ENERGY-ECONOMY INTERACTIONS

Anthony D. Owen
The University of New South Wales, Sydney, Australia

Keywords: Economic growth, EIA, energy coefficient, energy efficiency, energy indicators, energy intensity, prices, Gross Domestic Product, IEA, OECD, OPEC

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Summary

The availability of energy resources and their relation to economic activity is the core concern of the discipline known as energy economics. Energy use is pervasive in modern economies, since it is required as an input for every commodity produced. Yet the extraction and use of the important energy resources represents a major source of environmental pollution. Since economic growth is generally perceived as being a measure of a country's welfare, and thus a desirable objective in itself, achieving this objective whilst minimizing the undesirable environmental aspects of energy use has become of prime concern to the world's industrialized countries. In this article the close association between energy use and economic growth is addressed in the context of growing worldwide concerns with negative environmental impacts resulting from energy use based upon combustion of fossil fuels.

1. Introduction

The nexus between a country's energy consumption and its level of economic activity has long been recognized and, prior to the 1973 oil crisis, it frequently formed the basis for simple aggregate energy demand forecasting analyses for both developed and developing countries. Despite the simplicity, it was a remarkably reliable methodology. With relatively stable (real) energy prices, and both the primary fuel mix and the structural composition of GDP not undergoing dramatic changes, the correlation between energy consumption and GDP was very high.

Figure 1 illustrates the relationship between total annual energy consumption (in quadrillion Btu) and Gross Domestic Product (in hundred billions of 1996 dollars) for the US from 1949 to 1999. Both series are expressed as index numbers with 1949 = 100. The correlation coefficient between these two variables over the entire time frame is extremely high at 0.95, but this summary statistic masks some significant intervals of volatility over this period of time. For example, the same statistic calculated for the period 1974 to 1984 was just 0.27, reflecting a relatively low level of linear association. Energy intensity (i.e., energy use per unit of GDP) is also shown in Figure 1, again in the form of an index. After the mid-1970s the decline in energy intensity that had been evident since 1949 showed a marked acceleration. The factors that induced these major structural changes in world energy markets are the subject of other articles in this encyclopaedia. This article focuses specifically on the dynamics of the relationship between economic growth (at both aggregate and sector levels) and energy consumption.

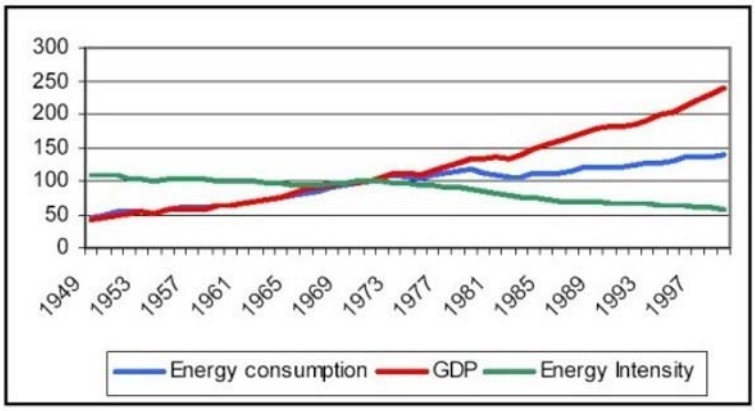

Figure 1. Energy Consumption and GDP: USA (1949 to 1999)

2. Historical Perspective

World consumption of primary energy doubled over the decade of the 1960s, predominantly as a result of high economic growth rates and falling (in real terms) fossil fuel prices. Following trends dating back to the 1930s, oil continued to increase in relative importance, and the share of petroleum products in total energy use increased from 36 percent in the early 1960s to over 45 percent by 1973.

Throughout the decade of the 1960s, the "energy coefficient" for OECD countries averaged exactly 1.0, indicating that overall energy consumption was increasing at precisely the same rate as economic growth. However this reflected a balance between a relatively fast rate of growth in energy demand for sectors such as transport and a relatively slow growth in energy for industry, where efficiency improvements continued to reduce the energy-output ratio. For the USSR and Eastern European countries the energy coefficient averaged 1.21 over the same period, reflecting a continuing shift from agriculture, with low energy use per unit of output, to heavy industry having a high-energy intensity. Developing countries also averaged 1.21, again reflecting the relative decline of their agriculture sectors. In addition, for the poorer developing

countries, the substitution from non-commercial to commercial fuels was a major factor causing a relatively high energy coefficient.

