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Energy and Economy Links – A Review of Indicators and Methods

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1. Introduction

Fossil fuels as the most important kind of energy are inevitably linked with the economy and the environment. A stable and continuous supply of fossil fuels and alternative ones is needed while we develop. Economic activity is predominantly related to the energy use, principally fossil fuels, which account for over 60% of global greenhouse gas emissions. This implies an urgent need to decouple economic growth from energy use. Thus this chapter surveys the relation between energy and economy growth.

From development perspective, energy is important for eradicating poverty, improving human welfare and raising living standards (UNDP, et al. 2000). However, in many areas of the world the current patterns of energy supply and use are considered unsustainable, which limits economic development. In other areas, environmental degradation from energy production and consumption inhibits sustainable development. So, energy is critical in the context of sustainable economy and clean environment. It is therefore important for policy makers to understand the implications of different energy programs and alternative policies.

The existing literature on energy and development does show that energy development is an important component of broader development. So we have attempted to pull together some of the ways in which energy might exert a significant influence on the development process. Development involves a number of other steps besides those associated with energy, notably including the evolution of education and labor markets, financial institutions, modernization of agriculture, improving environment and etc. Nevertheless, it is hard to imagine overall economic development succeeding without energy development being one part of the evolution.

Traditional economic theory disregards the importance of energy, because it postulates that the contribution of energy to economic growth is essentially determined by the low share of energy cost in the total cost of capital, labor, and energy. Even if the cost of energy can be neglected, being one of the driving forces in the economic process, the biophysical aspects of the economy should be considered. Therefore, the role of energy in intensifying processes with increasing automation is taken into account, where energy-driven machines replace human labor.

While the mainstream theory of economic growth pays little attention to the role of energy or other natural resources in promoting economic growth, the impact of energy prices on economic activity has attracted significant attention during the last two decades. Resource and ecological economists have criticized this theory in terms of the thermodynamics implications for economic production and the long-term prospects of the economy.

Energy development or increased availability of energy is a part of enhanced economic development. But even with trends toward greater energy efficiency and other dampening factors, total energy use and energy use per capita continue to grow in the advanced industrialized countries and even more rapid growth can be expected in the developing countries as their incomes advance. Generally, economic activities, structural and technological changes are important factors influencing energy use. So some time there is evidence of mutual interactions between economy and energy.

While there is a lack of alternative model of the growth process, extensive empirical work has examined the role of energy in the growth process. The principal finding is that energy used per unit of economic output has declined, but this is to a large extent due to a shift in energy use from direct use of fossil fuels to the use of higher quality fuels.

The role of energy in production is described in the following using neoclassical concept of the production function. This production theory is very general in comparison to the specific models of economic growth including new factors (such as substitution between energy and other inputs, technological change, shifts in the composition of the energy input, and shifts in the composition of economic output) affecting production process (stern, 2004).

Furthermore, energy and economic activity both affect the environment. However, understanding these effects has important implications, while technology has been evolved and improved dramatically. The chapter is structured to cover the key points of energy-economy- environment nexus, too.

The chapter is organized as follows. We begin with a brief review of theory of production and growth that describe the channels through which increased availability of energy might act as a "key" stimulus of economic development.

In the third part conceptual linkage between energy and development and also the role of economic activity in the energy use trend are described. Development of disaggregated energy indicators makes available a powerful set of analytical tools. Those tools reveal the relationship between energy uses and their underlying driving factors.

The next part reviews energy indicators, which are developed to describe the links between energy use and human activity in a disaggregated manner. After reviewing major indicators, we discuss the basic concepts of various indicators and the methodologies used to derive them. Then we review the use of decomposition methods to aid in the analysis of trends in energy use. The key factors in this analysis are (1) substitution between energy and other inputs within an existing technology, (2) technological change, (3) shifts in the composition of the energy input, and (4) shifts in the composition of economic output.

Then energy and economy are related to the environment. Therefore energy indicators can be extended to carbon emissions which play an important role in aiding negotiations over carbon reduction targets and evaluating progress toward meeting abatement goals.

Finally after laying out some conceptual ideas, we examine some empirical evidence.

