

**An Application of Cooperative Game Theory:
Strategic Investments in the Natural Gas
Network**

DISSERTATION

zur Erlangung des akademischen Grades
doctor rerum politicarum
(Doktor der Wirtschaftswissenschaft)

eingereicht an der

**Wirtschaftswissenschaftlichen Fakultät
der Humboldt-Universität zu Berlin**

von

M.Sc. Onur Cobanli

Präsident der Humboldt-Universität zu Berlin:

Prof. Dr. Jan-Hendrik Olbertz

Dekan der Wirtschaftswissenschaftlichen Fakultät:

Prof. Dr. Ulrich Kamecke

Gutachter:

1. Prof. Dr. Franz Wolfgang Hubert
2. Prof. Dr. Christian von Hirschhausen

Tag des Kolloquiums: 19.12.2014

Contents

Introduction	1
1 Pipeline Power: A Case Study of Strategic Network Investments	11
1.1 Introduction	12
1.2 The Framework	18
1.2.1 The Network Game	18
1.2.2 Specification & Calibration	20
1.3 Evaluating Network Power with the Shapley Value	23
1.3.1 Nord Stream	24
1.3.2 South Stream	26
1.3.3 Nabucco	30
1.3.4 Evaluating Network Power with the Core & Nucleolus	35
1.4 Concluding Remarks	36
A Appendix	39
A.1 Calibration	39
A.1.1 Demand	39
A.1.2 Production	41
A.1.3 Transport	43

A.1.4	LNG	45
A.1.5	New Projects	46
A.2	Tables for the Nucleolus	47
A.3	Robustness	50
A.3.1	Demand Intercept and Surplus	50
A.3.2	Access Right Regime	50
A.4	Tables for Robustness	52
A.4.1	Decreased Demand (Surplus) : Shapley Value	52
A.4.2	Decreased Demand (Surplus) : Nucleolus	55
A.4.3	Fragmented Market: Shapley Value	58
A.4.4	Fragmented Market: Nucleolus	61
2	Central Asian Gas in the Eurasian Power Game	65
3	LNG: a Game Changer in Europe?	67
3.1	Introduction	68
3.2	The Major Developments in the Global LNG Market	72
3.2.1	Europe: the Expansion of the Regasification Capacities	72
3.2.2	Asia Pacific: the Growth in LNG Imports	75
3.2.3	The United States: LNG Exports	76
3.3	The Model	77
3.3.1	The Network Game	77
3.3.2	Specification	79
3.4	Results	83
3.4.1	All Developments	86
3.4.2	Europe: the Expansion of the Regasification Capacities	87

3.4.3	Asia Pacific: the Growth in LNG Imports	88
3.4.4	The United States: LNG exports	89
3.5	Conclusions	90
B	Appendix	91
B.1	Calibration	91
B.1.1	Demand	92
B.1.2	Production	94
B.1.3	Pipeline network	95
B.1.4	LNG network	97
B.2	Robustness	99
B.2.1	Access Right Regime	99
B.2.2	Investment Options	99
	Bibliography	103
C	Appendix: Technical Documentation	115
C.1	General Network Optimization Problem	118
C.1.1	Data & Calibration	118
C.1.2	Set-up for Network Optimization	119
C.2	Value Function	122
C.2.1	Network Optimization	122
C.2.2	Visualization of Results	123
C.2.3	Calculating Value Function (and Shapley Value)	123
C.3	Solving the Game	124
C.3.1	Shapley Value	125

C.3.2 Nucleolus	126
C.3.3 Core	127