The volume of internationally traded crude oil also increased rapidly over this period, as many of the major industrialized countries had very limited domestic supplies of oil. In addition, many countries with significant domestic oil resources (for example, the United States) were unable to increase internal supply fast enough to meet increasing demand. As a consequence, countries with large oil reserves, and particularly those in the Persian Gulf, greatly increased their oil exports. By the early 1970s most OECD countries (and particularly Japan) were heavily dependent upon imported oil to fuel their rapidly expanding economies.

During 1971 and 1972, the Persian Gulf OPEC members began to assert their market power, raising posted prices and nationalizing the domestic activities of foreign owned oil companies. In early 1971 oil prices were US$2.55 per barrel. By late 1973 they had been pushed up to US$5.12 per barrel, and were more than doubled to US$11.65 per barrel on January 1, 1974. The previous October, the fourth Arab-Israeli war commenced and OPEC Arab states placed an oil embargo upon countries considered to be sympathetic to the Israeli cause. At the same time, the OPEC states reduced production, thus supporting the higher prices.

The rapid rise in oil prices during 1973/74 was matched by comparable increases in other forms of energy and non-energy minerals, and consequently the price of goods and services in general. Many countries experienced huge external trade deficits, and as a result economic growth slowed significantly, resulting in higher levels of unemployment.

The immediate impact of the fourfold increase in oil prices during 1973 was a sharp drop in energy use in industrialized countries as urgent conservation measures took effect and energy-intensive industrial activities were curtailed. It appears, however, that after an adjustment period of about two years, energy use returned more or less to its long term underlying relationship with GDP.

The 1979 oil price rises, combined with the Iranian Revolution, had a much greater impact than the 1973 events on OECD countries in terms of both energy use and industrial activity, despite the fact that the increase was relatively short-lived. In the wake of the 1979 OPEC-induced oil price hike and associated crises the nexus between energy consumption and economic growth for OECD countries was broken. Following the increase there occurred a world-wide period of industrial recession lasting three to four years and consequently energy use fell sharply while GDP stagnated. Although the level of economic activity in OECD countries increased relatively quickly during the second half of the 1980s, energy consumption did not return to its traditional trend. This was partly due to restructuring of these economies and partly to improvements in intrinsic efficiency. Energy intensive industries were either radically rationalized (for example, steel and chemicals) or largely shifted offshore (for example, aluminum smelting) to countries possessing relatively plentiful supplies of cheap indigenous fuel. In addition, the trend towards service economies and high technology, high value-

added, low energy use, industries became a feature of the last two decades of the twentieth century for many of the major developed economies of the world.

The relatively high rates of growth experienced by member countries of the OECD during the last two decades of the twentieth century provided both the financial resources and the competitive environment for investment in energy efficient practices. In addition, the growing environmental concerns enabled companies to reap the public relations benefits of such investments. It is not surprising, therefore, that energy consumption in the US in 1990 was only marginally above the level of 1979 despite an increase in (real) GDP in excess of 30 percent over the period. Similar patterns were evident for all OECD countries, in aggregate (Figure 2).

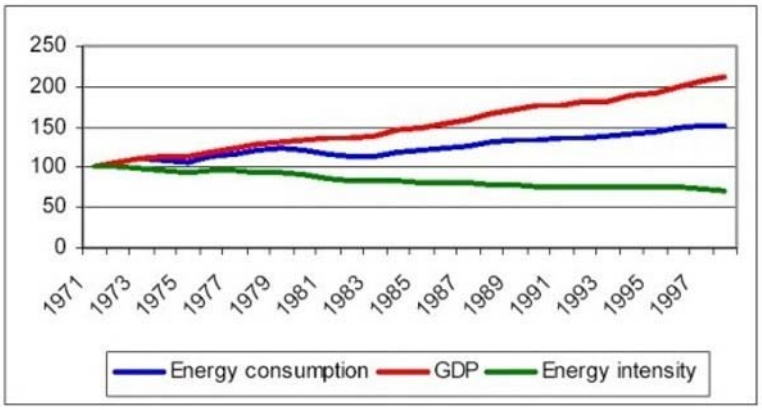

Figure 2. Energy Consumption and GDP: OECD (1971 to 1998)

