Doctoral Dissertation

Study on the Sustainability Assessment of Energy Subsidies Reform in Iran

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Chapter 1:

Introduction

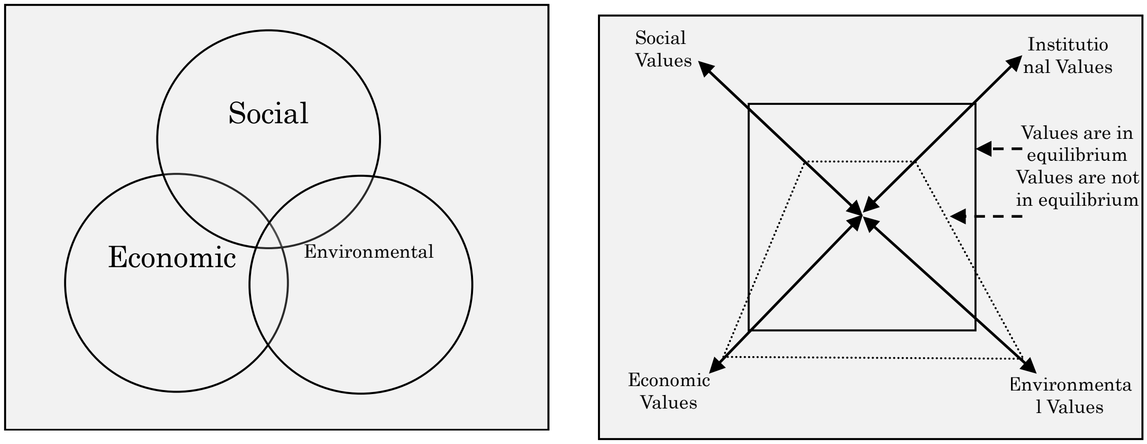
1.1 Introduction

As the first definition, World Commission on Environment and Development (WCED) (1987) report, Our Common Future, defined sustainable development as “a development which satisfies the need of the present without compromising the ability of future generations to satisfy their own necessities”. In fact, this definition converts the essence of classical development from the slogan of “more is better” to “sufficient is better” (Joseph, 2001). Restriction of above definition to “meet the needs” and “make it sustainable” has raised disagreements. As Marcuse (1998) believes, sustainability in above definition cannot be a good goal. Sustainability as a goal only benefits those who have everything that they want.

Although Agenda 21 clarified sustainable development by its three explicit pillars (Kahn, 1995), i.e. social, economic and environmental, focus of researchers on economic and environmental pillars, i.e. ecologically sustainable development, led others to conclude sustainability can work just as a constraint on the achievement of other goals. Indeed, they believed that even focusing on environmental concerns, “the problem for the world‘s poor is not that their condition ***cannot*** be sustained, but that they ***should not*** be sustained” (Marcuse, 1998).

Historically, the approach to sustainable development has tended to be sectoral. Illustrating three pillars in a sectoral context emerged the tripartite model of sustainability often represented diagrammatically by three intersecting circles depicting the natural, social and economic dimensions (Figure 1.1-A) (Stimson et al., 2006). The intersecting areas are in fact, areas where related capitals are exchanged and converted by societal values, principles, customs, laws and rules (Elkington, 1997). This tripartite model, however, presents conceptual difficulties on how to integrate the three dimensions of sustainability and create mechanisms that allow trade-offs over the use of social, economic and environmental resources.

Three decade working on the concept and components of sustainable development paved the way to a better understanding. First, researchers have concluded that it is probably not possible or even desirable to arrive at one standard definition of sustainability. Such a dynamic concept must evolve and be refined as our experience and understanding develop (Moldan and Dahl, 2007; Shearman, 1990; Davies, 1997). Second, a fourth institutional pillar was added by the UN Commission on Sustainable Development (CSD) (Karlsson et al., 2007; Söderbaum, 2007). Institutions have been described as essential to sustainable development because of their indispensable role in implementing social, economic and environmental objectives. Although some claimed this dimension is embedded in social pillar, some researchers believe that it is better to define it as a distinct pillar to avoid complexity and make room to describe its trade-offs with other pillars (Spangenberg, 2007). Third, they found four pillars of sustainability must be integrated and interlinked in a comprehensive manner (Basiago, 1999). If we consider sustainable development as a trade-off between pillars‘ values, then it is conceptually possible to plot these values on axes to create rectangular plane of sustainability (Figure 1.1-B). Indeed, sustainable development that aims to restore equilibrium between institutional, environmental, economic and social values leads us to square diagrams when discrimination between pillars, i.e. non-sustainability, can be shown by rectangles or trapezoids (Stimson, 2007).



Source: Modified from Stimson et al.(2006)

(A) (B)

Fig. 1.1: Traditional model of sustainability (A) versus recent framework for sustainable development (B)

This thesis is studying the sustainability of a public policy in energy sector using the above concept of sustainable development. In fact, it investigates the probable impact of energy subsidy reform on some selected variables in economic, social, and environmental pillars in Iran. Then, it answers to this question that the reform policy can address the sustainability targets in Iran or not. In the next sections, we will explain why a reform in the energy sector of Iranian economy is necessary.

1.2 Energy subsidy in Iran and necessity of reform

Iran is a country in Central Eurasia and Western Asia with a population of over 74 million (SCI, 2010). It is a country of particular geostrategic significance because of its location in the Middle East and Central Eurasia. In addition, it is the eighteenth largest country in the world, with an area of 1,648,000 km2 (SCI, 2010).

Although oil and gas production has accounted for an increasingly smaller share of real GDP, oil and gas revenues remain the main source of foreign exchange earnings and fiscal revenues. The share of oil in real GDP fell from an average of 40 percent of real GDP in the 1960s to about 10.5 percent in the last decade, reflecting average annual non-oil GDP growth rate of 5.7 percent compared to only 4.4 percent for oil and gas GDP. Oil and gas receipts accounted for about 72 percent of export revenues in the last decade, despite rapid non-oil export growth. Oil and gas revenues also account for 65 percent of fiscal revenues, and are likely to remain the main source of financing for development projects in the foreseeable future notwithstanding recent efforts to diversify fiscal revenues (Guillaume and Zytek, 2010; Guillaume et al., 2011; IMF, 2011)

Table 1.1 illustrates the energy balance of Iran in 2008. From the balance, Iran could produce 2428.4 MBOE of different types of energy, mainly petroleum and refined petroleum products (66%) and natural gas (33%). Near to 44% of total produced energy was exported, as the main source of fiscal revenue, and the remainder was consumed domestically. The main energy consumers in Iran were residential, public, and commercial sectors, transportation sector, and industrial sector that accounted for 37%, 25%, and 23% of total energy demand. Following the production pattern, the main consumed energy carriers were fossil fuels. Petroleum products and natural gas accounted for 47.9% and 42.6% of total energy consumption, respectively. The share of electricity consumption was only 8.6%.

