

**Trading and Economic Efficiency in Selected Victorian
Water Markets in Australia**

By

Tong Geng LIANG

This thesis is presented for the degree of Doctor of Philosophy of

Murdoch University

In October 2013

MURDOCH UNIVERSITY

Faculty of Law and Business

School of Business

Declaration

I declare that this thesis is my own account of the research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institutes.

Made By

Tong Geng LIANG

In October 2013

Signature: _____

TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	X
ABSTRACT	XII
CHAPTER 1: INTRODUCTION	1
1.1 Background	1
1.2 Objectives of the Research and Key Research Questions.....	5
1.3 The Significance of the Study.....	7
1.4 The Data Used and Approach.....	8
1.5 Thesis Structure and Outline.....	10
CHAPTER 2: ECONOMIC THEORY OF THE EFFICIENT ALLOCATION OF WATER RESOURCES.....	14
2.1 Introduction	14
2.2 Classification of Goods.....	16
2.2.1 Private Goods and Public Goods	17
2.2.2 Quasi Public Goods	20
2.3 Water Marketing.....	21
2.4 Efficient Allocation of Water Resource as a Private Good.....	24
2.4.1 The Efficient Allocation of Water Resource with Supply Constant	24
2.4.2 The Efficient Allocation of Water Resource with Supply Change	26
2.4.3 Efficient Market Hypothesis and Water Resources Allocation	28
2.5 Water Resource Allocation with Negative Externality.....	29
2.6 Market Structures and Their Efficiency.....	32
2.7 Natural Monopoly and Its Efficiency	38
2.8 Ground Water Resources Efficiency Allocation.....	41

CHAPTER 3: WATER RIGHTS SYSTEMS AND INSTITUTIONS GOVERNING

WATER RIGHTS IN AUSTRALIA.....	45	
3.1	Introductio	45
3.2	Water Rights Systems and Efficiency Allocation Analysis.....	47
3.2.1	Water Rights and Water Rights Systems	47
3.2.2	Riparian Water Rights System.....	50
3.2.3	Appropriative Water Rights System	51
3.2.4	Legislative Water Rights System.....	53
3.2.5	Economic Efficiency Analysis of the Three Water Rights Systems	55
3.3	Legislative Basis of Water Rights in Eight Jurisdictions in Australia	61
3.3.1	New South Wales	61
3.3.2	Victoria	65
3.3.3	Western Australia	68
3.3.4	Queensland	71
3.3.5	South Australia	75
3.3.6	Tasmania.....	78
3.3.7	Northern Territory	82
3.3.8	Australian Capital Territory.....	86
3.4	Updated water policy and legal frame in Australia.....	89
3.5	Conclusion.....	95

CHAPTER 4: IRRIGATION WATER DEMAND, SUPPLY, MARKETS AND

TRADING IN AUSTRALIA.....	99	
4.1	Introduction.....	99
4.2	Demand and Supply and Elasticity for Irrigation Water.....	101
4.2.1	Determination of Demand for Irrigation Water and Elasticity of Demand.....	101
4.2.1.1	Determination of Demand for Irrigation Water.....	101
4.2.1.2	Elasticity of Demand for Irrigation Water.....	105
4.2.2	Supply for Irrigation Water and Water Rights Market Supply	110

4.2.3	Market Price for Irrigation Water Rights.....	111
4.3	Water Markets in Australia.....	116
4.3.1	Evolution of Water Markets in Australia.....	116
4.3.2	Auction Markets for Water Trading	119
4.3.3	Water Trading Rules and Institutional Arrangements	122
4.3.4	Water Trading in Victoria.....	128
4.3.5	The Watermove Market in Victoria.....	130
4.4	Contestability Analysis of the Water Market in Victoria.....	134
4.4.1	Contestable Market Theory	134
4.4.2	Analysis of Characteristics of Water Markets against Contestable Market Assumptions ...	138
4.4.3	Factors that Constrain the Economic Efficiency of Water Markets in Victoria.....	142
4.5	Conclusion.....	148