2. Theory of production and growth

This part reviews the background theory of production and growth. The role of energy in production should be considered in order to understand the role of energy in economic growth. Mainstream economists usually think of capital, labor, and land as the primary factors of production, while goods such as fuels and materials are intermediate inputs (which are created during the production period under consideration and are used up entirely in production).

However, the theory of growth and its limitations of consideration of natural resource has been the subject of strong criticism. So the background theory of production and growth can be reviewed from different points of view.

There are essentially three mainstream categories of neo-classical growth models (Stern and Cleveland, 2004). The first one focuses on technological change as the only means by which growth can be achieved (Aghion and Howitt, 1998; Solow, 1956; Stern and Cleveland, 2004). Economic growth beyond equilibrium level (where further returns to capital are no longer possible) is only achievable by increasing returns to existing capital via improvements in technology.

The second category focuses on the consumption of natural capital in determining sustained economic growth. These models assume a priori that it is technically feasible to substitute between physical and natural capital (Stern and Cleveland, 2004). Achieving sustained growth relies on the correct institutional conditions (including property rights, market structure, means of considering future generations) to ensure that any depleted natural capital is substituted for with the corresponding value of man-made capital (Rockwell, 2008).

The last category of growth model considers both natural resources and technological change as the determinants of growth. (Stern and Cleveland, 2004).

In all three models of economic growth, the contribution of energy to economic activity is only considered relative to its cost within production process. In economic terms, the models consider energy to be an 'intermediate good' rather than a 'primary input' into production. This implies that decoupling economic growth from energy use is a possible subject, in the case of the latter two models. In the following the mentioned growth models are described briefly.

2.1 The basic growth model

The basic model of economic growth that does not include resources at all is Solow model (1956). This model subsequently was extended with nonrenewable resources, renewable resources, and some waste assimilation services (Kamien and Schwartz, 1982; Toman et al., 1994). These extended models are, however, only applied in the context of debates about environmental sustainability, not in standard macro-economic applications.

Economic growth models examine the evolution of a hypothetical economy over time, as the quantities or the qualities of various inputs into the production process change. In Solow

model (1956) using manufactured capital a constant-sized labor force produces output, which is equal to the national income. So, according to neoclassical growth theory, the only cause of continuing economic growth is technological progress. The relationship between productive inputs and output changes, as technological knowledge level rises.

However, the neoclassical the production function can be used to examine the factors that could reduce or strengthen the linkage between energy use and economic activity over time. A general production function can be represented as:

$$Q_i = f(X_i) \quad (1)$$

Where the Q_i is output, and the X_i are capital and labor inputs.

The neo-classical economic worldview sees the economy as a closed system in which goods are produced by capital and labor inputs, and then exchanged between consumers and firms. Economic growth is achieved by increasing inputs of labor or human capital or improvements in technology or quality improvements of capital and labor inputs. More recently, the role of natural capital in economic growth has also been considered.

The simple model does not explain how improvements in technology come about. More recent models explaining technological progress within the growth model as the outcome of decisions taken by firms and individuals.

In endogenous growth models the relationship between capital and output can be written in the following form:

$$Y = A.K \quad (2)$$

Where capital, K , is a composite of manufactured and knowledge-based capital. The key point is that technological knowledge, A , can be regarded of as a form of capital.

2.2 Growth models with natural resources

Most of the natural resources like fossil fuels exist in finite quantities. Finiteness and exhaustibility of fossil fuels make the notion of indefinite economic growth problematic. So far there has been relatively little work including these points in models that also examine the roles of resources in growth (Smulders, 1999).

When there is more than one input there are many alternative paths that economic growth can take. All production involves the transformation or movement of matter in some way and all such transformations require energy. So energy is an essential factor of production (Stern, 1997). Therefore, the role of energy and its availability in the economic production have been emphasized by natural scientists and some ecological economists.

In the neoclassical economics approach, the quantity of energy available to the economy in any period is endogenous (Stern, 1999). Nevertheless, this analytical approach leads to a downplaying of the role of energy as a driver of economic growth and production. Some alternative models of the economy propose that energy is the only primary factor of production. But this means that the available energy in each period is determined exogenously.