Table 1.1

Energy balance of Iran in 2008 (Million Barrel Oil Equivalent)

Description	Petroleum and refined petroleum products	Natural gas	Coke	Renewable energies (solid biomass and biogas)	Hydropower	Solar and wind energies	Total electricity	Total energy
Production	1606.6	805.3	7.8	5.6	2.9	0.1	-	**2428.4**
Import	84.3	44.5	3.7	-	-	-	1.0	**133.5**
Export	-1029.8	-29.7	-0.2	-	-	-	-2.3	**-1062.0**
Energy consumption in energy sectors and energy losses	-127.7	-344.9	-8.4	0.0	-2.9	-0.1	97.9	**-386.2**
Total energy supply	**533.5**	**475.2**	**2.9**	**5.6**	**0**	**0**	**96.6**	**1113.8**
Residential, public and commercial sectors	82.8	277.1	0.1	5.6	-	-	49.4	**415.0**
Industrial sector	73.0	147.3	0.3	-	-	-	32.2	**252.8**
Transportation sector	269.8	11.6	-	-	-	-	0.1	**281.6**
Agricultural sector	27.9	1.5	-	-	-	-	12.5	**41.9**
Other sectors	-	-	-	-	-	-	2.4	**2.4**
Non-energy utilization	79.9	37.7	2.5	-	-	-	-	**120.1**
Total energy demand	**533.5**	**475.2**	**2.9**	**5.6**	**0**	**0**	**96.6**	**1113.8**

Fig. 1.2 and 1.3 show the trend of fossil fuels and electricity consumption in Iran over the period 1973–2008. Despite a temporary decline in consumption of gas oil, fuel oil, and kerosene at the end of 1990s, the consumption of all types of fuels have increased enormously over the last decades. In the years after the Revolution (1979), the consumption of gas oil, fuel oil, gasoline, kerosene, LPG, natural gas, and electricity have grown annually 4.17%, 5.07%, 5.48%, 1.06%, 3.48%, 9.24%, and 8.54%, respectively. Fig. 1.4 compares the growth rates of GDP, final energy consumption, and population in Iran over the period 1968–2008. Almost, the growth rate of final energy consumption has been greater than the growth rates of GDP and population. It reflects the low share of energy expenditure in total spending of households and cost of producers due to low energy prices.

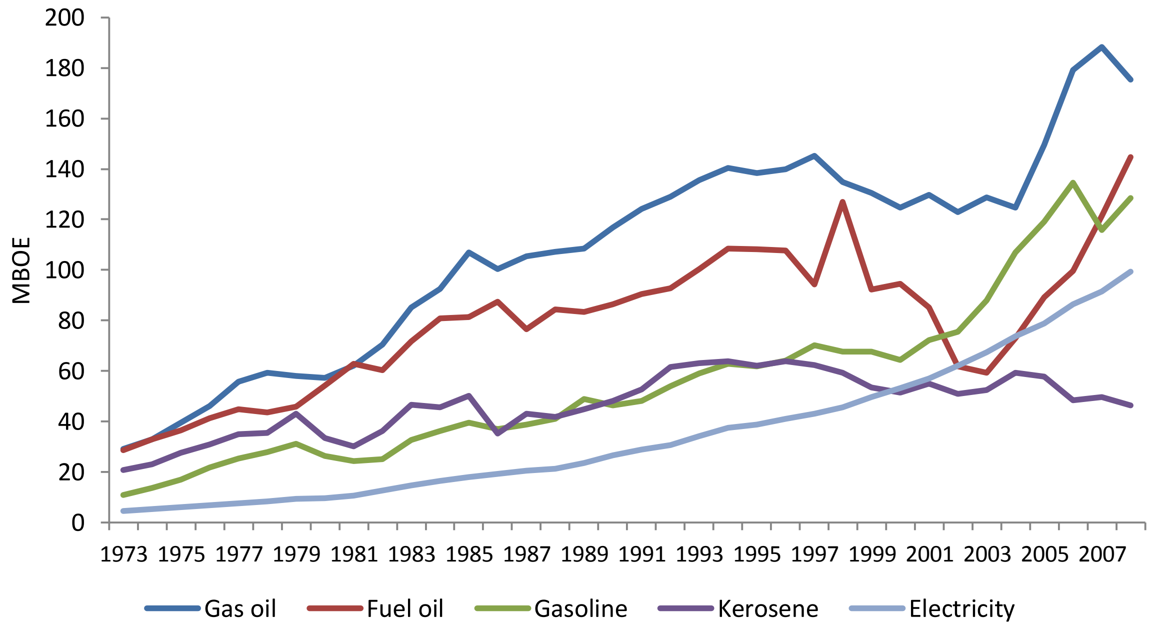


Fig. 1.2. Trend of total gas oil, fuel oil, gasoline, kerosene, and electricity consumption (1973-2008)

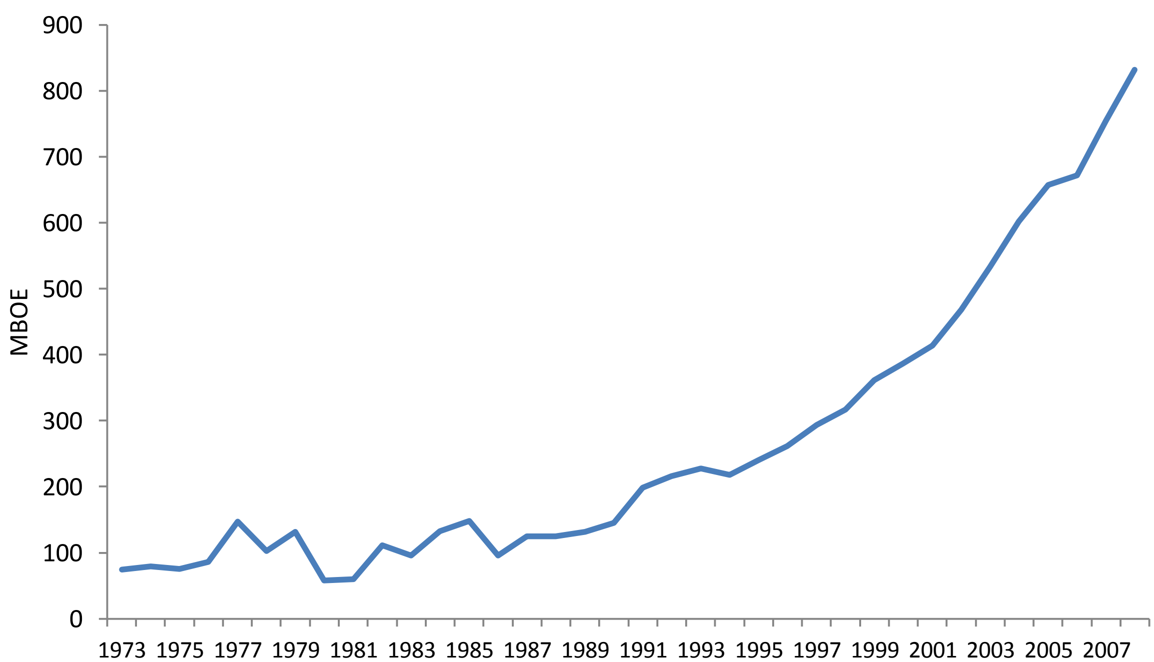


Fig. 1.3. Trend of total natural gas consumption (1973-2008)