CHAPTER 5: MARKET CONCENTRATION AND COMPETITIVENESS

ANALYSIS OF WATER MARKETS IN VICTORIA 151

5.1	Introduction.....	151
5.2	Description of the Empirical Data and Hypotheses.....	153
5.2.1	Description of the Empirical Data Used	153
5.2.2	Key Research Questions and Motivation.....	155
5.3	Market Size and Depth of the Three Water Markets Analysis	157
5.3.1	Market Size and Depth	157
5.3.2	Buyers and Sellers Surplus	165
5.4	Market Concentration and Competition Analysis of the Three Water Markets.....	168
5.4.1	Concentration Ratio Analysis	173
5.4.2	Herfindahl–Hirschman Index Analysis.....	176
5.4.3	Gini Coefficient Analysis	178
5.5	Conclusion.....	180

**CHAPTER 6: THE MARKETS EFFICIENCY EVALUATION OF VICTORIAN
WATER MARKETS.....182**

6.1	Introduction	182
6.2	Hypothesis Questions and Approaches.....	184
6.2.1	Hypothesis Questions and Motivations.....	184
6.2.2	Market Efficiency Analysis Using Efficient Market Hypothesis.....	185
6.3	Description of the Empirical Data	187
6.4	The Volatility of Water Prices	189
6.4.1	Descriptive Analysis.....	189
6.4.2	Bartlett’s Test for Price Volatility for the Period of August 2002 to June 2009.....	192
6.4.3	One way ANOVA for Water Prices in the Markets.....	197
6.5	Stationarity Tests of the Water Prices Time Series.....	199
6.6	White Noise Process Tests of the Water Prices in the Three Water Markets	203
6.7	Testing for Random Walks of the Water Prices Time Series	205
6.8	Zivot and Andrews Unit Root Test with One Structural Break.....	210
6.9	Lee and Strazicich LM Unit Root Test with One and Two Structural Break(s).....	213
6.10	Co-integration Tests of the Water Prices in the Three Water Markets	217
6.11	Conclusion	220

**CHAPTER 7: ESTIMATION OF THE ELASTICITY OF WATER DEMAND FOR
VICTORIAN WATER MARKETS.....223**

7.1	Introduction	223
7.2	The Irrigation Water Demand Model and Hypotheses Questions	224
7.2.1	The Irrigation Water Demand Model and Variables and Method.....	224
7.2.2	Hypothesis Questions or Key Research Questions	229
7.2.3	Data Descriptions and Sample Design.....	230
7.3	Water Demand OLS Models and Methods of Tests and Diagnoses	241
7.3.1.	Water Demand Short and Long Run OLS Models	241
7.3.2.	Methods of Tests and Diagnoses	246

7.4	Estimation, Tests, Diagnoses and Implications of Water Demand OLS Regression Models for the Three Water Markets	248
7.4.1.	Estimation of Water Demand OLS Regression Model for the Three Markets	248
7.4.2.	Heteroscedasticity and Autocorrelation Diagnostic Tests	254
7.4.3.	Performance Test and Implications Analysis.....	259
7.5	Conclusion.....	266
CHAPTER 8: CONCLUSION.....		269
8.1	Summary of this Research	270
8.2	Contribution of this Research	271
8.3	Further Research in the Field.....	277
REFERENCES.....		279
APPENDIX.....		I
Appendix - 1	Map of Northern Victorian Regulated Trading Zones	I

LIST OF TABLES

Table 2-1: Classification of Goods	17
Table 2-2: Market classification base on traders' influence in terms of price in a market	33
Table 2-3: Market structure classification in imperfect market situation	34
Table 3-1: Commonwealth Parties and Legislations in the Australian Water Market.....	92
Table 3-2: Legislations Related to Water Resources in Australia	98
Table 4-1: Allocation Trade from 2007/08 to 2011/12.....	129
Table 4-2 Seller's Schedule.....	132
Table 4-3 Buyer's Schedule	133
Table 4-4 Trading Constraints in the Allocation Market due to Physical Factors	143
Table 5-1: Descriptions of Seller Key Variables of Weekly Data	154
Table 5-2: Descriptions of Buyer Key Variables of Weekly Data.....	154
Table 5-3: Sizes of the Three Water Markets	158
Table 5-4: Number of Traders in the Three Markets	159
Table 5-5: Annual Water Supply and Demand in the Three Markets.....	163
Table 5-6: Weekly Average Water Price and Quantity Traded in the Three Markets	164
Table 5-7: Weekly Average Surplus of Successful Sellers and Buyers in the Three Markets	167
Table 5-8: Concentration Ratio for the Largest Four Sellers or Buyers in the Three Markets	173
Table 5-9: Concentration Ratio for the Largest Four Sellers or Buyers	175
Table 5-10: Herfindahl-Hirschman Index (HHI) of Water Offered to Sell or Buy	176
Table 5-11: Herfindahl-Hirschman Index (HHI) of Water Traded.....	177
Table 5-12: Gini Coefficient Based on Traders' Traded Data.....	179
Table 5-13: Gini Coefficient Based on the Data of Traders' Offers to Trade	180
Table 6-1: Descriptive Statistics of Weekly Water Prices for the Three Markets	190
Table 6-2: Descriptive Statistics of Weekly Quantities for the Three Trading Regions.....	191
Table 6-3: Summary of Weekly Water Prices in the Three Markets.....	198
Table 6-4: One Way ANOVA Results of the Three Markets ($\alpha = 0.05$).....	198
Table 6-5: White Noise Processes Test Results for the Three Water Markets	204
Table 6-6: OLS Unrestricted and Restricted Regressions of the Three Water Markets	208

