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## Uncertainty Analysis of the IEA/ORAU $C0_2$ Emissions Model

by J.M. Reilly, J.A. Edmonds, (Batelle Pacific Northwest Laboratories, Washington, D.C.), R.H. Gardner (Oak Ridge National Laboratory, Oak Ridge, TN, USA), and A.L. Brenkert (Science Application International Corp., Oak Ridge, TN, USA)

Future levels of carbon dioxide emissions from fossil fuels are an important determinant of the severity and timing of global warming due to elevated levels of radiatively active (greenhouse) gases in the atmosphere. Many studies have addressed this issue. These include Rotty (1977), Keeling and Bacastow (1977), Siegenthaler and Oeschger (1978), JASON (1979), Marchetti (1980), IIASA in Haefele (1981), Lovins (1981), Hamm (1982), Nordhaus and Yohe (1983), and Reister and Rotty (1983). Ausubel and Nordhaus (1983) provide a recent critical review of emissions forecasts with a focus on methodological development, citing the advance in methodological sophistication leading to improvements in understanding long-term patterns of energy use and their relationship to $C0_2$ emissions. This paper presents the findings of a Monte Carlo uncertainty analysis of the IEA/ORAU Energy/$CO_2$ Emissions model. Of particular interest is the finding that, in the absence of any explicit policy intervention to control $C0_2$ emissions, over half the scenarios generated by the analysis failed to raise the concentration of atmospheric $C0_2$ beyond 600 ppm by the year 2100. (The present concentration is 345 ppm (DOE 1985).) This represents a major reduction in expected future loading of carbon, particularly in comparison to expectations formulated a mere five years earlier, and implies the postponement of $CO_2$-induced climate change (corresponding to equilibrium $CO_2$ concentration of 600 ppm) by more than half a century.

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## Optimum Depletion of Oil Resources in a Developing Country

by Ali M. Parhizgari (Associate Professor, Florida International University, Miami, FL)

The majority of resource-based developing countries finance a high percentage of their development efforts through extraction and export of nonrenewable natural resources. Though the extraction and export policies of these countries might be subject to noneconomic international causes and effects (i.e., those that do not easily yield to empirical analysis (Mikdashi, 1976)), the need for each country to plan and implement an optimal and consistent policy in this regard is already well established (Meier 1984; Kemp

and Long 1984; Neary and Wijnbergen 1986). The literature on the exhaustion of nonrenewable natural resources is vast but mostly theoretical (RESTUD 1974; Pindyck 1978, 1980; Dasgupta and Heal 1979; Kneese and Sweeney 1986). It often addresses the issue in a general manner and treats the empirical side of the problem lightly. Notwithstanding substantial empirical work during the last decade, the vacuum between theory and practice as well as between generality versus specialty is more acute in the case of less-developed countries (LDCs). This paper fills this vacuum by addressing oil through a theoretical model that yields to realistic implementation in LDCS. The following section of this paper suggests a policy for oil extraction in LDCS. The third section, drawing upon the Pontryagin maximum principle of optimal processes (Pontryagin 1962; Bryson and Ho 1984), presents an empirical model for optimum resource extraction. The fourth section applies this model to Iran and reports the results. Finally, the last section provides some brief concluding remarks.

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**Energy for Transport in Developing Countries**

by Joy Dunkerley (Senior Analyst, U.S. Congress, Office of Technology Assessment, Washington, D.C.) and Irving Hoch (Professor of Economics, University of Texas, Dallas, TX)

Transportation is the major market for liquid fuels in many developing countries, accounting on average for one half of total consumption. Unlike the other end-use sectors, possibilities for fuel switching in transport are limited, at least for the time being. Given the existing stock of transport it equipment, virtually the entire increase in consumption of transport fuels for the next 15 years or so will involve petroleum products. A rapid expansion in consumption of petroleum products could seriously exacerbate economic management problems in developing countries. For many oil-importing countries, transport fuel imports alone account for 20 percent of total export earnings. In the oil-exporting countries, rising consumption of transport fuels also poses problems by cutting into exportable surpluses. A clearer idea of the relationships determining transport energy consumption and the likely growth in consumption of transport fuels is therefore important-not only for energy management but also for wider macroeconomic policy aims. We use data on transport energy consumption and vehicle stocks (together with data on associated price and income variables) to project transport energy consumption and vehicle stocks for developing countries to the year 2000. These projections, supplemented by case studies of India and Ecuador, from the basis of a discussion of transport policies that could help save energy while still providing those transport services necessary for economic development.

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**The Demand for Insulation-A Study in the Household Demand for Conservation**

by J. Daniel Khazzoom (Professor of Quantitative Studies, School of Business, San Jose State University, San Jose, CA)

This paper presents my effort to provide the means of estimating a major ingredient of the demand for conservation-namely, home insulation. A detailed account of the effort and its motivation can be found in Khazzoom (1984, 1986a). The demand relationships of this model provide one block (out of three) in a jointly determined system of demand relationships: demand for electricity, demand for insulation, and demand for efficient appliances. The study is pitched toward the service-area level. I estimated a model of the household demand for insulation in the Sacramento Municipal Utility District's (SMUD's) service area, which has a population of over 760,000. The study focused on home insulation rather than on home thermal integrity. This was because during the sample period, changes in home insulation were practically the only source of change in the thermal integrity of homes in the Sacramento area. But the methods developed in this study to generate the indices of insulation demand (as well as the extension of the limited information maximum likelihood method developed here to estimate a Box-Cox-transformed model) can all be used directly to estimate the demand for measures, other than just home insulation, that affect the thermal integrity of the home (double glazing, installation of hangovers, and so forth).