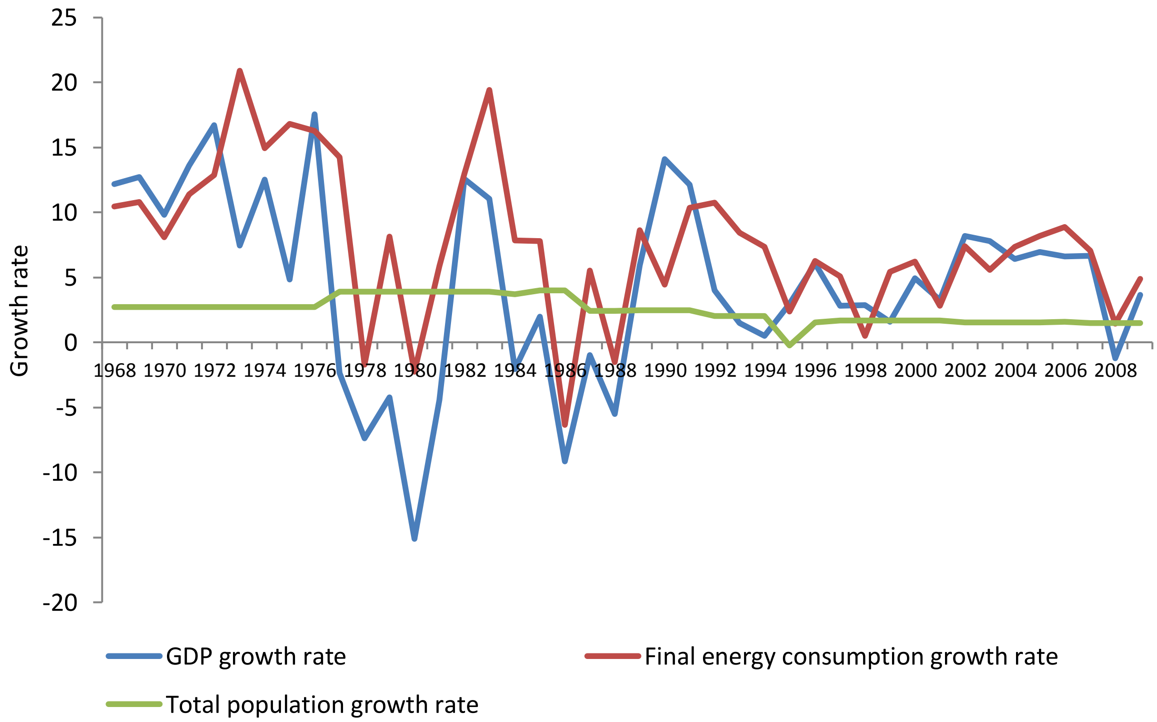


Fig. 1.4. Comparison of GDP, final energy consumption, and population growth rates in Iran (1968-2008)

As it is obvious in Fig. 1.5, the consumption pattern of some sectors has changed essentially since 1970. Although the predominant fuels in transportation sector are still refined petroleum products, electricity and natural gas have substituted with petroleum products in residential, public, and commercial sector, industrial sector, and agricultural sector. Iran has the second largest natural gas reservoirs in the world and invested hugely to increase its production. In addition, it followed an ambitious and prolonged plan to expand the domestic natural gas pipelines, especially because it is a clean fuel and substitutable to petroleum, which can be exported more easily. While the extraction of natural gas started in 1972, it accounted for 66.38%, 58.29%, 4.12% and 3.52% of total energy consumption in residential, public, and commercial sector, industrial sector, transportation sector, and agricultural sector respectively in 2008. As well, electricity accounted for 12.42%, 12.73%, 0.05% and 29.47% in the respective sectors.

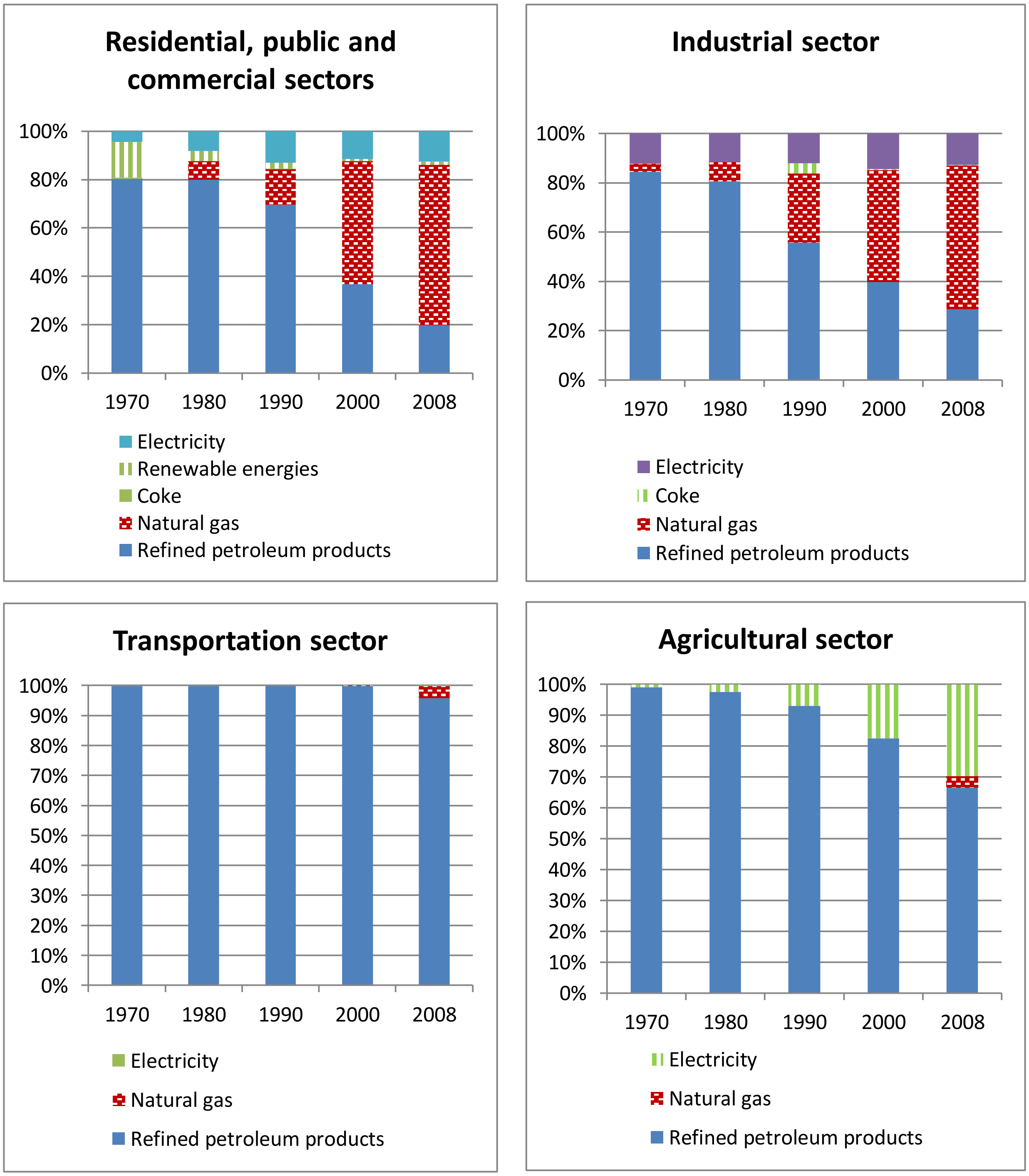


Fig. 1.5. Composition of sectoral energy consumption by fuel type in Iran at selected years

Fig. 1.6 shows the trend of energy intensity (energy consumption/GDP) in Iran as a whole and by fuel over the period 1973-2007. The graph illustrates when total energy intensity was 0.66 BOE/Million IR. Rials in 1973, it increased extremely to 2.18 after three decades. The main contributor is undoubtedly natural gas which accounted for 69% of total energy intensity in 2007. Due to the low price of natural gas (1.03 cents/m3), the energy intensity of natural gas increased from 0.42 BOE/Million IR in 1973 to 1.51 in 2007, that shows an averagely 6.23% growth rate per year.