The Leontief input-output model can be regarded as an alternative to the neoclassical marginal productivity distribution theory. It represents an economy in which there is a single primary factor of production with prices that are not determined by marginal productivity. This representation of the economy or an ecosystem with energy as the primary factor was proposed by Hannon (1973).

Ecological economists express a more realistic view. They argue that economy should be considered as an open subsystem of the global ecosystem. This accounts for a broader view of inputs of natural capital. These include the absorption of waste from economic activity and the maintenance of the climate that facilitates human life. In the other world, the ecological economists' worldview attempts to account for the laws of thermodynamics.

For ecological economists, energy is a fundamental factor enabling economic production. Some others even argue that energy availability actually drives economic growth, and in turn economic growth resulting in increased energy use (e.g. Cleveland et al., 1984). From this perspective, the possibility of decoupling energy use from economic growth seems more limited.

The relationship between energy and aggregate output can then be affected by some factors such as substitution between energy and other inputs, technological change, shifts in the composition of the energy input and shifts in the composition of output. A common interpretation of standard growth theory is that substitution and technical change can effectively de-couple economic growth from energy and environmental issues.

3. Energy and development: Conceptual linkages

There are significant differences in quality and quantity between energy flows from renewable sources, nonrenewable stocks of fossil fuels and other minerals, and slowly renewable stocks of organic matter (in the form of vegetable and animal biomass), water, etc. in their current and potential contributions to society. Therefore, some inputs to production are non-reproducible, while others can be manufactured at a cost within the economic production system. The primary energy inputs are not given an explicit role in the standard growth theories which focus on labor and capital. However, capital, labor, and in the longer term even natural resources, are reproducible factors of production, while energy (except fuels) is a nonreproducible factor of production (Stern, 1999).

Since the two oil price shocks of the 1970s, there has been extensive debate concerning the trend of energy use and economic activities. It is commonly asserted that there has been decoupling of economic output and resources, which implies that the limits to growth are no longer as restricting as in the past.

The existing literature on energy and development does make clear that energy development is an important component of development more broadly. In this section we have attempted to explore some of the ways in which energy might have influence on the development process. A very simple model of the economy can be used to discuss the possible ways in which increased energy availability might be especially important to economic development. Suppose that

$$Y = F(K_Y, H_Y, E) \quad (3)$$

$$E = E(K_E, H_E) \quad (4)$$

Where Y represents output of final goods and services, and K represents the application of physical capital, H represents human capital services to the production of final good and services, and E represents energy services. Energy services in turn are produced through the application of other physical and human capital services.

A standard assumption from economic growth theory is that the production functions F , E are homogeneous of degree one that if all inputs are increased by some percent, outputs grows at the same percentage.

Energy development – increased availability of energy in quantity and quality terms – is part of enhanced economic development. Energy use per unit of output seem to decline over time in the more advanced stages of industrialization, reflecting the adoption of increasingly more efficient technologies for energy production and utilization as well as changes in the composition of economic activity (Nakicenovic, 1996).

Energy intensity in today's developing countries probably peaks sooner and at a lower level along the development path than was the case during the industrialization of today's developed world. But even with trends toward greater energy efficiency, total energy use and energy use per capita continue to grow in the developed and developing countries. Although, development involves a number of other issues (such as labor markets, financial institutions and provision of infrastructure for water, sanitation, and communications) besides those associated with energy, it is hard to imagine overall economic development succeeding without energy development.

The fact that expanded energy use (in quantity and quality) is associated with economic development still depends on the importance of energy as a factor in economic development, however. Much of the literature on energy and development, focuses mainly on how energy demand is driven by economic development (see, e.g., Barnes and Floor 1996) and on how energy services can be improved for developing countries (Dunkerley et al 1981; Barnes and Floor, 1996). Less is found in the literature on energy and development in the context of the margin of energy advance versus other inputs growth as an agent of economic development. However, there are substantial differences in energy forms and in the nature of economic activities across different stages of development. The linkages among energy, other inputs, and economic activity clearly change significantly as an economy moves through different stages of development. It is referred to "energy ladder" to describe this phenomenon (Barnes and Floor, 1996). At the lowest levels of income, energy sources tend predominantly to be biological sources (wood, dung, sunshine). More processed fuels (charcoal), animal power, and some commercial energy become more prominent in the intermediate stages. Commercial fossil fuels and other energy forms – primary fuels, and ultimately electricity – become predominant in more advanced stages of industrialization and development.