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**Technology and Energy Use Before, During, and After OPEC: The U.S. Portland Cement Industry**

by Charles A. Capone, Jr. (Department of Economics, Baylor University, Waco, TX) and Kenneth G. Elzinga (Department of Economics, University of Virginia, Charlottesville, VA)

For 12 years analysts have watched industries respond to increased energy prices. In particular, there as been an extensive effort to measure the substitutability of inputs in production, much of which has focused on energy and capital. We may now be at a point where the relevant question is, have firms increased the substitutability of energy with other inputs by what they have done these past 12 years, or will they be caught unawares as the current drop in oil prices precipitates a fall in the market prices of all energy sources? Will we see firm production moving back toward a more energy-intensive process either in the short run or the long run? A prime candidate for such a study is the U.S. portland cement industry. Portland cement is the sixth most energy-intensive manufacturing process in the United States. It has significantly changed its standard production technology in response to energy price changes. The authors have performed an analysis of the industry's response for the period 1947-1980. During this time there has been a full cycle of falling (pre-1971) and rising energy prices (1971 and after) relative to other inputs. Through adoption of energy-intensive technology prior to 1971, and energy-saving technology from that point on, the industry has responded as economic theory predicts. Results of this study show, however, that firms may be no more able to adjust quickly to energy price changes

today than they were in 1970. Technical substitution possibilities do exist between labor and energy in cement production, but they are no stronger today than they were at that time.

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**Competition in Natural Gas Pipeline Wellhead Supply Purchases**

by Harry G. Broadman (Harvard University, and Resources for the Future, Washington, D.C.)

Throughout most of the last three decades, interstate natural gas pipeline companies - operating mainly as private carriers, buying gas supplies in the field and reselling them downstream - have competed primarily on the basis of nonprice terms. Under the regime of wellhead regulation stemming from the 1954 Supreme Court decision on *Phillips Petroleum Company vs Wisconsin et al.*, in upstream (*field*) markets binding price ceilings meant that interpipeline competition in gas purchases were governed principally by the attractiveness of take-or-pay provisions pipelines offer in their contracts with gas producers. In downstream (*city-gate*) markets the chronic excess demand induced by wellhead regulation meant that pipelines competed for gas sales to local distribution companies and direct wholesale consumers (large industrial end-users and electric utilities) largely on the basis of the maximum quantity of gas that could be delivered.

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**Alternative Technological Indices and Factor Demands in the Electric Power Industry**

by Randy Nelson (Department of Economics, Colby College, Waterville Maine, USA)

The role of technical progress as a means of extending energy resources, together with the widespread use of flexible functional forms, has led to increased interest in the estimation of nonneutral technical change in recent Studies by Binswanger (1974), Berndt and Khaled (1979), and Berndt years. and Wood (1982) at the aggregate level and Wills (1979), Toevs (1980), Moroney and Trapani (1981), and Jorgenson and Fraumeni (1981) at the sectoral level have provided estimates of biased technical change. Stevenson (1980), Gollop and Roberts (1981, 1983), and Nelson (1984, 1986) have also estimated models of nonneutral technical change for the electric power industry. Almost all these studies have two features in common. To begin with, they have employed a time trend to represent the rate at which new technology is introduced. A recent study by Kopp and Smith (1985), however, indicates that time trends may fail to provide a consistent description of the direction of technical change and calls for the use of technologically explicit indicators of the pace of innovation.

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**Futures Trading and the European Oil Market**

by Peter J. W. N. Bird (Chr. Michelsen Institute, Bergen, Norway, and Uranium Institute, London, UK)

The subject of this paper is the behavior of daily gas oil futures prices on the London-based International Petroleum Exchange (IPE). It reports results consistent with the hypothesis that prices on the IPE follow a random walk. The oil market now closely resembles other international commodity markets. The underlying cause has been the world glut of oil, occasioned by the 1979 price rises and the consequent world recession. This has encouraged oil importers to move away from long-term purchase agreements in favor of reliance on the international spot market. This has both led to and been helped by the parallel development of futures trading. In supporting well developed spot and futures markets, oil is now in a position similar to a number of internationally traded mineral and agricultural commodities. The world centers of oil futures trading are New York and London. In New York both crude- and heating-oil futures are traded on the New York Mercantile Exchange (NYMEX). Gas oil futures have been traded on the London IPE since April 1981, and the market quickly established itself as one of the more active London futures markets. The dominant paradigm in futures market analysis is the efficient markets hypothesis (Fama 1970), that all information available to the market is reflected in the current market price. The most commonly examined aspect of the literature is weak-form efficiency, in which the information set is simply the history of market prices. Rejection of the hypothesis implies two tasks. The first is to demonstrate statistical dependencies in the history of price changes, that is, to reject the hypothesis that prices follow a random walk. This is referred to as testing for dependency.