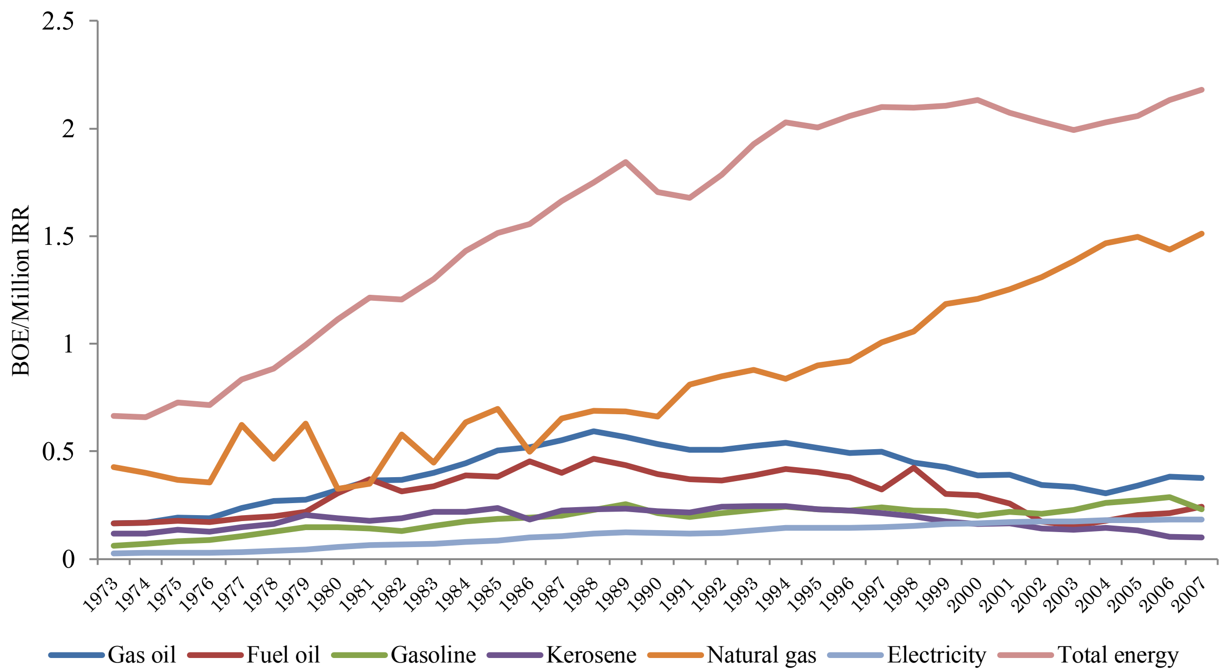
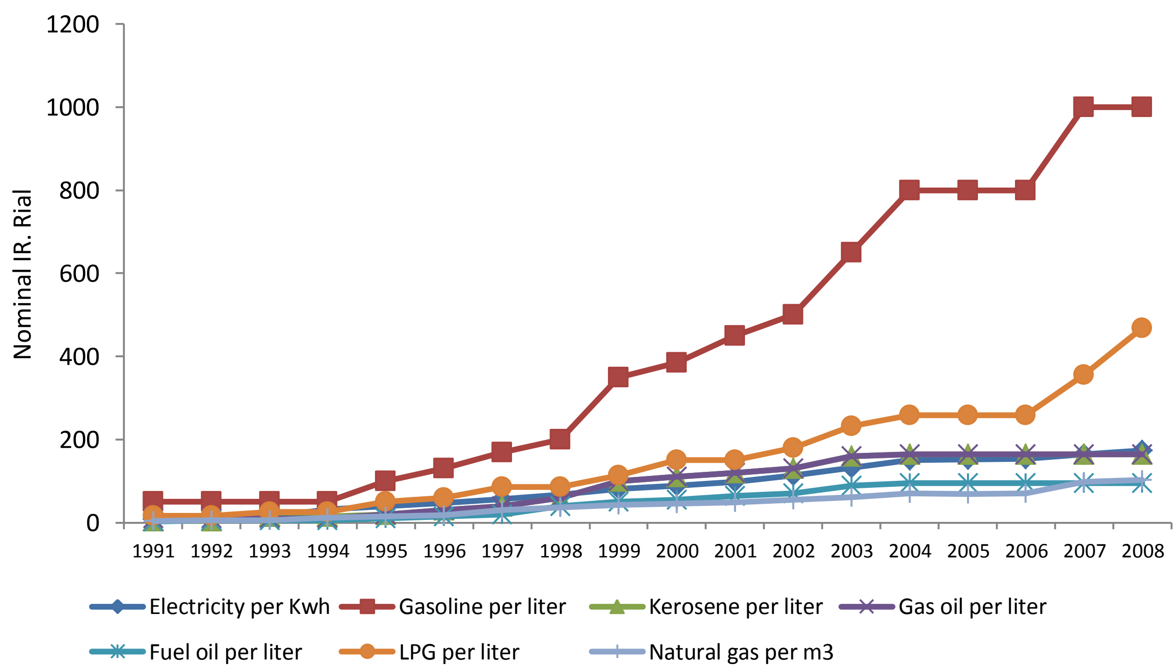