Energy provision requires a variety of different kinds of inputs. Energy utilization also depends on the opportunity costs of other inputs. Finally, the literature makes clear that observed patterns of energy production and utilization reflect a great deal of subtle optimizing behavior, given the constraints faced by the economic actors.

There are different ways in which the economic system might experience some form of increasing returns related to energy services. Therefore, increased energy availability somehow might make a disproportionate contribution to expanded economic activity. Increasing returns in energy services provision would take different forms at different stages of development. The industrial production and distribution of various forms of modern energy show increasing technological returns to scale. Moreover, the transformation of primary energy into deliverable energy (petroleum refining) also exhibits returns to scale. Energy quality is the relative economic usefulness per heat equivalent unit of different fuels. One way for measuring the energy quality is the marginal product of the fuel which means marginal increase in the quantity of a good or service produced by the use of one additional heat unit of fuel (Toman & Jemelkova, 2003).

Over the course of economic development the output mix might change. In the earlier phases of development there is a shift away from agriculture towards heavy industry, while in the later stages of development there is a shift from the more resource intensive extractive and heavy industrial sectors towards services and lighter manufacturing. It is often argued that because of different energy intensities in industries there will be an increase in energy used per unit of output in the early stages of economic development and a reduction in energy used per unit output in the later stages of economic development. Pollution and environmental disruption would be expected to follow a similar path (Panayotou, 1993). This argument can be pursued further to argue that the shift to service industries results in a decoupling of economic growth and energy use. Furthermore, shifts away from the use of coal and particularly towards the use of oil can explain the majority of declining energy intensity. The idea that a shift towards a service-based economy can achieve decoupling is one that is often put forward (Panayotou, 1993). But this notion ignores the large amounts of energy involved in producing services including some service industries such as transport (Stern and Cleveland, 2004). This implies that a shift to a service-based economy cannot achieve a complete decoupling of energy and economic growth.

4. Energy indicators

Energy indicators relating energy to economic issues can be useful tools for policy makers. They provide a way to structure and clarify statistical data to give better insight into the factors that affect energy, environment, economics and social well-being. Indicators can also be used to monitor progress of past policies.

All sectors of an economy – agriculture, manufacturing and mining, and services – require energy. These energy services in turn foster economic and social development at the local level by raising productivity and facilitating local income generation. Energy indicators provide a measure of efficiency and sustainability in economical, social, and environmental programs. Indicators of energy use are usually expressed as normalized quantities of total energy use to facilitate comparison.

The following Energy indicators within the economic dimension are the most commonly used:

- Energy Production and Supply;
- Energy consumption;

- Energy prices;
- Energy intensities of economic sectors;
- Energy mix;
- Energy supply efficiency;
- Energy use per unit GDP;
- Energy consumption per capita;
- Taxation and subsidies;

Energy intensity is a common indicator to measure the relationship between energy use and economic development of a country through time. It means ratios of energy consumption to gross domestic products (GDP) or value added measured in energy units per monetary unit at constant prices. In the same way electricity intensities or carbon intensities can be computed.

This indicator provides an assessment of how much energy intensive is an economy. Energy intensities variations over time indicate trends in “overall economic efficiency” or “energy productivity”. The economy is more “energy intensive” when the energy consumption increases more rapidly than the GDP. Energy intensity can be used to indicate the general relationship of energy consumption to economic development and provide a basis for projecting energy consumption and its environmental impacts with economic growth. There are other credible and viable indicators that focus on energy, but they are notable for their flexibility of use and their specific orientation towards sustainability dimensions, such as economic, social and environmental.

Energy consumption indicator is aggregate energy consumption which measured in Tones of Oil Equivalent (TOE). It can be expressed as per capita or per unit GDP (at market prices). This indicator provides an indication of the level and trend of the total annual amount of commercial energy consumed in the country. The indicator can be disaggregated by energy carrier (liquid petroleum fuels, electricity, and coal), then measures the contribution of each commercial energy carrier towards the total national consumption. It can provide warning signals on inefficient and unsustainable utilization of resources and environmental impact.