Table 6-7: The Results of the ADF Unit Root Tests for the Three Markets.....	209
Table 6-8: Zivot-Andrews test results with one structural break.....	213
Table 6-9: Lee-Strazicich LM test results with one structural break.....	216
Table 6-10: Lee-Strazicich LM test results with two structural breaks.....	216
Table 6-11: The Statistics of Regressors of OLS Co-integration of Regression for the Three Markets.....	218
Table 7-1: The Descriptions of the Demand Variables.....	231
Table 7-2: Quantity of Demand is Greater than the Quantity of Supply at the Pool Price.....	236
Table 7-3: Quantity of Supply is Greater than the Quantity of Demand at the Pool Price.....	237
Table 7-4: Sample Distribution for the Period September 2002 to June 2009.....	238
Table 7-5: Statistics of Logit Models for the Three Water Markets.....	241
Table 7-6: Log Linear Water Demand Regression Regressors and Statistics of the Three Markets.....	251
Table 7-7: Log Linear Water Demand Regression Regressors and Statistics of the Three Markets.....	252
Table 7-8: Change in Demand for Water of the Three Markets.....	260
Table 7-9: Comparison of the Results of Testing the Demand Model with Actual Data.....	263

LIST OF FIGURES

Figure 2-1: Two Consumers' Demand Curves Comparison.....	19
Figure 2-2: An illustration of Two Water Uses	25
Figure 2-3: The Efficient Allocation of Surface Water with Supply Change.....	27
Figure 2-4: Two Water Users with External Cost	31
Figure 2-5: Comparison of Monopoly and Monopsony with Perfect Competition	37
Figure 2-6: Long-run Equilibrium of a Natural Monopolist.....	40
Figure 2-7: Optimal Ground Water Depletion Model in Competitive and Monopolistic Markets.....	43
Figure 3-1: The Flow Chart of the Institutions of Water Allocation in NSW	64
Figure 3-2: The Flow Chart of Institutions of Water Allocation in Victoria	66
Figure 3-3: The Flow Chart of Institutions of Water Allocation in Western Australia	69
Figure 3-4: The Flow Chart of Institutions of Water Allocation in Queensland	74
Figure 3-5: The Flow Chart of Institutions of Water Allocation in South Australia	78
Figure 3-6: The Flow Chart of Institutions of Water Allocation in Tasmania.....	82
Figure 3-7: The Flow Chart of Institutions of Water Allocation in NT.....	84
Figure 3-8: The Flow Chart of Institutions of Water Allocation in ACT	88
Figure 4-1: Factor Demand for Water Used as an Input in Agriculture.	103
Figure 4-2: Irrigation Water Entitlements Demand and Supply and Equilibrium	113
Figure 4-3: Welfare Effects of Negative Externality in a Competitive Water Market	145
Figure 5-1: Weekly Average Supply and Demand (ML) for 2002/03 to 2008/09.....	162
Figure 5-2: Weekly Average Water Price and Quantity Traded for 2002/03 to 2008/09	164
Figure 5-3: Buyers' and Sellers' Surplus in Water Market	166
Figure 5-4: Lorenz Curve and Gini Coefficient for a Water Market	171
Figure 5-5: Herfindahl Hirschman Index.....	177
Figure 6-1: Actual Weekly Water Prices in the Three Markets.....	191
Figure 6-2: Weekly Moving Average Water Prices with 4 Intervals in the Three Markets	192
Figure 6-3: Wheat Prices for the Period of 8/1/2004 to 23/7/2009 in Australia (\$ per bushel)	196
Figure 6-4: Autocorrelation Function of Water Prices for GG.....	200
Figure 6-5: Autocorrelation Function of Water Prices for VMDB.....	201