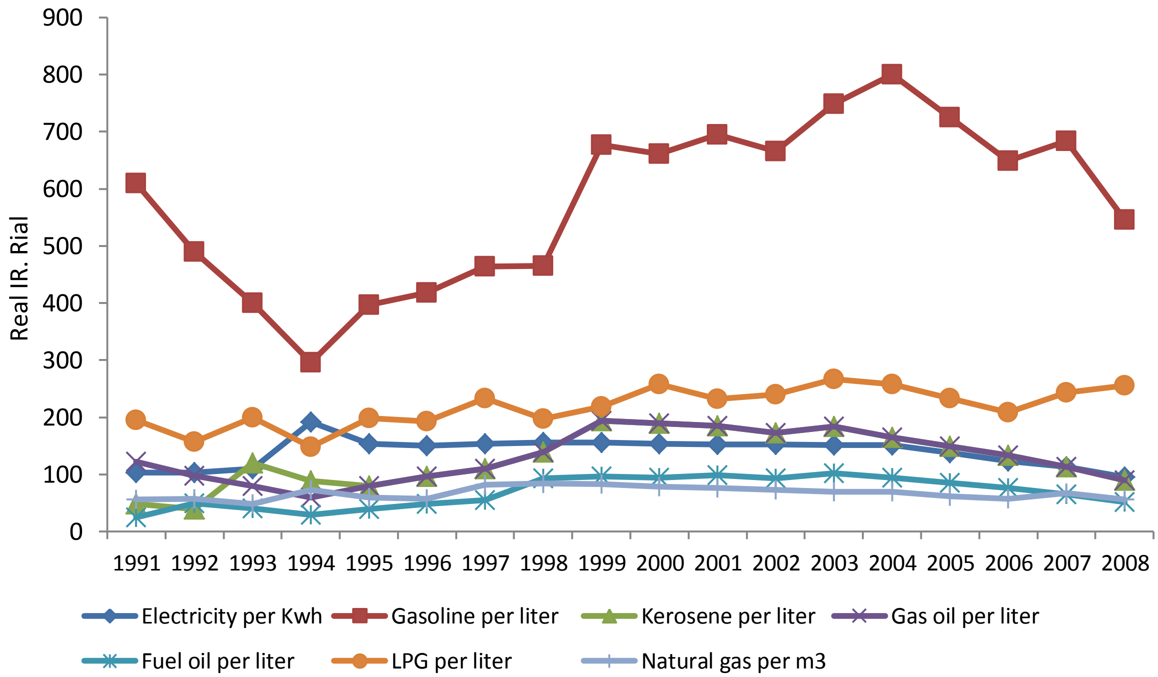
Fig. 1.6. Trend of energy intensity by fuel type in Iran (1973-2007)

Domestic energy prices have historically been set administratively in Iran. Fig. 1.7 and 1.8 depict the level and trend of nominal and real energy prices over the period 1991–2008. Apparently, the nominal prices have been increased by government through the period of study. In the last decade (1998-2008), nominal prices of LPG, gasoline, natural gas, gas oil, kerosene, electricity, and fuel oil were increased 10.6%, 11.1%, 9.2%, 5.1%, 5.1%, 7.5%, and 6.6%, respectively. However, deduction of annual inflation rate from the nominal price growth rate makes an inverse picture. In the same period, real prices were growing -3.6%, -3.1%, -4.7%, -8.3%, -8.3%, -6.3% and -7.1% respectively, that evidence the energy prices got cheaper relatively.



Source: MoE (2010)

Fig. 1.7. Nominal energy prices in Iran (1991–2008)



Source: MoE (2010)

Fig. 1.8. Real energy prices in Iran (1991–2008)

IEA (1999) defines an energy subsidy as any government action that concerns primarily the energy sector that lowers the cost of energy production, raises the price received by energy producers or lowers the price paid by energy consumers. Table 1.2 shows an approximate of energy subsidy in Iran by sector and energy type in 2008. All the figures are calculated by taking the gap between the domestic and global prices, adding all of direct financial payments which reduce the final prices for consumers. Table 1.2 indicates that all types of subsidies in energy sector were totally near to 442,033 billion IR. Rials (44.5 billion USD), or 6,002 thousand IR. Rials per person (605 USD) in 2008. Among the consumers, transportation sector accounted for 40.2% of total energy subsidies. The next most significant consumers were residential and industrial sectors that accounted for 25.2% and 17.8% of total energy subsidies, respectively. Commercial sector received the least amount of subsidy (3.6%). From the fuel perspective, most of subsidies are paid for gas oil (27.3%), and then electricity and gasoline fuels (26.2% and 18.2% respectively). The least amount of subsidies was paid for LPG which has the smallest share in total energy consumption. Total amount of energy subsidies is equal to about 11% of GDP at 2009.

Table 1.2

Energy subsidy in Iran at 2009 (Billion IR Rials)

Sector	Residence	Industry	Agriculture	Transport	Commerce	Public	Total	%	% of GDP
Gasoline	-	285.8	124.8	79914.6	2.4	235.7	80563.3	18.2	0.020
Kerosene	319	239.5	-	80.7	252.1	26364.5	27255.7	6.2	0.007
Gas oil	2724.8	12809.9	18649.3	80214.6	1915.1	4486.6	120800.3	27.3	0.030
Fuel oil	-	23505.7	-	12837.8	3841.1	791.2	40975.7	9.3	0.010
LPG	9619.4	1232	-	2421.2	-	-	13272.7	3	0.003
Electricity	47596	27321	15006	134.3	8673.3	17044.5	115775.5	26.2	0.028
Natural gas	25173.9	13411.3	209.9	2100.8	1448.6	1045.3	43389.7	9.8	0.011
Total	111478.6	78817.9	34071.2	177623.2	16119.9	23922.2	442033	100	0.108
%	25.2	17.8	7.7	40.2	3.6	5.4	100	-	-
% of GDP	0.027	0.019	0.008	0.044	0.004	0.006	0.108	-	-

Source: MoE (2010) and author calculation - 1 USD = 9,917 Rials

1.3 Energy subsidy reform in Iran

The Iranian targeted subsidy plan also known as the subsidy reform plan was passed by the Iranian Parliament on January 5, 2010. [1] The government has described the subsidy plan as the biggest surgery to the nation's economy in half a century and one of the most important

[1] The Reform Act is available in Appendix 1.

undertakings in Iran's recent economic history. The goal of the subsidy reform plan is to replace subsidies on food and energy (80% of total) with targeted social assistance, in accordance with Five Year Economic Development Plan and move towards free market prices in a 5-year period. The subsidy reform plan is the most important part of a broader Iranian economic reform plan (Guillaume and Zytek, 2010).

According to the government, approximately $100 billion per year is spent on subsidizing energy prices ($45 billion for the prices of fuel alone) and many consumable goods including bread, sugar, rice, cooking oil and medicine. However, some experts believe direct subsidies are about $30 billion, depending on oil prices.

The subsidy system has been inherited from the Iran-Iraq war era but was never abolished. Iran is one of the largest gasoline consumers in the world, ranking second behind the United States in consumption per car. The government subsidy reform has been years in the making for various reasons. Iran's Supreme Leader has backed the government's latest subsidy reform plan.

Iran was the largest provider of fuel subsidies in the world by 2009. Many Iranian experts agree that these unsustainable subsidies encourage waste among goods, including in the production sector, ranging from gasoline to bread that must be stopped and the only way to do that is to redirect subsidies.

The stated goal of the subsidy reform is to rejuvenate Iran's economy, increase productivity, give it a new footing and bring it out of the slump it has been in for so long. Concretely, the government plans to replace the subsidies with targeted social assistance. Consequences of the economic reform plan are that Iran will be less vulnerable to US sanctions because it will reduce fuel imports. The reform plan will also save money for the Iranian people because it will end a multi-billion dollar-a-year contraband (17% percent of fuel production in Iran is smuggled abroad daily). Due to subsidies, Iran had long had one of the cheapest gas prices in the world, 10 cents per liter or 40 cents per gallon (Guillaume and Zytek, 2010).

Implementation of the plan will reduce waste and consumerism. In fact, according to official data, the higher income strata of the population has enjoyed the same subsidies as the poor until now. On the other side, subsidies reduction will reduce air pollution by reducing car traffic in Tehran. Finally, the subsidy plan will increase social justice through targeted social assistance. According to official data, the richest decile of households benefits 12 times more from gasoline subsidies than the poorest decile. Overall, implementation of the plan will increase productivity, efficiency, and competitiveness of Iran's economy, economic growth, oil exports and per capita income (all other things being equal).

