
Contents

1	Introduction	1
2	The Issue of Climate Change	5
2.1	The Causes of Climate Change	5
2.1.1	The Carbon-Temperature Conundrum	5
2.1.2	Global Warming Scenarios and Mitigation Strategies	9
2.1.3	The Environmental and Economic Impacts	12
3	The Rise of the Emission Markets	17
3.1	The CO ₂ Emission Market: History and Institutions	17
3.1.1	From the UNFCCC to the Kyoto Protocol	17
3.1.2	The EU ETS	23
3.1.3	The Kyoto's Flexible Mechanisms: Clean Development Mechanism and Joint Implementation	29
3.2	The Current State of the CO ₂ Emission Markets	39
3.2.1	Carbon Exchanges and Market Players	39
3.2.2	Carbon Products	43
3.3	The Future of the CO ₂ Markets	49
3.3.1	At the International Level: The Limited Steps of COP 16, 17 and 18	49
3.3.2	At the Domestic Level: A Fragmented Landscape	52
4	The Economics of Mitigation Strategies	59
4.1	The Cause of GHG Pollution: The Negative Externalities	59
4.2	Using Price Constraint as a Centralized Solution: Taxes and Subsidies	61
4.3	Using a Decentralized Solution: Tradable Permits	63
4.4	The Quest for the Best Solution and the Influence of Uncertainty	65
4.4.1	The Quest for the Best Solution Using a Quantity Instrument: Cap-and-Trade	65
4.4.2	The Influence of Uncertainty	69
4.5	Growth and the Environment: Is It Possible to Have Both?	75
4.5.1	Growth and the Environment: A Curse?	76
4.5.2	A Possible Solution: Substituting Nature	77

4.5.3	A Possible Solution: Targeting the Clean Economy	81
4.5.4	A Possible Solution: Mixing Adaption and Mitigation Strategies	84
4.6	Investing in a Uncertain Environment: The Importance of Quasi-option as a Decision Tool	89
5	The Finance of Environmental Investments	93
5.1	Introduction	93
5.2	Characteristics of Investment Projects	94
5.3	The Neoclassical Approach: The Net Present Value (NPV)	94
5.3.1	Limitations of the NPV Approach	95
5.3.2	Relationship to Option Pricing Theory	96
5.4	Investment Opportunities as Options	96
5.4.1	An Intuitive Example	97
5.4.2	From NPV to Real Options: A Second Example	99
5.4.3	Real Options and Incentives to Invest: A Third Example	102
5.5	Option Pricing with the Binomial Model	103
5.5.1	The One-Step Binomial Model	103
5.5.2	Multi-step Binomial Model	104
5.5.3	Multi-period Binomial Model and Option Pricing	105
5.6	The Black–Scholes Formula	108
5.6.1	Pricing European Options	108
5.6.2	Pricing American Options	111
5.6.3	How Can the Volatility Be Estimated?	113
5.7	The Real Options Approach as a Decision Making Tool for Compliance with Environmental Regulation	114
5.7.1	A First Example: One-Period Binomial Model for the Emissions and Price Processes. What Is the Optimal Decision in Terms of Emission Rights Trading?	115
5.7.2	A Second Example: Two-Period Binomial Model for the Emissions and Price Processes. What Are the Optimal Decisions in Terms of Emission Rights?	119
5.7.3	A Third Example: One-Period Binomial Model for the Emission and Price Processes. What Is the Optimal Decision in Terms of Emission Rights Trading and Technology Changes?	128
5.7.4	A Fourth Example: A Two-Period Binomial Model for the Emission and Price Processes—What Are the Optimal Decisions in Terms of Emission Rights Trading and Technology Changes?	131
5.7.5	A Last Example: One-Period Binomial Model for Emission: What Are the Optimal Decisions in Terms of Emission Rights Trading when Price Dynamics Are Endogenously Derived?	140

6	The Emission Price Dynamics	147
6.1	Econometric Analysis of the EUA Price	147
6.1.1	Key Statistics for the EUA Price	148
6.1.2	Fuel Switch	150
6.2	Deterministic and Stochastic Equilibrium Models	153
6.2.1	Deterministic Equilibrium Models	154
6.2.2	Model of Montgomery 1972	154
6.2.3	Model of Rubin (1996)	157
6.2.4	Model of Kling and Rubin (1997)	161
6.2.5	Model of Seifert et al. (2008)	163
6.2.6	Model of Carmona et al. (2009)	166
6.2.7	Model of Chesney and Taschini (2012)	170
	Appendix	174
	Solving Static Optimization Problems	174
	Solving Dynamic Optimization Problems	176
	Relationship Between Optimality Conditions	178
	The Solution for a Representative Agent in Seifert et al. (2008)	179
	References	183