Figure 6-6: Autocorrelation Function of Water Prices for BN	201
Figure 6-7: Autocorrelation Function of First Difference for GG	202
Figure 6-8: Autocorrelation Function of First Difference for VMDB	202
Figure 6-9: Autocorrelation Function of First Difference for BN	202
Figure 7-1: An Illustration of Two Cases	235
Figure 7-2: GG Scattered Quantity of Water Traded on Demand Curve.....	239
Figure 7-3: BN Scattered Quantity of Water Traded on Demand Curve.....	240
Figure 7-4: VMDB Scattered Quantity of Water Traded on Demand Curve	240
Figure 7-5: Plot of Residuals and the Autocorrelation Function for GG Market.....	256
Figure 7-6: Plot of Residuals and the Autocorrelation Function for BN Market.....	256
Figure 7-7: Plot of Residuals and the Autocorrelation Function for VMDB Market	257
Figure 7-8: Plot of Actual and Fitted Values of the Three Markets.....	262

ACKNOWLEDGEMENTS

This thesis is the research outcome of my over ten years' effort¹ from 2002 to 2013 on a part time basis. During these years I have worked for three state government agencies in Western Australia; the Office of Water Regulation, the Economic Regulation Authority, and the Department of Health on a full time basis. It proved to be a long journey for me, but I enjoyed overcoming the difficulties and challenges throughout my study. Despite some tough times, I eventually achieved my goal in the end. I would like to say here that this thesis would not have been possible without the help of many people during the course of my study, and it is a pleasure to thank those who made this thesis possible. If there are any merits in this study, they are in large measure due to them.

First and foremost, I owe my highest gratitude to my principle supervisor Professor Gavin Wood of RMIT University. I deeply appreciate all his contributions of time, ideas and advice to make my Ph.D. experience both productive and stimulating. I particularly appreciated that Dr. Gavin did not cease supervising me, but continued his supervision following his move to Melbourne from Perth in 2004. It has been an honour and an unforgettable experience for me to have been one of his Ph.D. students. I have learned so much from him, not only his high level of logical thinking and academic analytical skills, but also his rigorous scientific attitudes towards research.

I also would like to express my gratitude to my secondary supervisor, Dr. Kumar Sathiendrakumar of Murdoch University, for his help, support and contribution. I deeply appreciate his time, guidance and patience during all these years, particularly over the last

¹ I suspended for six months during the study period.

three years. In addition, I would like to thank Dr. Frank Harman, who was my first supervisor for a short period, for his contributions in determining my research direction and topic.

I have received a lot of help in improving my writing skills from the Student Learning Centre at Murdoch University. I would specifically like to thank Mr. Colin Beasley and Dr. Julia Hobson for their help and support. I must also thank my colleagues in the Industrial Relations Service of the Department of Health for their encouragement, understanding and support. I particularly would like to thank Mr Ron Gabelish and Mrs Sasha Gabelish, for their contribution in editing and proofreading of the thesis.

I would like to thank Professor Henning Bjornlund, Professor Andrew Worthington and Professor Lin Crase for their valuable comments and suggestions so that I can revise and improve the quality of this thesis. I am very much encouraged by their positive comments and assessments. I also would like to thank Professor Harry Block for his precious advice and supervision during the revision process.

I wish to sincerely thank my wife, Qi Shi, for her understanding, support and patience as I undertook this work, as well as my lovely daughter Lena Liang for her spiritual support for these years. Finally, I would like to thank my parents and my brother for their long term encouragement, love and support.