For implementation of the bill, an entity has been established as a duly authorized governmental company under the name ―Targeting Subsidies Organization". The amount saved by the government, will be distributed as follows: 50% towards the poorest strata of Iranian society; 20% at the government's disposal (to compensate for increased costs or as safety net); and the remaining 30% will be directed towards improving the efficiency of the utility, fuel and energy production infrastructure, public transportation development, industry and farming.

The plan will commence with energy, fuel and utilities in the first year and consumable goods will start in the second year. The start of the cuts will coincide with the beginning of the second half of the Iranian year on Sept. 23, 2010. At that time, the 2007 Gas rationing plan will come to an end.

In March 2010, the Iranian Parliament approved a $347 billion budget, in which the allocation from subsidies and the oil price were set at $20 billion and $65 per barrel, respectively. According to the Vice President for Parliamentary Affairs, Iran's subsidy reforms would save 20 percent of the country's budget. Iran wants to save up to $100 billion on subsidies within three to four years. In 2011, the Iranian parliament approved a $508 billion budget based on $80/barrel oil price. This bill also factors in $54 billion from price hikes and subsidy cuts.

According to the IMF, until recently a four-member Iranian household received an average of $4,000 a year in subsidies for oil and natural gas, compared with a typical annual income of about $3,600 a year. In 2010, Iran's Department of Statistics announced that 10 million Iranians live under the absolute poverty line and 30 million live under the relative poverty line. President Mahmoud Ahmadinejad says implementation of the targeted subsidy system will eradicate unemployment and poverty in Iran within three years (Guillaume and Zytek, 2010).

1.4 Main questions and objectives

Current thesis studies the sustainability of energy subsidies reform in Iran. Studying different impacts of energy subsidy reform on some selected variables in economic, social, and environmental pillars, we are trying to assess the sustainability of this policy in Iran. Therefore, the main questions of the research are:

1. What is the impact of energy subsidies reform on producer costs and inflation rate in Iran?
2. How much the reform increases the expenditures and reduces the real income of Iranian households?
3. Can the price reform reduce energy consumption and CO_2 emission in Iran?
4. Considering the answers of the above questions, is the energy subsidies reform a sustainable policy?

The main objectives of the research are as follow:

1. Evaluating the sustainability of energy subsidies reform policy in Iran

2. Proposing effective policies to improve the reform

1.5 Structure of thesis

This thesis consists of six chapters, illustrated in Fig. 1.9. In Chapter 2, the sustainability of Iran is assessed in a comparative manner. In Chapter 3, the energy intensity of nonenergy sectors are derived and the potentials for reduction in energy consumption are examined. In Chapter 4, the inflationary impact of energy subsidy reform on producers and households are estimated. In Chapter 5, the probable energy conservation and CO_2 mitigation of the reform are studied. In the last chapter, the analysis is concluded and some further studies are proposed.

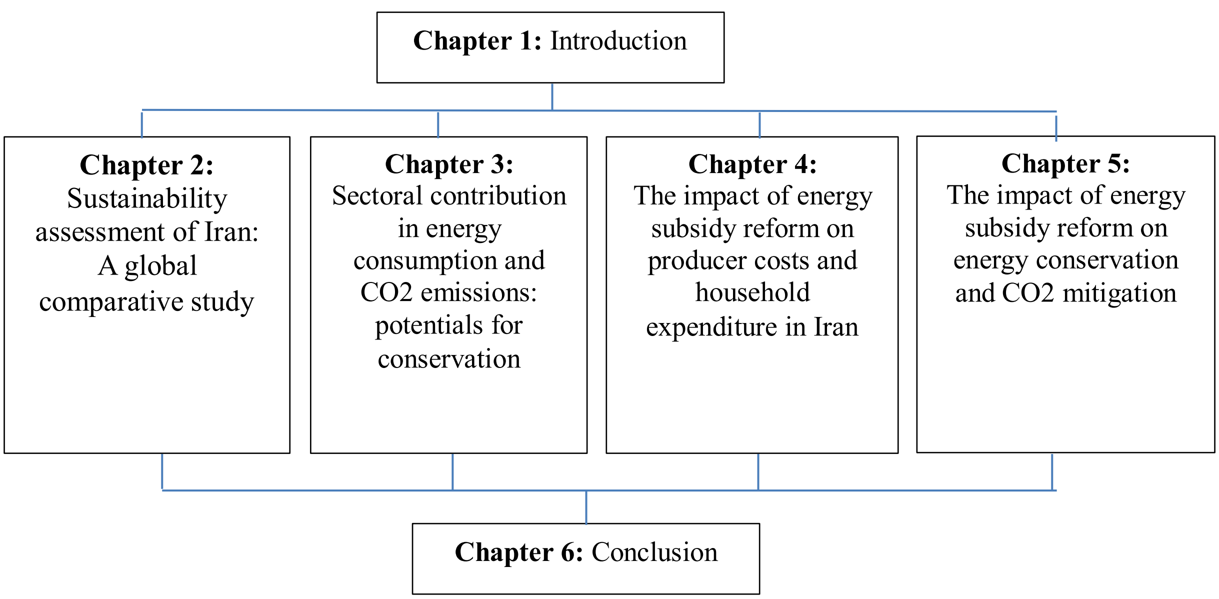


Fig. 1.9. The structure of thesis

Chapter 2:

Sustainability assessment of Iran: A global comparative study

2.1 Introduction

The World Commission on Environment and Development (WCED) (1987) report, Our Common Future, provided the first definition of sustainable development as ―a development which satisfies the need of the present without compromising the ability of future generations to satisfy their own necessities". Agenda 21, revealed at the United Nations Conference on Environment and Development (Earth Summit) in 1992, clearly identified three key building blocks of sustainable development: economic, environmental and social pillars. However, the restriction to ‗meet the human needs' and ‗make it sustainable' has raised some disagreements (Marcuse, 1998). Three decades of debate on the concept and components of sustainable development have paved the way to a better understanding of the issues.

First, researchers have concluded that it is probably not possible or even desirable to arrive at one standard definition of sustainability. Such a dynamic concept must evolve and be refined as our experience and understanding develop (Shearman, 1990; Davies, 1997; Mog, 2004; Moldan and Dahl, 2007). Second, a fourth institutional pillar was added by the UN Commission on Sustainable Development (CSD) (Karlsson et al., 2007; Söderbaum, 2007). Institutions have been described as essential to sustainable development because of their indispensable role in implementing social, economic and environmental objectives. Although some claimed this dimension is embedded in social pillars, some researchers believe that it is better to define it as a distinct pillar to avoid complexity and make room to describe its trade-offs with other pillars (Spangenberg, 2007). Third, researchers have found that the four pillars of sustainability must be integrated and interlinked in a comprehensive manner (Basiago, 1999).

Since the Earth Summit, authorities at different spatial levels have committed to implementing sustainability measures (ICLEI, 2002; Fernández-Sánchez and Rodríguez-López, 2010). Sustainable development indicators (SDIs) are used to collect, process and use information with the goal of making better decisions, directing smarter policy choices, measuring progress and monitoring feedback mechanisms in all of the sustainability pillars, as emphasized in Agenda 21. SDIs as an interaction between values and objectives, policy and science (Shields et al., 2002; Rametsteiner et al., 2009) increase the accuracy of evaluating/quantifying the diverse sustainability issues in different temporal (short, medium or long run) and spatial (international, national, regional, urban or local) dimensions (Spangenberg et al., 2002; Ramos and Caeiro, 2010).