Energy mix indicator shows the importance of each fuel in the total energy consumption and development scene.

Energy price indicator provides an indication of the efficiency across the different fuels. It also enables prices comparison in one country with other countries. In general fuel consumption tends to be price related. Thus price can be used to influence use of particular fuels.

The energy indicators are useful to track the changes in energy in relation to economic dimensions. From another perspective there are three types of indexes that explain the change in energy use over time:

1. Activity index shows the changes in the level of activity for a sector of an economy.
2. Component-based energy intensity index represents the effect of changing energy intensity for sub-sectors or detailed components of the economy.
3. Structural index shows the effect of changing economic structure.

At the sub-sector or component level, energy intensity is defined as the ratio of energy use per unit of activity. Thus, if E_i is the energy use for component E_i and A_i is the activity for component i , the component-based intensity is defined as:

$$I_i = E_i/A_i \quad (5)$$

When two or more components or sub-sectors are aggregated, the aggregate intensity I is defined as:

$$I = \frac{\sum E_i}{\sum A_i} \quad (6)$$

For some applications, the aggregate energy intensities are useful summary indicators, as they have either a straightforward interpretation expressed in physical units or they can be converted to a time series based index. However, changes in the aggregate intensity over time are influenced not only by changes in the energy intensities of the various components but also the relative shares of each activity components.

Various types of factorization methods have been employed by which structural and compositional effects can be distinguished from the overall change in the energy intensities as represented by the component-based intensity index. A key objective in the system of energy intensity indicators is the development of time series indexes that satisfy a multiplicative relationship of the energy-economy. Decomposition analysis is a tool to quantitative assessment of factors that contributes to changes in energy consumption. It helps in understanding the past trends of energy use for measuring the effectiveness of energy-related policies, and forecasting future energy demand and pollutant emissions. The three main factors that play a significant role in affecting the level of energy consumption in an economy are: the level of overall activity or production, the composition or structure of the economy, and the output or activity per unit of energy consumed (Nooji et al, 2003).

$$\text{Energy use} = \text{activity} \times \text{structure} \times \text{intensity}$$

Energy consumption can be expressed as an extended Kaya identity, which is a useful tool to decompose total national energy consumption. It is shown as bellow:

$$EC^t = \sum \frac{E_i^t}{GDP_i^t} \times \frac{GDP_i^t}{GDP^t} \times GDP^t = \sum EI_i^t \times ES_i^t \times G^t \quad (7)$$

The change of energy consumption between a base year 0 and a target year t , denoted by ΔEC , can be decomposed to three effects in additive form: (i) the changes in the energy intensity effect (denoted by EI effect); (ii) the changes in the structural changes effect (denoted by ES effect); and (iii) the growth in the economic activity effect (denoted by G effect), as shown in Eq. (8):

$$\Delta EC = EC^t - EC^0 = EI + ES + G \quad (8)$$

In this regard, energy intensity indicators play a significant role to study the trend and the changes in the output levels. Energy intensity is thought to be inversely related to efficiency. Therefore, declining energy intensities over time may be indicators of improvements in energy efficiencies. The decomposition of the overall change into these

three categories can provide policymakers with the information needed to design appropriate strategies for reduction in energy use while helping to mitigate the environmental impacts of industrial energy use. Three factors of structural, activity or technological changes play a significant role in reducing the energy consumption and intensity with respect to the output value.

5. Environmental implications

Would a more efficient use of energy resources reduce the environmental burden of economic activity? This question has become prominent in recent years as governments across the world have implemented energy efficiency program. The environmental impacts of energy use vary depending upon how energy is produced and used, and the related energy regulatory actions and pricing structures. Gaseous emissions and particulates from the burning of fossil fuels pollute the atmosphere and cause poor local air quality and regional acidification.

