
Introduction

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Energy security, the impact of energy use on the environment, fuel prices and fuel poverty are all issues at the forefront of public attention. The economics of energy is a vital element which contributes to our understanding of these complex issues and influences policy makers' thinking as energy policy is determined.

This handbook reviews the key aspects and research issues in the economics of energy. It brings together a collection of contributions from international experts (both practitioners and academics) in the economics of energy, which synthesise the current literature and provide an analysis of the key issues. The handbook covers historical aspects of the economics of energy and the important topical research and policy issues of the day with the focus very much on the 'economics of energy' and subsequent policy. Aiming to be accessible to final-year undergraduates and postgraduate students studying the economics of energy, as well as practitioners in industry and government, the handbook summarises the current state of knowledge and provides an insightful commentary. The handbook starts with a historical perspective of energy and associated public policy issues, followed by an overview of the economics of energy supply and demand. The economics of energy efficiency including the 'rebound effect' are discussed, and then various energy economics modelling techniques are presented. Key issues associated with the various energy markets are addressed in turn: oil, coal, natural gas and electricity. The book concludes with a focus on contemporary energy policy issues.

In Chapter 1, Fouquet considers the history of energy use and the global economy in starting from the evolution of agrarian economies and discussing the attempts in Europe to overcome the limits in organic energy systems and the first successful transition to a fossil-fuel economy in Britain. Fouquet also considers the long-term trends in the global energy system and different energy policies through time. In Chapter 2, Weyman-Jones provides an overview of the theory of 'energy economics', arguing that this is really just a phrase used for convenience given that there is no such commodity as 'energy'; it is really the 'economics of fuel markets'. Weyman-Jones analyses resource allocation in capital-intensive fuel industries covering the nature of short- and long-run marginal cost of energy supply, the process of investment decision making, the design of efficient price mechanisms, and the market conditions that are frequently found in the fuel industries.

In Chapter 3, Medlock reviews the economics of energy supply considering the way in which energy sources are allocated through space and time. He outlines and develops the economists' model of optimal extraction of depletable resources that is used to examine a range of energy economics issues; and assesses the worth of such models by analysing 'firm behaviour' and 'peak oil'. In Chapter 4, Gordon examines the theory and practice of energy policy, considering examples of energy programmes that he argues were ill advised, reviewing the errors in policies in search of energy security. For the US, Gordon considers policies that have attempted to alter energy choices and those with an

environmental focus, whereas for Western Europe and Japan he considers the reluctance of governments to accept the uneconomic position of coal.

In Chapter 5, Medlock turns his attention to the theory of energy demand, highlighting that energy is a *derived* demand, required in order to obtain energy services such as heating, lighting, automotive power and so on. He discusses energy accounting, the relationship between energy use and economic development and the issues of structural and technological change, before going on to consider the micro foundations of energy demand and the elasticity of energy demand. In Chapter 6, Ryan and Plourde focus on the empirical modelling of energy demand. They consider the historical development of empirical models of energy demand from single-equation models to systems approaches, the implications of non-stationarity of appropriate data series on empirical models of energy demand, and the issues associated with allowing for asymmetric price responses in empirical models of energy demand.

The next few chapters focus on energy efficiency and the 'rebound effect' (where an increase in energy efficiency reduces the price of the energy service, resulting in an increase in demand for energy that moderates any energy saving). In Chapter 7, Allan et al. analyse the economics of energy efficiency, given the arguments that improvements in energy efficiency are important for meeting sustainability and security of supply goals. Allan et al. adopt an analytical approach to investigate the impact of an improvement in energy efficiency in a stylised open economy, aiming to identify and clarify the nature of the various system-wide factors that can affect the change in energy use that accompanies improvements in energy efficiency. In Chapter 8, Saunders presents the theoretical foundations of the rebound effect in order to explore the 'subtle' relationship between energy efficiency and energy consumption. He develops a simplified, but rigorous, theoretical framework for understanding the relationship, highlighting that the potential rebound impact is unknown but could be significant and have important policy impacts. In Chapter 9, Sorrell further examines the definitions and estimation of the rebound effect, highlighting that there are a range of mechanisms that may induce the rebound effect or even 'backfire' (where the introduction of certain types of energy efficiency results in an overall increase in energy demand). He clarifies the definition of direct, indirect and economy-wide rebound effects, highlights the methodological challenges associated with quantifying such effects, and summarises the estimates of rebound that are currently available. Sorrell concludes that rebound effects are significant, but they need not make energy efficiency policies ineffective in reducing energy demand.

In Chapter 10, Ryan and Young present an application of modelling the energy savings and environmental benefits from energy policies and new technologies. Drawing primarily on examples from the residential sector, they develop empirical microeconomic modelling approaches to evaluate the outcomes of policies that focus on the adoption of new technologies as a means of reducing energy demand and/or improving environmental quality, assessing the strengths and weaknesses of the various approaches.