The first step in making any public policy with the target of sustainable development is studying the current performance of the countries in each pillars of sustainable development. While there are continuous opportunities to improve the sustainability in each country, the sustainability assessment of countries should be carried out in a comparative basis. If we understand the relative performance of a specific country (such as Iran), we can easily find the rooms for the further improvements. In addition, we can get a list of priorities by assessing the pillar gaps exist between each country and the best performer.

In this chapter, we are going to make the same study for Iran. Therefore, as a first step, sustainability pillar variables for 131 countries are defined and derived for the period 2000–2007. In the next step, the comparative performance of Iran is investigated.

2.2 Sustainability indicators for intercountry comparison

As McGlade (2007) believes, the main purpose of SDIs is to provide a comprehensive and highly scalable information-driven architecture that is policy relevant and understandable to members of society and can help them understand previous trends, current situations and future outlooks. In other words, SDIs based on their communication power, help different layers of society, from governors to the general population, to decide on what to do. To meet this target, indicators should be purposeful, measurable, representative, reliable and communicable (Bauler et al., 2007).

One of the main applications of SDIs is to measure and compare the sustainability of countries. It is recognized that SDIs need to be applicable over a variety of spatial scales and conditions to support global as well as local comparisons (Rees et al., 2008). Comparisons help to determine what does and what does not work and why. Karlsson et al. (2007) state that approaches to developing indicators suitable for intercountry comparisons should strive to:

- develop a sound, simple and unified method for the selected indicators,
- select indicators that reflect commonly agreed aspects of sustainable development or commonly agreed targets for action,
- avoid indicators that are highly influenced by diversity in natural, socioeconomic and cultural circumstances,
- have full transparency of the whole process (development of indicators, methods, data collection and presentation),
- obtain agreement among the partners involved in the process, including public availability of results,
- be complementary to other indicator sets developed according to local, national or regional priorities.

One problem in the establishment of intercountry SDIs is deciding between weak versus strong sustainability assessment. Weak sustainability assumes perfect substitutability between produced and natural capital, whereas strong sustainability assumes no substitutability. The argument of weak and strong sustainability is sometimes seen as a discussion between neoclassical environmental economics and ecological economics. Where the former believes that the equilibrium quantity of pollution or extraction is not necessarily zero (based on equality between marginal rates of benefit and costs of pollution emissions or natural resource extraction), the latter believes that some services of nature cannot be replaced by man-made capital or human labor (Ayres, 2007; Shmelev and Rodríguez-Labajos, 2009). It seems that for intercountry comparisons, weak SDIs have more capacity to satisfy the Karlsson criteria (especially obtaining agreement of countries), because for the poor but resource-rich countries, natural resources are the only asset at least for the current time. Therefore, we use weak SDIs in this study.

Different organizations, institutions, universities and NGOs are publishing their SDIs to show macro sustainability trends and rank countries. UNDP (2003) detailed the sources of various published governance indicators for different geographical coverage. Böhringer and Jochem (2007) reviewed the explanatory power of 11 sustainability indices applied in policy practice. They concluded that the indices fail to fulfill fundamental scientific requirements making them rather useless if not misleading with respect to policy advice. Singh et al. (2009) provided an overview of 70 sustainability indices focusing on their formulation strategy, scaling, normalization, weighting and aggregation methodology. Some authors also tried to produce their own indicators. For instance, Udo and Jansson (2009) tried to use several human survival, development and progress variables to create aggregate sustainable development parameters that describe the social, environmental and technological sustainability capacities of 132 nations and rank them. Chen et al. (2009) used data envelopment analysis (DEA) to carry out comparison of BRICSAM (Brazil, Russia, India, China, South Africa, ASEAN states and Mexico) and G7 members' overall performances. Raab and Feroz (2007) also used DEA to develop a generalized efficiency index for a set of 57 national governments, both of developing and developed countries, by employing four components of gross national product and five resource-availability indicators.

2.3 Principal component analysis

A vast domain of approaches, from bivariate to multivariate techniques, can be used to construct sustainability indicators. Whereas bivariate analysis measures the strength of the association between all pairs of variables, multivariate analysis assesses the overall power of any collection of variables to measure any other variable (Singh et al., 2009). The power of multivariate techniques in addition to the complexity of the concept and elements of the sustainability, inevitably dominated these methods and their indicators, i.e., composite indicators. Table 2.1 summarizes some of multivariate analytical techniques and their applications.

Table 2.1

Summary of some multivariate techniques and their applications.

Type	Technique	Purpose	Application
Classification	Cluster analysis	Exploratory and confirmatory	Classification of objects into groups displaying similar properties
	Discriminant analysis	Explanatory and predictive	Determine variables responsible for segregation of objects into groups
	Correspondence analysis	Descriptive and exploratory	Analyze discrete variables with many categories and to group relevant information
	Data envelopment analysis	Explanatory	Evaluate efficiency of objects and ordering of them
Summary	Principal components analysis/empirical orthogonal functions	Exploratory and data reduction	Identify sources of variation in multivariate data

	Factor analysis	Explanatory	Determine underlying factors responsible for variations
	Cronbach coefficient alpha	Explanatory	Investigate the degree of the correlations between a set of variables
	Canonical correlation analysis (CCA)	Explanatory	Investigate the relationship between two groups of variables
	Self-organizing maps	Predictive	Identify commonly encountered scenarios or patterns within spatial data sets
Spatial relationship analysis	Semivariogram	Assessment and predictive	Understanding spatial relationships between measurements. Interpolate between samples
	Geographically weighted regression	Exploratory and predictive	Understand changes in relationships between variables in space

Adapted from Bierman et al. (2009) and OECD (2008).

PCA is one of the most popular methods among multivariate techniques to construct SDIs. The central idea of PCA is to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set. This is achieved by transforming it into a new set of variables, the PCs, which are uncorrelated and ordered so that the first few retain most of the variation present in all of the original variables. In summary, it can be said that PCA is a variable reduction technique that can be used when variables are highly correlated; it reduces the number of observed variables to a smaller number of PCs that account for most of the variation of the observed variables and is a large sample procedure (Jolliffe, 2002). These characteristics are the reasons why researchers use PCA to construct their SDIs.

Different sustainability indices can be constructed using PCA. These composite indicators include the Internal Market Index, Business Climate Indicator, General Indicator of Science and Technology, City Development Index and Environment Performance Index (Singh et. al., 2009). Jollands et al. (2004) applied PCA to derive eco-efficiency indices for New Zealand. Adler et al. (2009) combined PCA and DEA to design a framework to measure the relative socioeconomic performance of developing countries. Finally, Lai (2003) used PCA to measure and analyze the progress of human development in Chinese provinces since 1990. He also compared his scores with Human Development Index (HDI) scores.