ABSTRACT

Optimal allocation of irrigation water is a modern economic and social concern of growing importance in Australia, as well as in many other countries. The market based mechanism has been advocated in the economics literature as an efficient and effective measure for allocation of irrigation water. Water markets and water rights trading have been operating for many years aiming to improve the efficiency of water allocation in the Murray–Darling Basin (MDB) in Australia. Several stages of the Council of Australian Government's water reform agenda have been implemented. Water right and land ownership have been separated so that allocations or entitlements of water rights become transferable. Farmers can therefore trade their water rights in water markets without having to transfer their land ownership.

Few empirical studies have been conducted into the efficiency and effectiveness of water markets. This study examines economic efficiency, competitiveness, and irrigators' response to the changes of economic and non economic variables in allocation water markets in Victoria that permit trading in irrigation water rights.

This study begins with an analysis of the economic theory of efficient allocation of water, the theory of goods underlying water markets, the public and private nature of these markets, along with attention of externalities, market structures and the role of natural monopolies in water industry. It provides an examination of the systems of water rights found in the literature, a discussion of the legislative basis of the water right systems that govern access to and use of irrigation water in each of Australian states and territories including the institutional arrangements shaping trade in Victorian water markets. The

legislative water right in Australia is the contemporary water allocation system and governs water entitlements and allocations. Water rights are essentially a bundle of entitlements that define the rights, privileges and limitations for the use of the water of an owner. The characteristics of water rights include universality, exclusivity, transferability and enforceability. In Victoria, under the *Water (Resource Management) Act 2005*, new regulations were issued, and a number of major changes to the water trading landscape were made, including the creation of an environmental water reserve; the unbundling of existing water entitlements into water shares, and the creation of the Victorian water register. On a national level, the key water policies are specified in the National Water Initiative in 2004. The *Water Act 2007* (Commonwealth) secures the water supply and water allocation equitably including the allocation for the riverine environment in MDB.

The demand and supply for irrigated water, the markets for water rights trading and the contestability of Australian water markets is analysed. Also, the existing water market mechanisms and trading including the evolution of the markets, their structure, and the trading rules and institutional arrangements in the Murray–Darling Basin region in Australia is described. The Murray–Darling Basin region is the most active region of irrigation water trading in Australia. The relevance of the determinants of demand and supply for irrigation water and the price elasticity of demand are discussed. The auction form of water trading in the water market is also described, and the Watermove water market in Victoria is analysed.

Empirical evidence on the economic efficiency of three water markets in northern Victoria is provided. The stochastic time series properties of water prices are established through statistical tests commonly used to evaluate market efficiency in financial and

commodity markets. The random walks of the stochastic properties of water price time series for the three markets are tested. The results of Augmented Dickey–Fuller’s unit test, Zivot and Andrews unit root test with one structural break, and Lee-Strazicich LM unit root test with one structural break and two structural breaks suggest that the water price time series in the three markets that the water price time series are non stationary and follow random walks. The findings are very important, and prove that the three markets are efficient according to the theory of Efficient Market Hypothesis since the water prices cannot be predicted based on the available market information for traders.

More conventional scrutiny of industry efficiency is achieved through measures of the size distribution of firms. The measures which include concentration ratio, Herfindahl–Hirschman index, and Gini coefficient, are applied to analyse the three markets’ concentration and competitiveness in terms of the market size, the number of traders who participated, the number of successful traders, and the quantity of water traded. These measures for the three water markets have consistent results. The outcomes of the three measures in the market structure, and the competitiveness for the three markets suggest that there are no monopolies and oligopolies in supply, and there are no monopsonies and oligopsonies in demand in the three water markets. Also, the outcomes of the analyses suggest that there are many irrigators participating in the three water markets, either as sellers or buyers, and they are price takers. However, one market is a relatively moderate concentrated market and a monopolistic competitive. The results suggest that the three water markets are between perfect competition and monopolistic competition.

Finally, models of water demand for the three water markets are developed and estimated with a view to measuring the strength of price and non-price factors driving changes in

the demand for irrigation water. The estimated OLS models of demand for water for the three water markets in this study suggests that the macro economic variables in relation to agriculture including the rural commodity index, the rural GDP and the rural export in Australia do not have influence on the demand for water in the three water markets. The estimated water demand models for the three water markets show that the evaporation has positive impact on the demand for water, and the water price and the rainfall have negative impact on the demand for water. The findings are consistent with the economic logic. The findings suggest that the direct explanatory variables, the water price, the rainfall and the evaporation, influence the demand for water in the three water markets, but they are water demand inelastic.