

INTERNATIONAL ENERGY MARKETS

UNDERSTANDING PRICING, POLICIES, AND PROFITS

2ND EDITION

CAROL A. DAHL



Contents

Acknowledgments	xv
List of Figures	xxi
List of Tables	xxvi

Chapter 1

Introduction to Our Journey	1
Some Scientific Principles	2
Outline of the Book	6

Chapter 2

Energy Lessons from the Past and Modeling the Future	13
Introduction	13
Energy Geological History	13
Natural Gas	18
Unconventional Oil Resources	21
Coal Resources	23
Energy's Human History	23
Energy Modeling	27
Summary	39

Chapter 3

Perfect Competition and the Coal Industry	43
Introduction	43
Perfect Competition	47
Energy Demand and Supply	54
Shifts in Supply and Demand	59
Demand and Supply Elasticities	61
Supply Elasticities	66
Using Elasticities to Forecast Supply	67
Price Changes from a Supply Disruption	67
Creating Demand and Supply from Elasticities	68
Summary	69

Chapter 4

Energy Price Controls, Taxes, Subsidies, and Social Welfare	71
Introduction	71
Social Welfare	71
Government Price Controls	74
Government Taxes and Subsidies	78
Types of Taxes	79
Modeling Taxes in a Competitive Market	86
Incidence of Tax Depends on Demand and Supply Elasticities	89
Consumer and Producer Surplus Show Deadweight Loss from a Tax	90
Energy Subsidies	91
Summary	91

Chapter 5

Natural Monopoly and Electricity Markets	93
Introduction	93
Electricity Market Evolution	96
Modeling Electricity Markets	98
Load Cycle	104
Monopoly in a Decreasing Cost Industry	105
Government Policy for a Natural Monopoly	111
Rate of Return Regulation	112
Problems with Rate of Return Regulation	112
Valuing Money across Time	113
Utility Rate of Return on a Bond or Stock	115
Utility Rate Base	117
Utility Cost Allocation	120
Peak-Load Pricing	120
Summary	122

Chapter 6

Restructuring in the Electricity Sector	125
Introduction	125
Problems with Regulated and Government-Owned Utilities	125
Models for the Electricity Sector	127
Examples of Electricity Restructuring	128
Evaluation of Early Reforms	139
Summary	150

Chapter 7

Monopoly, Dominant Firm, and OPEC	153
Introduction	153
Monopoly Model	155

Monopoly Compared to Competition.....	159
Price Controls in a Monopoly Market.....	160
Antitrust Laws.....	162
Brief History of Oil Markets.....	165
Multiplant Monopoly Model.....	171
OPEC's Demand Curve and Marginal Revenue Curve.....	174
Price Elasticity of Demand for OPEC's Oil.....	178
Non-Profit Maximization Goals for OPEC.....	180
Summary.....	183

Chapter 8

Market Structure, Transaction Cost Economics, and US Natural Gas Markets.....	185
Introduction.....	185
Natural Gas Consumption and Production Worldwide.....	186
Natural Gas Conversions.....	189
Transaction Cost Economics.....	191
Evolution of the US Natural Gas Industry.....	197
Gas Consumers.....	202
Gas Transmission.....	203
Volatility in the Natural Gas Market.....	205
Contracts.....	208
North and South of US Borders.....	212
Summary.....	213

Chapter 9

Monopsony: Japan and the Asia-Pacific LNG Market.....	217
Introduction.....	217
LNG Production and Trade.....	220
LNG Monopsony on Input Market, Competitor on Output Market.....	225
Monopsony Model Compared to Competitive Model.....	229
Monopsony Model with Price Discrimination.....	229
Monopoly and Bilateral Monopoly.....	230
Bargaining and Negotiation.....	234
Summary.....	234

Chapter 10

Game Theory and the European Natural Gas Market.....	237
Introduction.....	237
Coal and Oil Consumption.....	238
Coal and Oil Production.....	242
Natural Gas Markets.....	245
Primary Electricity.....	256
European Market Structure.....	258
Cournot Duopoly.....	264

