INTERFUEL SUBSTITUTION

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Preface

The effects of output growth and changing fuel prices on the demand for energy depend on interfuel substitution and the substitutability of energy and other factors of production. Over the years, these issues have attracted a great deal of attention in a large number of energy demand studies, with most of these studies taking the approach of using a flexible functional form for the underlying aggregator function, following Diewert's (1971) influential paper. In fact, this approach to empirical energy demand analysis was pioneered by Berndt and Wood (1975), Fuss (1977), and Pindyck (1979). It involves specifying a differentiable form for the cost function, and applying Shephard's lemma to derive the resulting cost share (or input-output) equations. Using these equations and relevant data, one then could estimate the parameters and produce inferences about the demand for fuels (including those about the own- and cross-price elasticities as well as the elasticities of substitution).

Although the role of energy in the structure of production has been the focus of a large number of econometric studies, the evidence on interfactor and interfuel substitutability is mixed. For example, the early studies by Berndt and Wood (1975), Fuss (1977) and Magnus (1979) all used time series data for a single country and found substitutability between energy and labor, but complementarity between energy and capital. Also, Fuss (1977), using Canadian data, found oil, gas, and coal to be substitutes, but found no substitutability between each of these energy inputs and electricity. Moreover, Pindyck (1979), taking a similar approach to that used by Fuss (1977), used pooled time-series data for a cross section of countries and found energy and labor to be substitutes and also energy and capital to be substitutes, and not complements as earlier studies had indicated. Such variability in results can be partly explained by significant inherent differences between short- and long-run adjustments.

In this book I am not interested in interfactor substitution. Instead, I am interested in interfuel substitution, an issue that is (and will likely remain) an important topic of inquiry for many years, as governments around the world seek to set policies that are intended to restrain carbon emissions or steer economies toward or away from certain fuels. In this regard, it should be noted that the results of most energy and climate change policy models, no matter whether they are partial equilibrium or general equilibrium type, are highly sensitive to elasticity parameters, particularly the elasticities of interfuel substitution. However, there exists only limited recent literature estimating such elasticity parameters. Moreover, with the exception of a few sporadic local articles, there is still a huge void in the literature dealing with energy demand and interfuel substitution in developing countries. This book contributes to filling the literature gap by estimating interfuel substitution elasticities through the use of recent advances in microeconometrics and the use of recent international data for a number of OECD and non-OECD countries.

Over the years, there has been a large number of studies investigating interfuel substitution and the demand for energy — see, for example, Uri (1979), Considine (1989), Hall (1986) and Jones (1995), among others. The major contributions in this area, however, are quite outdated by now, since their data incorporate observations before the 1970s. Also, very few studies deal with energy demand and interfuel substitution in developing countries, probably due to the lack of reliable data at that time. Moreover, most of this literature ignores the theoretical regularity conditions of neoclassical microeconomic theory. However, as Barnett (2002, p. 199) put it, without satisfying the theoretical regularity conditions,

“the second-order conditions for optimizing behavior fail, and duality theory fails. The resulting first-order conditions, demand functions, and supply functions become invalid.”

In this book, I investigate short- and long-run interfuel (i.e., oil, natural gas, coal, and electricity) substitution, using international time series data. In doing so, I investigate interfuel substitution within the industrial, residential, transportation and electricity generation sectors, since the structure of interfuel substitution is different for different sectors of use. My objective is to improve our understanding of how economic growth, government policies, and the development and implementation of new technologies, will affect interfuel substitution and the demand for energy in the future. In order to achieve this, I use recent advances in microeconometrics, including duality theory and flexible functional forms and provide

inference, and also a policy perspective, using parameter estimates that are consistent with the theoretical regularity conditions of neoclassical microeconomic theory.

Because the existing major contributions in this area are quite outdated, since their data incorporate few (if any) observations subsequent to the oil price shocks in the 1970s, I use the most recent data (since 1980), published by the International Energy Agency (IEA), for a number of OECD and non-OECD countries (including China and India) for which reliable data are available. This is important as recent IEA projections show that non-OECD countries will account for close to 90% of the increase in energy demand in the next 20 years, with China and India likely to account for over 50% of this growth. In particular, I provide evidence for six high-income countries (Canada, France, Japan, Italy, the United Kingdom and the United States), for five upper-middle to high-income economies (Poland, Hungary, Mexico, Turkey and Venezuela), and for four lower-middle to low-income economies (China, India, South Africa and Thailand).

Of the four essays which follow, Chapter 1 is new, while Chapters 2, 3, and 4 are reprints, with relatively minor revisions, of recently published work. The revisions which I have made were meant to eliminate repetitive passages and a certain amount of overlap among the individual essays.

A number of institutions and individuals have made the completion of these essays possible. The World Bank Research Support Program provided financial support for the essays that appear in Chapters 3 and 4 of this book. However, the views expressed in this book do not necessarily represent the World Bank and its affiliated organizations. I would like to thank my coauthors, Govinda Timilsina and Olexandr Vasetsky, of the original papers that have been reprinted in this book as Chapters 2, 3, and 4. Thanks are also due to the colleagues that commented on one or more of these essays, William Barnett, Erwin Diewert, Shahidur R. Khandker, Guohua Feng, Daniel Gordon, Alexander David, the Editor of *The Energy Journal*, James Smith, the Editors of *Energy Economics*, Beng Ang, Richard Tol, and John Weyant, and the anonymous referees of *The Energy Journal* and *Energy Economics*. Of course, none of them is responsible for the finished product.

Finally, I would like to thank Joanne Canape for a thoroughly professional job of preparing the camera-ready copy of this book. This work would not have been possible without her help.