The following few chapters consider a range of energy economy models used by energy analysts and energy policy makers. In Chapter 11, Greening and Bataille provide an overview of technology-orientated 'bottom-up' models of energy, focusing on the efforts to embed economic dynamics in bottom-up models by increasing their behavioural realism and macroeconomic completeness, as well as the possibility of including sufficiently large amounts of technological detail in existing macroeconomic or

computable general equilibrium (CGE) frameworks. Greening and Bataille therefore discuss simulation models and hybridisation. They demonstrate that bottom-up models have become increasingly more detailed and sophisticated in the way they handle technology choice and represent the dynamics of the energy system, in addition to increasing their capabilities for simulating the relationship between the physical stock and the wider economy. One particular type of model reviewed by Greening and Bataille is the MARKAL model (MARKet ALlocation model), which is a bottom-up dynamic, linear programming optimisation model. MARKAL is a commonly used model for energy policy analysis and in Chapter 12, Kannan et al. consider MARKAL further by detailing the development of a UK MARKAL model. Kannan et al. present indicative results to demonstrate MARKAL's strengths, range of outputs, and how MARKAL deals with uncertainties between alternative energy pathways.

In Chapter 13, Jaccard investigates the combining of 'top-down' and 'bottom-up' energy economy models, exploring public policy efforts to influence the direction of technological evolution, known as 'induced technological change' (ITC). He explores the ideal attributes of ITC policy models, noting the deficiencies and strengths of conventional approaches before explaining some recent modelling innovations that attempt to combine the best qualities of competing conventional models and parameter estimation. Jaccard then considers a specific ITC as an example of the challenge to provide a real-world empirical basis for estimating the response to ITC policies, and concludes that there remains considerable uncertainty concerning future responses of consumers and businesses to ITC policies. In Chapter 14, Sue Wing provides an exposition of CGE modelling for analysing energy and climate policies in order to 'de-mystify' the CGE approach. By developing the general algebraic framework of a CGE model from micro-economic principles, Sue Wing demonstrates how such a model might be calibrated using actual data, solved for the equilibrium values of economic variables, and the equilibrium perturbed by introducing price and quantity distortions; hence demonstrating how the economy-wide impact of energy and climate policies might be analysed. In Chapter 15, Kemfert and Truong survey energy–economy–environment modelling. Recent modelling has attempted to integrate climate, ecosystem and economic impacts into a single framework of so-called integrated assessment modelling (IAM), and Kemfert and Truong provide an overview of such models covering the theoretical backgrounds, the methodologies and model designs.

The following chapters focus on different fuels. In Chapter 16, Huntington evaluates the contributions of several strands in the energy security literature that emphasise the US oil security problem; however, the methodologies and basic principles also apply to many European and Asian countries. Huntington reviews and discusses three key economic issues central to the discussion of oil security: the oil import premium, the risk of oil supply interruptions, and the vulnerability of the economy to an oil disruption. In Chapter 17, Nakhle discusses the challenges inherent in designing and implementing an appropriate petroleum tax system aimed at achieving an appropriate balance between both government and industry interests. She recognises that there are no uniform solutions to these challenges; nevertheless, she argues that variety, flexibility and a readiness to adapt and evolve are the key requirements. In Chapter 18, Garis investigates the behaviour of petroleum markets beyond supply–demand fundamentals, arguing that there are circumstances where traders reject these in petroleum

markets in favour of psychological characteristics and trader expectations. Garis conducts a behaviour analysis to show how petroleum market prices behave under various scenarios in order to try to understand why, at various times, the supply–demand fundamentals are ignored. In Chapter 19, Gordon plots the history of the coal industry and the world coal market, highlighting that in the twentieth century coal moved from being a general-use fuel to primarily being used for electricity generation – with all the associated environmental implications. Following the historical review, Gordon examines coal trade patterns and US policy before concluding with a brief discussion of the uncertain future of coal.

The opening up to markets, competition, alternate market structures, and incentives in electricity and gas industries is the focus of a number of following chapters. In Chapter 20, Walls provides an overview of the issues around the opening up of gas and electricity markets, as the industries are increasingly being regulated by ‘market forces’. Walls argues that the transition for natural gas to markets was easier in the US than it might have been; however, due to the complexity of balancing supply and demand, the introduction of market-based allocation mechanisms has proved to be far more difficult for electricity. In Chapter 21, Weyman-Jones presents a summary of the key theoretical ideas underpinning the incentive regulation of energy networks. He outlines the main regulatory principles and tools employed and the different regulatory models and mechanisms that are applied in the real world: price-cap, revenue-cap, sliding scale, and yardstick competition.

In Chapter 22, Getachew and Lowry also explore the regulation of transmission and distribution in the developed world. Using the US as a case study, they demonstrate the importance of scale economies to illustrate the factors that affect the electricity industry in the developed world, going on to discuss the use of incentive-based regulation in the US, Canada, Europe, and the Pacific Region. In Chapter 23, Getachew explores the market structure of electricity networks in the developed world, presenting the various ways in which power industry restructuring by separating the natural monopoly activities of distribution and transmission from the competitive sectors has been instituted in the US, Canada, Western European countries, Japan, Australia and New Zealand. Getachew highlights the various transmission service arrangements that have been put in place across the developed world, concluding that the restructuring of the power industry is far from finished. In Chapter 24, Rosellón reviews incentive mechanisms for electricity transmission expansion, arguing that the economic analysis of electricity markets has typically concentrated on short-term issues whereas investment in transmission capacity is long term in nature, as well as stochastic. He discusses the two main disparate analytical approaches to transmission investment (the incentive regulation hypothesis and the merchant approach) before offering insights into how to build a more comprehensive approach that combines both mechanisms.