Duopoly Compared to Competitive Market 267
 Monopoly Compared to Competitive and Duopoly Market 269
 Other Game Theory Models: Bertrand and Stackelberg 270
 Limit Pricing Model 271
 Summary 272

Chapter 11

Externalities and Energy Pollution 275
 Introduction 275
 Pollution as a Negative Externality 277
 Optimal Level of Pollution 278
 Regional Differences in Optimal Pollution Levels 282
 Evolution and International Comparison of Vehicle Emission Standards . . . 283
 Abatement across Firms 284
 Difficulties Measuring Costs and Benefits of Pollution 288
 Summary 289

Chapter 12

Public Goods and Global Climate Change 291
 Introduction 291
 Public Goods 292
 Two Other Abatement Policies 297
 Energy Conservation and Its Cost 300
 Energy Efficiency Gap and Policy Options 303
 Government Failure 307
 Global Carbon Policy 308
 Adaptation 311
 Summary 312

Chapter 13

Safety and Security 315
 Introduction 315
 Market Responses to Uncertainty and Disruption 321
 Governments and Energy Security 325
 Energy Accidents 328
 US Government Promotion of Nuclear Power 330
 Summary 333

Chapter 14

Allocating Fossil Fuel Production over Time and Oil Leasing 335
 Introduction 335
 Reserves and Reserves-to-Production Ratios (R/P) 336
 Dynamic Two-Period Competitive Optimization Models without Costs . . . 339
 Model One (No Costs, No Income Growth) 341

Model Two (No Costs, Income Growth)	346
Model Three (No Costs, No Income Growth, Lower Interest Rate)	347
Model Four (No Costs, No Income Growth, Increased Reserves)	348
Model Five (No Income Growth, with Costs)	349
Model Six (No Income Growth, No Costs, with Backstop Technology)	352
Dynamic Multiperiod Models	354
Dynamic Models with Market Imperfections	354
Taxing and Bidding Decisions	357
A Foray into the Real World	362
Summary	363

Chapter 15

Supply and Costs Curves	367
Introduction	367
Nuclear Fuels	371
Hydroelectricity	375
Other Renewable Energy Sources	377
Unit or Levelized Costs of Wind Electricity	378
Solar Energy	379
Geothermal Energy	381
Inground and Aboveground Costs for Gas and Oil	383
Unit Costs with No Decline Rate	387
Developing Cost Data	390
Estimating Total Energy Resources	390
Summary	393

Chapter 16

Energy Balances and Energy Demand	397
Introduction	397
Energy Balances	398
Household or Consumer Demand	417
Consumer Demand and a Subsidy	425
Factor Demand for the Industrial, Commercial, and Electricity Sectors	426
Econometric Estimates of Energy Demand—Picking the Functions	429
Summary	433

Chapter 17

Linear Programming, Refining, and Energy Transportation	437
Introduction	437
Crude Oil Refining	438
Gasoline Blending	444
Linear Programming to Optimize Refinery Profits	446
Energy Transportation	451
Summary	463

Chapter 18

Energy Futures Markets for Managing Risk	465
Introduction	465
Energy Futures Contracts	468
Hedging with Energy Futures	473
Arbitrage	475
What Determines Energy Future Prices on Commodities?	476
Efficient Market Hypothesis	482
Crack and Spark Spreads	483
Speculation and High Prices	484
Summary	488

Chapter 19

Energy Options for Managing Risk	491
Introduction	491
Pricing Options	493
Options Quotes	495
Valuing Options with Replicating Formulas	496
Creating Probabilities for a Binomial Lattice Model	499
Variables that Affect Option Prices	505
Option Trading Strategies	505
Energy Swaps	507
Summary	508

