.....	25
3.1.1 Approaches to constructing the time-varying z-score measure	25
3.1.2 Challenges in the computation of the time-varying z-score measures.....	28
3.2 Construction of country aggregate z-score	30
3.3 Conceptual background of Leave-One-Out z-score.....	31
Chapter Four: Measuring bank risk: An exploration of z-score.....	34
4.1 Research focus	34
4.2 Data and methodology	37

4.2.1 Sample and data	37
4.2.2 Methodology.....	39
4.2.2.1 Measuring individual bank risk	39
4.2.2.2 Development of the LOO z-score systemic risk measure	43
4.2.2.3 Testing the predictive ability of the LOO z-score measure	44
4.2.2.4 Comparisons between z-score and other risk measures.....	45
4.3 Core results	47
4.3.1 Evaluating different time-varying z-score measures for New Zealand banks.....	47
4.3.2 Comparison between z-score and accounting-based risk measures, New Zealand banking market	51
4.3.3 Comparison between z-score and market-based risk measures, Australian banking market.....	56
4.3.4 Measuring systemic risk using z-score.....	62
4.3.5 Predictive ability of the LOO z-score measure	67
4.3.6 Impact of window lengths on time-varying z-scores.....	68
4.3.7 Extension of z-score: risk-weighted z-score	77
4.3.8 Decomposition of z-score	86
4.4 Robustness checks, using approaches Z3 and Z4	92
4.5 Conclusions	99
Chapter Five: Investigation of systemic risk contribution using an accounting based measure	101
5.1 Research focus	101
5.2 Data and methodology	102
5.2.1 Sample and data	102
5.2.2 Methodology.....	108
5.2.2.1 Construction of LOO Z-score systemic risk measure	108
5.2.2.2 Market-based systemic risk measures	110
5.3 Core results	114
5.3.1 Systemic risk contribution of individual banks using the LOO z-score measure, global perspective.....	114
5.3.2 Systemic risk contribution of groups of banks, global perspective	122
5.3.3 Assessing systemic risk contribution, individual country-level	126

5.3.4 Market data-based systemic risk measures	131
5.3.4.1 Systemic risk contribution based on ΔCoVaR	132
5.3.4.2 Systemic risk contribution based on MES.....	138
5.3.4.3 Systemic risk contribution based on SRISK	143
5.3.5 Comparisons between the LOO z-score and market-based systemic risk measures...	149
5.4 Robustness checks	155
5.5 Conclusions	167
Chapter Six: Summary and conclusion	169
6.1 A review of this research	169
6.2 Limitations of this research.....	172
6.3 Future research challenges and opportunities	173
Appendix	175
References	182

List of Tables

Table 1 – Summary statistics of individual z-scores for New Zealand banks, quarterly data	.49
Table 2 – Summary statistics of individual z-scores for New Zealand banks, annual data	.....50
Table 3 – Mean value of different account-based risk measures, New Zealand banks	.....53
Table 4 – Correlations between z-score and different risk measures, New Zealand banks	...55
Table 5 – Summary statistics of different risk measures, Australian banks	.....59
Table 6 – Correlations between accounting data based z-scores and market data based risk measures, Australian banks	.....60
Table 7 – Summary statistics of aggregate z-score and minus one z-scores for New Zealand banks, quarterly data	.....62
Table 8 – Summary statistics of aggregate z-score and minus one z-scores for Australian banks, annual data	.....65
Table 9 – Time series correlation with aggregate deposits	.....67
Table 10 – Comparison based on 3 to 6 year rolling windows, New Zealand banks, using approach Z1 and quarterly data	.....73
Table 11 – Mean values of aggregate z-score and coefficient of variation, rolling window	...75
Table 12 – Components of risk-weighted z-score, New Zealand banks	.....77
Table 13 – Summary statistics of risk-weighted z-scores, New Zealand banks	.....79
Table 14 – Summary statistics of risk-weighted z-scores, Australian banks	.....83
Table 15 – Correlations among different components of z-score, Lepetit and Tarazi method of decomposition	.....87
Table 16 – Correlations among different components of z-score, simple decomposition into elements of z-score	.....91
Table 17 – Summary statistics of individual z-scores, aggregate z-score, and minus one z-scores for New Zealand banks, using approaches Z3 and Z4	.....94
Table 18 – Correlations among different components of z-score, using approaches Z3 and Z4	.....98
Table 19 – List of banks	.....104
Table 20 – Summary statistics of U.S. state variables	.....108
Table 21 – Summary statistics of individual z-score, aggregate z-score and minus one bank z-score, global perspective	.....115