In Chapter 25, Farsi and Filippini review and discuss the empirical measurement of the productive efficiency of electricity and gas distribution. Following a review of production theory and the concepts of economies of scale and scope, they illustrate the different statistical approaches used to measure efficiency in the distribution sectors of electricity and gas (benchmarking), providing a selection of previous empirical studies. This is followed by a short discussion of actual benchmarking practice undertaken and a short case study of Switzerland. Farsi and Filippini conclude that the measurement of

efficiency is a contentious issue, so it is important to try to measure the efficiency from several angles, applying a number of models with different assumptions.

Perekhodtsev and Blumsack review wholesale electricity markets and generators' incentives in Chapter 26, outlining the critical properties of the markets applied in different wholesale electricity markets around the world. Highlighting the three design characteristics of 'market design rules', 'market power' and 'resource adequacy and capacity mechanisms', Perekhodtsev and Blumsack conclude that the poor design of electricity markets may increase significantly the cost of electricity to customers and that no market has managed to overcome all the identified problems. In Chapter 27, Losekann et al. discuss security of supply in large hydropower systems. They use a simulation model to apply the 'missing money problem' to Brazil and conclude that if the issue of energy storage incentive is not adequately addressed the system is likely to run into security of supply problems – despite capacity payments to ensure an abundant supply of generation capacity.

In Chapter 28, Blumsack and Perekhodtsev turn their attention to electricity retail competition, discussing the transition from regulated monopoly pricing to competition. By reviewing the various retail electricity market models across the world, they highlight that there is no widely accepted way to design such markets, and conclude by offering a set of policy prescriptions for successful retail electricity markets. In Chapter 29, Reedman and Graham consider emissions trading and the convergence of electricity and transport markets in Australia. Following an examination of the relative cost of greenhouse gas (GHG) abatement in the Australian electricity and transport sectors, they employ a partial equilibrium model to formulate three emission reduction scenarios. Some of their key findings include the need for emission permit prices to be significantly higher in order to achieve rapid and deep GHG emission abatement targets and that without further measures, the combined electricity and transport sectors will be unable to meet aggressive cuts in GHG emissions in the short term.

The fundamental purpose for derivatives is to facilitate risk mitigation and to aid in price discovery of the underlying asset, and in Chapter 30 Ripple provides historical background on the introduction of derivatives, futures, forwards, options and other financial instruments into the energy markets, which assist market participants with their risk mitigation needs. Ripple outlines the underlying economics of these instruments and their markets with some examples of how such instruments might be employed, providing an analysis of the evolution of both price volatility and the relative roles of hedgers and investors/speculators in these markets.

Some of the major themes and strands of research on the economics of energy supply and use in developing countries are presented by Madlener in Chapter 31, highlighting the literature on: the relationship between energy consumption and economic growth; the relationship between rapid fossil-fuel price rises on development; and interfuel substitution. Madlener concludes by predicting an increase in research activity on the impact of energy price rises on the sustainable development of developing countries, while indicating that the issues of equity and energy poverty should also be addressed.

The final two chapters examine energy policy from very different perspectives. In Chapter 32, Frei presents an example of the use of 'energy visions' analysis to consider alternative routes that energy policy might take in the future to address the twin problems of energy security and climate change. Using a combination of economics, and Weber's

classifications of social behaviour, Frei builds ‘energy visions’ that investigate different possible futures to aid the thinking of policy makers. In Chapter 33, Weyman-Jones takes a different perspective considering the current key issues in the design of energy policy.¹ Recognising that energy policy is the attempt to correct the three market failures of asymmetric information, market power and externality, Weyman-Jones focuses on the positive economics of market power and externality (the normative economic policy towards asymmetric information being covered in Chapter 21). He therefore critically analyses a number of key contemporary energy policy issues including the social cost of carbon, carbon permits versus taxes, integrated assessment models, and the UK Stern Review of the economics of climate change.

We hope that the wide spectrum of issues and techniques in this Handbook, as well as the depth of analysis, makes the economics of energy accessible to all those who are interested in understanding the current issues in energy economics. We would like thank all who contributed a chapter (or in some cases two or even three chapters) to this volume – even the late ones that we had to chase – the Handbook is the richer for each contribution. Finally, our thanks also to Matthew Pitman of Edward Elgar, who originally persuaded us to undertake this project, and also to the publishing team.

Note

1. In Chapter 4, Gordon considers the energy policy as previously designed, whereas in Chapter 33 Weyman-Jones considers the key energy policy issues currently faced by energy economists.