Chapter 20

Climbing the Energy/Development Ladder to Sustainability	511
Introduction	511
Combustible Biomass and the World's Poor	518
Collecting Wood from the Commons	526
Energy and Water	530
Renewable Energy Policies	532
Optimal Timber Rotation	532
Summary	536

Chapter 21

Sustainable Wealth in Fossil Fuel–Rich Developing Countries	541
Introduction	541
Fossil Future for FR Countries	545
Primary Electricity and Modern Biofuels	551
Economic Issues in Fossil Fuel–Rich Countries	556
Investing Fossil Rents for a Sustainable Future	570
Summary	574

Chapter 22

Managing in the Multicultural World of Energy	577
Introduction	577
Culture	578
Time	585
Universalism and Particularism	585
Cognitive Styles	588
Life Values	589
Business Protocols	589
Human Dimensions of Managing Technology	596
Think Like an Economist	598
Managing on the Margin	598
Managing across Time	600
When Markets Fail	601
Summary	602

Appendix A

Energy Conversions	607
---------------------------------	-----

Appendix B

Bibliography	613
Index	655

2

Energy Lessons from the Past and Modeling the Future

Those who cannot remember the past are condemned to repeat it.

—George Santayana

Introduction

Energy markets continually evolve. How they evolve in the future will be influenced by many of the factors that we will discuss in this book, including energy resources, technology, population growth, demographics, climate change, costs, preferences, government policy, regulation, and risk. In this chapter, we will consider energy in the great historical panorama, which sets the stage for coming chapters. We will also consider models that help us forecast coming events, analyze policies, make business decisions, and simulate interactions between energy and other sectors.

Energy Geological History

Science suggests that the most cataclysmic energy event for the universe was at its beginning, with the big bang and subsequent inflation of the universe some 14 billion years ago (NASA 2013). These and other geological energy milestones are shown in table 2–1.

Although there is not total agreement or understanding of how the universe began, physicists generally believe it to have proceeded as follows. Before the big bang, time, space, matter, and energy did not exist. Then an anomaly caused negative gravity and positive energy to form from nothing. The net energy was zero, but the universe had zero size and infinite temperature. The negative gravity caused an expansion, and the high temperatures caused the formation of a small amount of matter in the form of subatomic particles from energy according to Einstein's $E = mc^2$. With the expansion, temperatures started to drop.

Dates	Era or Event
1901	Using the first rotary drill, Spindletop was discovered in East Texas.
1903	Wright brothers completed the first airplane flight powered by gasoline engine.
1908	Anglo Persian struck first oil in Persia.
1911	US government broke up Standard Oil.
1928	“Red Line” and “As Is” agreements limited international oil company competition.
1938	Mexico nationalized its oil industry; oil was discovered in Saudi Arabia and Kuwait.
1948	Jersey Standard (Exxon), Socony Vacuum (Mobil), California Standard (Chevron), and Texaco formed the Arabian American Oil Company (Aramco).
1951	Iran nationalized Anglo Persian Oil into the National Iranian Oil Company (NIOC).
1954	Western companies took over NIOC in Iran after the previous year’s coup.
1959	Groningen gas field found in the Netherlands.
1960	OPEC was formed in response to cut in posted prices that reduced their tax revenue.
1968	Prudhoe Bay oil field was discovered in Alaska.
1969	Oil was discovered in the North Sea.
1970	US oil production peaked.
1971–79	Increased government participation and/or nationalizations occurred in OPEC countries (e.g., Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, Iran, and Iraq).
1973	Arab oil embargo of United States and the Netherlands began as result of Yom Kippur War.
	United States dismantled price controls implemented in 1971 as part of a price stabilization policy, but crude oil, oil product, and natural gas price controls were not lifted.
1974	International Energy Agency (IEA) was formed.
1975	Brazil implemented an ethanol program designed to eliminate fossil fuels in vehicles. United States authorized the Strategic Petroleum Reserve (SPR) and removed price controls on old oil.
1978	US Natural Gas Policy Act started natural gas price decontrol.
1979	Energy crisis resulted from the Iranian Revolution and oil production cuts. Iran renationalized NIOC.
1980	United States enacted windfall profit tax on crude oil.
1981	US domestic oil price controls were lifted.
1984	OPEC first established production quotas.
1985–86	Oil price plummeted more than 50% with Saudi Arabian netback pricing and increased production.
1991	Gulf War ousted Iraq from Kuwait.
1997	Qatar started exporting from world’s largest LNG facility.
1997–98	Asian financial crisis caused oil prices to plummet.
1998	Landlocked Caspian Sea area became exploration hot spot, with export pipelines built in the following decade.
1999–2006	Oil company acquisitions and mergers: BP/Amoco; Exxon/Mobil; TotalFina/Elf; Repsol/YPF; Norsk Hydro/Saga; Chevron/Texaco; Conoco/Phillips; and Rosneft/Yukos.
2004	World Bank agreed to new lending rules intended to prevent the funding of corrupt regimes with revenues from oil and natural gas projects.
2005–08	Shale gas production took off in the United States.
2006	Russia temporarily cut natural gas supplies to Ukraine over a pricing dispute, which caused continuing security concerns in Western Europe.