Table 22 – Summary statistics of z-scores for minus one group of banks	123
Table 23 – Summary Statistics of country aggregate z-scores and domestic systemic significance, country-level perspective	128
Table 24 – Rankings of banks’ contributions to systemic risk, based on ΔCoVaR	133
Table 25 – Rankings of countries’ contributions to systemic risk, based on ΔCoVaR	136
Table 26 – Rankings of banks’ contributions to systemic risk, based on MES	139
Table 27 – Rankings of countries’ contributions to systemic risk, based on MES.....	141
Table 28 – Rankings of banks’ contributions to systemic risk, based on SRISK%.....	145
Table 29 – Rank correlations among MES, ΔCoVaR , and SRISK for individual banks.....	151
Table 30 – Rank correlations of MES, ΔCoVaR , SRISK, and Δz -score for individual banks	153
Table 31 – Rankings of banks’ contributions to systemic risk, using range-based z-score measure	156
Table 32– Rankings of banks’ contributions to systemic risk, non-U.S. sample.....	159
Table 33 – Rank correlations of MES, ΔCoVaR , SRISK and Δz -score for individual banks, non-U.S. sample.....	161
Table 34 – Rankings of banks’ contributions to systemic risk, based on ΔCoVaR , MES, and SRISK%, respectively, using GDP-weighted MSCI Index	163
Table 35 – Rank correlations of MES, ΔCoVaR , SRISK and Δz -score for individual banks, using GDP-weighted MSCI Index.....	165

List of Figures

Figure 1 – Trends of individual z-scores for New Zealand banks.....	48
Figure 2 – Trends of different accounting-based risk measures, New Zealand banks.....	53
Figure 3 – Trends of different risk measures, Australian banks	58
Figure 4 – Trends of aggregate z-score and minus one z-scores for New Zealand banks.....	63
Figure 5 – Trends of aggregate z-score and minus one z-scores for Australian banks	66
Figure 6 – Aggregate deposits of New Zealand banks.....	68
Figure 7 – Trends of individual z-scores, aggregate z-scores, and minus one z-scores, with 3-year to 6-year window lengths	72
Figure 8 – Mean value of aggregate z-scores with rolling windows, New Zealand banking market.....	76
Figure 9 – Trends of risk-weighted z-scores, New Zealand banks.....	80
Figure 10 – Trends of risk-weighted z-scores, Australian banks	85
Figure 11 – Decomposition of aggregate z-score, Lepetit and Tarazi method of decomposition, New Zealand market.....	88
Figure 12 – Trends of ROA and standard deviations of ROA, New Zealand banks	89
Figure 13 – Decomposition of aggregate z-score, simple decomposition into elements, New Zealand market	90
Figure 14 – Trends of individual z-scores, aggregate z-scores, and minus one z-scores, using approaches Z3 and Z4.....	96
Figure 15 – Aggregate z-score of the sample	118
Figure 16 – Relationship between total assets and %Change of z-score	120
Figure 17 - Trends of country aggregate z-scores	127
Figure 18 – Systemic risk contributions of each country, based on ΔCoVaR	137
Figure 19 – Systemic risk contributions of each country, based on MES.....	142
Figure 20 – Aggregate SRISK of the sample	148