Energy use has a variety of impacts. Energy extraction and processing always involves some forms of environmental degradation. As all human activities require energy use, in fact all human impacts on the environment could be seen as the consequences of energy use. In this way energy use is sometimes seen as a proxy for environmental impact of human activity. Principal issues related to the environmental dimension include global climate change, air pollution, water pollution, wastes, land degradation and deforestation. The consideration of global environmental issues such as the greenhouse effect and the 'resulting' climate change problem has led to the development of numerous theoretical models and empirical studies that making it hard to distinguish between environment and energy models (Fauchaux and Levarlet, 1999: 1123).

The impacts of climatic problems associated with the increased accumulation of pollution on the world economy have been assessed intensively by researchers since 1990s. Greenhouse gas emissions are directly related to the use of energy, which is an essential factor in the world economy, both for production and consumption. Therefore, the relationship between greenhouse gas emissions and economic growth has important implications for an appropriate joint economic and environmental policy. It is confirmed that in both poor and rich countries, economic development is not in a sufficient condition to reduce emissions. In nearly all industrial countries there is a permanent discussion on policies to reduce greenhouse gas (GHG) emissions and secure energy supply. A shift from lower to higher quality energy sources not only reduces the total energy required to produce a unit of GDP but also may reduce the environmental impact of the energy use. An obvious example would be a shift from coal use to natural gas use. However, we need to consider that kinds of fuels with higher quality necessarily do not have less environmental impacts.

In addition to energy conserving of technological change, it may also change the environmental impact of energy use over time. So that it reduces the emissions of various pollutants or other environmental impacts associated with each energy source. Therefore, despite the strong connections between energy use and economic growth there are several pathways through which the environmental impact of growth can be reduced. However, if there are limits to substitution of other kinds of energy and technological change then

the potential reduction in the environmental intensity of economic production is eventually limited.

There is a hypothesis that states an inverted U-shape relation between various indicators of environmental degradation and income per capita. It is named EKC hypothesis in which pollution or other forms of degradation rises in the early stages of economic development and falls in the later stages.

The production of energy (fossil fuel production and power generation) consumes a significant amount of energy and produces much of GHG emissions. These emissions can be reduced, through the adoption of more sustainable forms of energy production, such as community energy systems. Transportation contributes to GHG emissions, partly because the energy used to power vehicles is usually generated from fossil fuels. Regarding the supply side, the identified priority area is to diversify the energy mix, while promoting sustainable development, mainly by increasing the use of renewable energy resources. Comprehensive utilization of energy saving potential can be the main Strategy.

6. Iran case study

This section of the chapter explores energy and economic growth trends in Iran. Taking the example of the Iran economy in the period 1967 to 2007, the final fossil fuel consumption increased by about 617%, and carbon dioxide emissions sharply increased about 610%. This was in accordance with a significant increase in GDP.

The major energy carriers in Iran are liquid petroleum fuels, electricity, coal and biomass. As the growth of petroleum fuels consumption has been higher than population growth, the per capita consumption of petroleum fuels has been increasing. Furthermore, increased petroleum energy use generally indicates air pollution increase, particularly because technologies to control emissions are almost non-existent as in Iran.

Figure .1 shows the GDP trends of Iran during 1994-2007. Empirical evidence on economic growth in Iran over the last decade seems increasing simultaneously as energy increase. National Commercial Energy Consumption indicator provides a broad overview of the energy use situation and makes it possible to compare with other countries. As Fig. 2 illustrates, since the 1994 the amount of energy used has increased in almost all sectors.