Growth rates of coal production have varied over time, as well. They averaged more than 4% per year on a global basis from 1860 to 1913. More than 45% of this output came from a rapidly industrializing United States, with annual average increases of 6.8% during this period. Then with a world war and a world recession, global coal production in 1938 had not regained its prewar level from 1913. World production increased more than fourfold from 1938 to 1990. However, during this time period, it never regained its pre-1913 growth rates except in the 1970s, when the oil crisis and surging oil prices caused industry and electric utilities to switch toward cheaper and politically safer coal. Falling consumption in the 1990s was followed by growth rates after 2000 of 4.7%, rivaling those of the heady years before 1913, when coal was king.

Fossil fuel markets are rarely dull. We can see this from coal prices, which have fluctuated rather dramatically, as shown by US coal prices since 1800 (fig. 3–3).

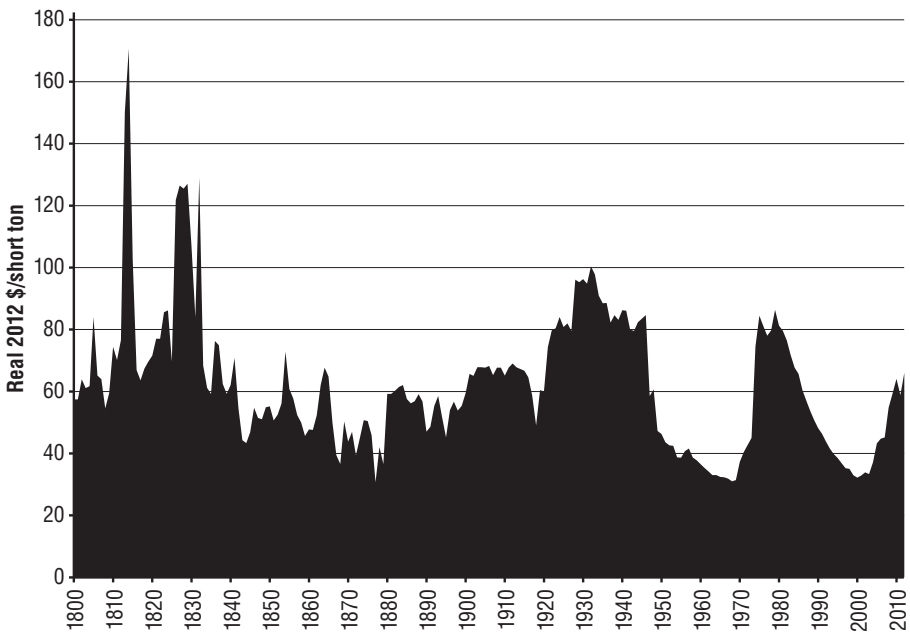


Fig. 3–3. US historical coal prices adjusted for inflation

Sources: The price variable is bituminous price deflated by the consumer price index. Price from 1949 to 2012 is from US EIA (n.d.b), which is extrapolated back to 1800 using the price of anthracite coal. Price of anthracite coal from 1800 to 1949 and consumer price index from 1800 to 1913 are from US DOC (1975). Consumer price index from 1913 to 2012 is from the US BLS (n.d.).