For developing countries, however, the relationship between GDP and energy use barely falters throughout the three decades, although in absolute terms its impact on the world total is relatively minor. Energy demand in developing countries increased particularly strongly over the last three decades of the twentieth century, underpinned by population growth, increased economic activity, and rising per capita incomes. This was particularly noticeable in Asia, where per capita energy use rose from 0.47 tonnes of oil equivalent (toe) in 1971 to 0.90 toe in 1997. For the remainder of Asia the figures are 0.32 and 0.57 toe, respectively. Outside of Asia, per capita energy use in the developing world rose at a much slower rate. For Africa and Latin America, per capita energy use was 0.55 and 0.87 toe in 1971, rising to 0.64 and 1.11 toe in 1997. Comparable figures for the world and the OECD were 1.48 and 3.85 in 1971, rising to 1.66 and 4.63 toe in 1997.

Underlying the growth in economic output was rapid expansion in industrial activity. Combined with the increasing rates of urbanization evident throughout the developing world, these factors have led to sharp increases in the demand for motorized transportation. In most developing countries, growth in energy demand outpaced that of GDP over the period considered, leading to increases in aggregate energy intensities. The exceptions were some of the more advanced economies in East Asia where industrial structures became less energy intensive or where the services sector increased its share of economic output.

In many developing countries, traditional fuels or biomass remain an important component of the fuel structure and, for rural populations in particular, can constitute by far the major energy source. The increase in traditional fuel consumption, however, has been less than that of commercial energy, reflecting the declining availability of fuelwood and other biomass, and reduced accessibility of the population to supply sources. If traditional fuels were included in the calculation of energy intensities, it is clear that intensity increases would have been lower than if commercial energy alone were considered, as a result of substitution between the two fuel sources. Energy demand has also increased strongly on a per capita basis over the period considered although, even if traditional fuels are included, per capita energy consumption remains well below the average for OECD countries.

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Bibliography

BP Statistical Review of World Energy (2000). London. [Annual publication containing current and historical statistics on the world's commercial energy resources, production, and consumption. The current version can be downloaded from the BP web site www.bp.com]

Energy Information Administration (EIA) (1999). *International Energy Outlook*, Washington D.C.: US Department of Energy, [Annual publication containing projections of international energy consumption and associated data. Freely available on www.eia.doe.gov/oiaf/1eo99/home.htm.]

International Energy Agency (IEA) (1994). *Energy in Developing Countries*, 130 pp. Paris: OECD. [A sector analysis of determinants of energy use in a range of developing countries.]

International Energy Agency (IEA) (1997). *The Link between Energy and Human Activity*, 119 pp. Paris: OECD. [Detailed industry sector analysis of determinants of energy use in a number of OECD countries.]

Biographical Sketch

Anthony David Owen B.A., M.A., Ph.D., F.S.S. Anthony Owen is currently Associate Professor of Economics at The University of New South Wales, where he has been employed since 1974. He was Director of the Centre for Applied Economic Research (CAER) from 1989 to 1995, and has been Director of the University's Energy Research Development and Information Centre (ERDIC) since 2000. He has almost 30 years of research experience in the fields of econometrics, energy economics, and environmental economics, and currently serves on the International Editorial Boards of *Energy Policy* and *Energy Economics*. He was Conference Chair for the 23rd Annual International Conference of the International Association for Energy Economics, held in Sydney, June 2000. He has had extensive consulting experience with the Organisation for Economic Co-operation and Development (OECD), and the Governments of Australia, Norway, and the United Kingdom. Professor Owen is the author of four books, five monographs and more than 50 papers published in academic journals. He is a Fellow of the Royal Statistical Society (FSS).
His key publications are: (1999) The Kyoto Protocol and Emission Trading, in Kriesler P. R. (editor), *The Australian Economy, The Essential Guide, Volume 3*, Allen & Unwin, Sydney; with Lattimore J. C.

(1998) Oil and Gas in Papua New Guinea, *Energy Policy* 26, 655–660; (1995) The Environment: The Role of Economic Instruments, in Kriesler P.R. (ed.), *The Australian Economy, The Essential Guide, Volume 1*, Allen & Unwin, Sydney; (ed.) (1994) *Energy Policy, Special Issue on Australia* 22; (1992) Oil Self-Sufficiency for Australia, in Dorian J. P. and Fesharaki F. *International Issues in Energy Policy, Development, and Economics*, Westview Press, Colorado; and (1985) *The Economics of Uranium*, Praeger Press, New York.