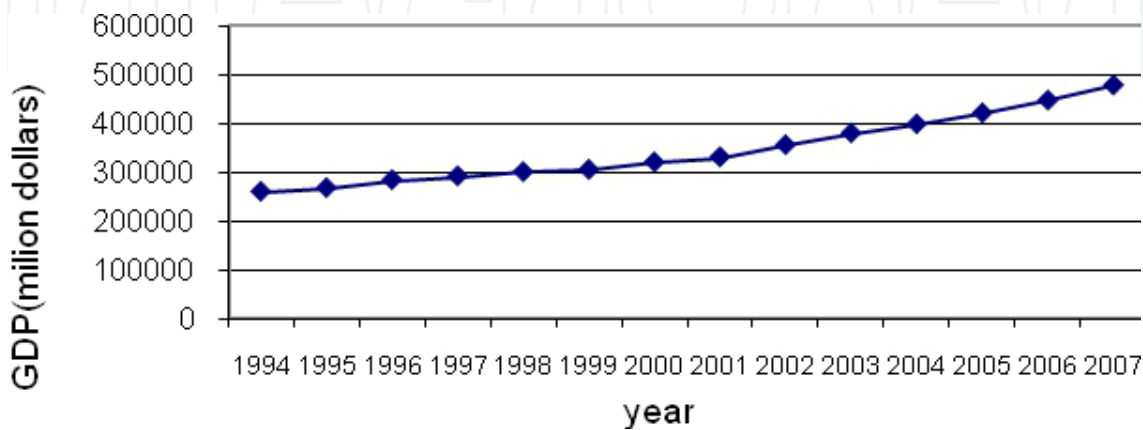


Fig. 1. Iran gross domestic products

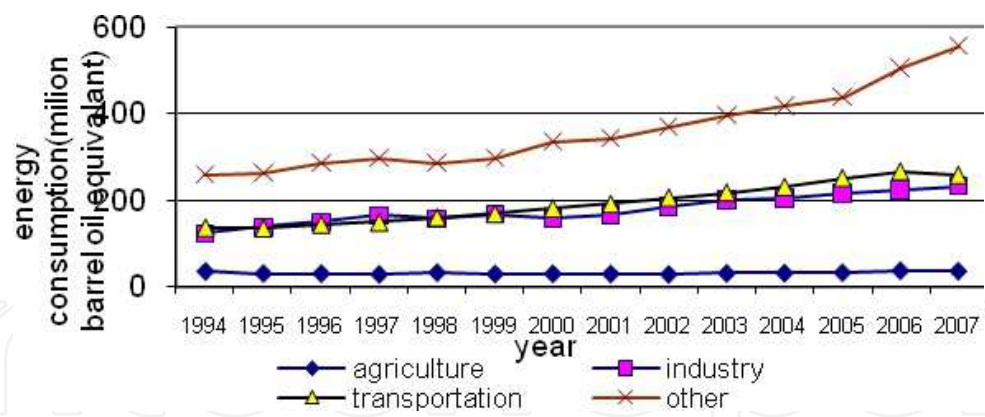


Fig. 2. Iran total energy consumption by sectors

As Fig. 3 demonstrates, once the indicator of energy intensity is used it shows a decreasing trend in some sectors. This has traditionally been assumed to be the result of the application of more energy-efficient technologies within production processes or changes of energy mix inputs. Closer examination of this trend has, however, suggested that this apparent decoupling has in fact been achieved largely by a switch away from the direct use of low-quality fuels to higher quality fuels and energy inputs, electricity in particular.

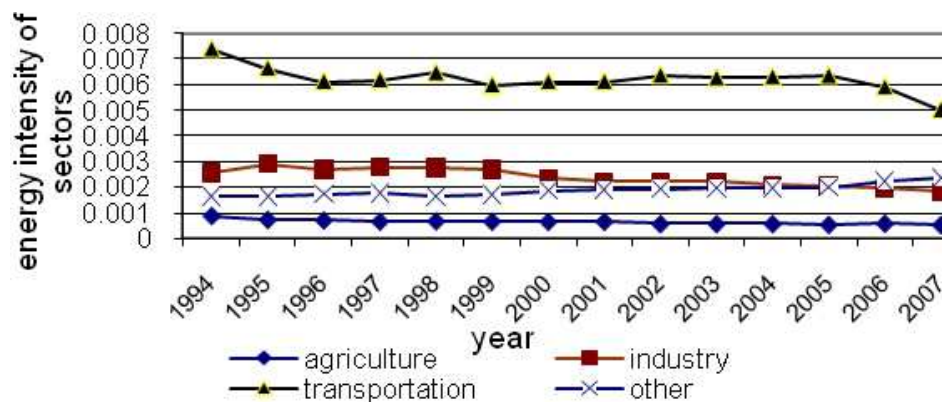


Fig. 3. Iran energy intensity by sectors

Energy intensity is a measure of how much energy is used to produce a unit of economic output. The decoupling of increasing economic activity from increasing energy consumption is a goal for sustainable development. Energy intensity tends to decline over time as a function of underlying efficiency gains and the transition to a more service-based economy. So, it shows less energy needed to generate GDP. It should be considered that Government policies can play a crucial role in how energy intensity changes. Increasing per capita energy consumption is generally associated with development. However, with increasing environmental awareness this is not necessarily a desirable trend.