The price has been adjusted for inflation to real 2012 dollars. (See <http://dahl.mines.edu/st03/st03.pdf>, question 34, if you want to see how to use a price index to change nominal to real dollars.) It has averaged about \$62 per short ton over the past 200 years. (Multiply by 1.1 to convert price to dollars per metric

Subsequent to 1979, US coal mine productivity has shown dramatic improvements, with production per miner-hour increasing. Production increased from 1.9 tons per minor hour in 1980 to average more than 5.5 tons per miner-hour in the most recent decade (US NMA, n.d.). (For an Excel model that can be used to simulate supply and demand models similar to the one above, as well as other models in this chapter, go to <http://dahl.mines.edu/ch03m.xlsx>.)

Demand and Supply Elasticities

Often we want to measure how responsive quantities demanded and supplied are to prices or other variables, or both, to help design energy plans and policy. For example, if coal demand in Asia is very responsive to income growth and income rises or falls sharply, there will be a large effect on the coal market. If coal demand and supply are very responsive to price, only a small change in price will be needed to bring about equilibrium after demand or supply shocks. Economists use elasticities to provide such a measure of responsiveness. The price elasticity of demand is the percentage change in quantity divided by the percentage change in price:

$$\varepsilon_d = \frac{\% \text{ change quantity}}{\% \text{ change in price}} = \frac{\Delta Q_d}{Q_d} \bigg/ \frac{\Delta P_d}{P_d} \quad (3-7)$$

If the price elasticity is -0.5 , and price goes up by 100%, quantity demanded falls by 50%. If the price change is very large, we often get a different elasticity depending on whether the price and quantity in the respective denominators are those before (P_{d1}, Q_{d1}) or after (P_{d2}, Q_{d2}) the price and quantity changes. So arc elasticities are typically defined using the average of the respective denominators as follows:

$$\varepsilon_d = \frac{\% \text{ change quantity}}{\% \text{ change in price}} = \frac{\frac{\Delta Q_d}{(Q_{d1} + Q_{d2})/2}}{\frac{\Delta P_d}{(P_{d1} + P_{d2})/2_d}} = \frac{(Q_{d2} - Q_{d1})}{(Q_{d1} + Q_{d2})/2} \bigg/ \frac{(P_{d2} - P_{d1})}{(P_{d1} + P_{d2})/2_d} \quad (3-8)$$

It is often convenient to rewrite equation (3-7) as follows:

$$\varepsilon_d = \frac{\Delta Q_d}{\Delta P_d} \frac{P_d}{Q_d}$$

New Mexico				6%	15%
<i>Severance Tax—Oil, Gas, & Uranium</i>	7.09%	7.94%	3.50%		
<i>Surface Coal</i>			7%		
<i>Underground Coal</i>			3.75%		
West Virginia				4%	9%
<i>Severance Tax—Oil & Gas</i>	10.00%	10.00%			
<i>Severance Tax—Coal</i>			5.00%		
<i>37–45 in. Seam Thickness</i>			2.00%		
<i>Less than 37 in. Seam Thickness</i>			1.00%		

Sources: Kent and Eastham (2011); Temte (2010); New Mexico Taxation and Revenue Department (2013); Alaska Department of Revenue Tax Division (2013).

Note: See the Alaskan government tax return forms for more information on how the mining license tax varies with mining net incomes. The % symbol refers to an ad valorem tax. See individual state government tax forms for the most complete and updated severance tax information.