7. Conclusion

The production, distribution and use of energy create pressures on the environment in the household, workplace and city, and at the national, regional and global levels. Therefore, energy indicators are useful for evaluating impacts of energy systems in all these areas. Trade-offs among three objectives - energy security, environmental protection, and

economic growth – has been dominant concerns in energy policy making during recent years. Thus, the main aim of this paper is to present and discuss the use of a particular kind of analytical tool to reinvestigate energy-environment-economy interactions theoretically.

We begin by providing some background that appears to underlie the energy- economy relation which in turn consider environmental issues. Energy poses a challenge to those working to achieve sustainable development goals. We need to use energy to alleviate poverty, promote economic growth and foster social development. But as more energy is consumed, stress is placed on the environment at the local and regional levels.

The fact that expanded energy use is associated with economic development still depends on the importance of energy as a factor in economic development. However, there are substantial differences in energy forms and in the nature of economic activities across different stages of development. The linkages among energy, other inputs, and economic activity clearly change significantly as an economy moves through different stages of development. The energy mix in a developed country can be dominated by non-carbon emitting energy sources, notably hydroelectricity, used in the household and industrial sectors, used in the transport sector. Breaking energy consumption down by sector, by region and for urban and rural areas will be useful in identifying strategies for energy policy implementation. Currently it is possible to disaggregate all data by sector, by region, and between urban and rural.

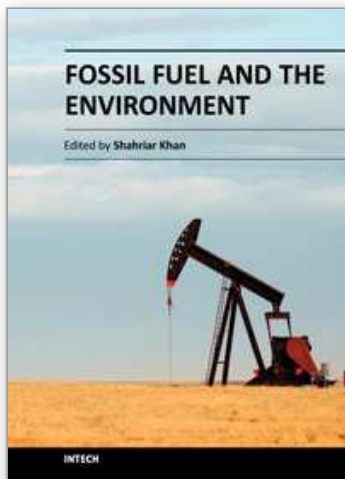
Internationally, the efficient use of resources has seen a growing role in policy making. In fact, there has been an extensive debate in the energy economics about the impact of improvements in energy efficiency and environmental consequences. If we work together to safeguard the environment without slowing socio-economic development, we look for technological solutions. So, we should change unsustainable patterns of consumption and production toward the least costly ways of achieving sustainable development goals. Analytical tools, such as the energy indicators described before, can be helpful in finding the best solutions in a menu of available options, aimed at achieving these goals.

The cutback in emissions according to the Kyoto Protocol and the maintenance of social well-being require a fragile balance between policies that often have opposite effects. Hence, it is very important to determine the link between economic performance and energy consumption. Emissions of greenhouse gases, especially CO₂ emissions, are closely linked to the energy consumption of primary energy, but the final consumption is crucial for the consumption of primary energy. In fact, energy demand is a derived demand that depends on the productive structure of the economy, the energy content, the sectoral production, the age of the stock of capital, etc. Recently, global and regional environmental problems associated with the utilization of conventional fuels seek to the Renewable Energy Sources (RES) as a competitive participant in the energy scenery. Legislative measures have been adopted in order to reduce dependency from fossil fuels to further integrate non-polluting technologies in the energy mix.

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The world today is at crossroads in terms of energy, as fossil fuel continues to shape global geopolitics. Alternative energy has become rapidly feasible, with thousands of wind-turbines emerging in the landscapes of the US and Europe. Solar energy and bio-fuels have found similarly wide applications. This book is a compilation of 13 chapters. The topics move mostly seamlessly from fuel combustion and coexistence with renewable energy, to the environment, and finally to the economics of energy, and food security. The research and vision defines much of the range of our scientific knowledge on the subject and is a driving force for the future. Whether feasible or futuristic, this book is a great read for researchers, practitioners, or just about anyone with an enquiring mind on this subject.

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