2.4 Designing the model

OECD (2008) clarifies the methodology of composite indicator construction by defining ten steps: theoretical framework, data selection, imputation of missing data, choosing multivariate analysis, normalization, weighting and aggregation, uncertainty and sensitivity analysis, back to the data, links to other indicators and visualization of the results. Following the theoretical framework explained in Section 2.2, 29 variables were selected. Data are arranged in the same ordering to create the input matrix for PCA. In the next step, the data matrix is normalized based on three methods to study the sensitivity of the normalization methods. Using PCA, eigenvalues, factor loadings and PCs are derived. Finally, the PCs are used to construct SDIs for each country for each year. These steps will be explained in more detail in the following sections.

2.4.1. Data

Originally, we used UN reports (UN, 2001a, 2001b) to classify and choose the variables. However, some important points should be considered before discussing the variables. First, in most similar studies, there is a severe trade-off between the length of the sample period and the number of countries. A longer period generally means having to omit some countries because of data unavailability. For greater spatial coverage (especially in institutional and social pillars), authors inevitably decide to use short sample periods. Second, as mentioned in Section 2.2, it seems that weak sustainability is more plausible than strong sustainability for intercountry comparisons. Therefore, based on data availability, five environmental variables are chosen by using their adjusted saving measures. The share of adjusted savings in gross national income (GNI) is an interesting weak sustainability measure that enables us to consider both pollution damages or natural resource depletion and their converted capitals such as human capital in monetary terms. Third, interesting pillars could be introduced to account for interactions between pillars that are neglected in the current study to avoid more complexity. Consequently, some variables could be found that have two pillar dimensions, e.g., the improved water source variable. Regarding water pollution, the variable is an environmental sustainability issue, but as access of population to improved water is a health concern, water pollution has to be located in the social sustainability pillar. Of course, isolation of pillars from each other is a weak point of this study that should be mentioned in future studies.

Considering the above-mentioned points, 136 countries were selected for this research. During the process, five countries (Azerbaijan, Belarus, Democratic Republic of the Congo, Estonia and Gabon) became outliers that were omitted from the list and the research was completed for 131 countries. The time span of the study is 2000 to 2007. Because of missing observations, data for 2008 were omitted. Table 2 lists the variables used to construct each pillar.

Table 2.2

Variables of sustainable development pillars and their sources.

Sustainability pillar	Variable	Scale	Source
Institutional sustainability	1. Political rights	Qualitative, 1–7, best to worst	Freedom House: www.freedomhouse.org
	2. Civil liberties		
	3. Press freedom index	Qualitative, from 0, best to worst	Reporters Without Borders: www.rsf.org
	4. Voice and accountability	Qualitative, (–2.5)–(2.5), worst to best	Kaufmann et al. (2009), Governance Matters VIII: Aggregate and Individual Governance Indicators (1996–2008), World Bank Policy Research
	5. Political stability & absence of violence/terrorism		
	6. Government effectiveness		
	7. Regulatory quality		
	8. Rule of law		
	9. Control of corruption		
Environmental sustainability	10. Adjusted savings: carbon dioxide damage	Quantitative, % of GNI	World Bank, World Development Indicators (2000–2007 reports)
	11. Adjusted savings: energy depletion		
	12. Adjusted savings: mineral depletion		
	13. Adjusted savings: net forest depletion		
	14. Adjusted savings: particulate emission damage		
Economic sustainability	15. GDP per capita	Quantitative, PPP (constant 2005 international $)	World Bank, World Development Indicators (2000–2007 reports)
	16. GDP per capita growth	Quantitative, annual %	
	17. Inflation, consumer prices	Quantitative, annual %	
	18. Cost of business start-up procedures	Quantitative, (% of GNI per capita)	
	19. Current account balance	Quantitative, % of GDP	
	20. Foreign direct investment, net inflows	Quantitative, % of GDP	
	21. Internet users	Quantitative, per 100 people	
Social sustainability	22. GINI index	Qualitative, %, best to worst	World Bank, World Development Indicators (2000–2007 reports)
	23. Health expenditure, total	Quantitative, % of GDP	
	24. Improved water source	Quantitative, % of population with access	
	25. Life expectancy at birth, total	Quantitative, years	
	26. Mortality rate, under 5 years old	Quantitative, per 1,000	
	27. Proportion of seats held by women in national parliaments	Quantitative, %	
	28. Public spending on education, total	Quantitative, % of GDP	
	29. Ratio of girls to boys in primary and secondary education	Quantitative, %	

2.4.2. Normalization

The PCA methodology is well documented (Manly, 1994; Sharma, 1996; Jolliffe, 2002) and consists of seven steps: construct a data matrix, standardize variables, calculate the correlation matrix, find eigenvalues (to rank PCs) and eigenvectors, select PCs (based on stopping rules), interpret the results and calculate scores. The variables in Table 2.2 are of different types (quantitative and qualitative), units (number, percentage etc.), and ordering (ascending and descending). To manipulate the data for further PCA analysis, data should be modified in two steps. In the first step, data should be rearranged in the same ordering to facilitate the possibility of pillar aggregation and derive the total sustainable indicator for each country. Therefore, data in descending order (from best to worst) were multiplied by minus one to be converted into ascending manner (from worst to best).

In the second step, three normalization methods, i.e., standardization, min–max and cyclical techniques are applied to remove the data units and allow the possibility of running sensitivity analysis by comparing the ranking of the countries derived from each normalization method. All normalization methods were calculated based on the performance of countries in the initial time period, t_0, to assess their performance across years. Using this method, the final PCs of countries can be compared over time.

For each variable, z-scores were calculated based on the following normalization formula:

$$I_q^t = \frac{x_q^t - \bar{x}_c^{t_0}}{\sigma_c^{t_0}}, \qquad (2.1)$$

where I_q^t is the normalized score for country q, $\bar{x}_c^{t_0}$ is the variable average across countries for the reference year (here 2000) and $\sigma_c^{t_0}$ is the standard deviation across countries for the reference year. The min–max method is applied based on equation 2.2.

$$I_q^t = \frac{x_q^t - \min_c(x^{t_0})}{\max_c(x^{t_0}) - \min_c(x^{t_0})} \qquad (2.2)$$

$\max_c(x^{t_0})$ and $\min_c(x^{t_0})$ are the minimum and maximum values of variable *x* across all countries in the reference year. When variables are in the form of time series, cyclical transformations can be made by subtracting the mean over time $E_t(x_q^t)$ and then dividing by the mean of the absolute values of the differences from the mean (equation 2.3).

$$I_q^t = \frac{x_q^t - E_t(x_q^t)}{E_t(\left|x_q^t - E_t(x_q^t)\right|)} \qquad (2.3)$$

2.4.3. Ranking countries

Normalization of raw data leads us to three input data sets. Different normalized input data allow researchers to test the robustness of the derived sustainability scores and ranking of countries. Deriving factor loadings from PCA, PCs can be calculated based on equation 2.4.

$$Z_{Q\times P} = X_{Q\times P}.A_{P\times P} \qquad (2.4)$$

Letting Q and P be the numbers of countries and variables, $X_{Q\times P}$ represents the normalized matrix of input data, $A_{P\times P}$ is the factor loading matrix and finally, $Z_{Q\times P}$ represents P vectors of PCs for Q countries. The next step is to select the first PCs that preserve a ‗high' amount of the cumulative variance of the input data. There are different rules to define a ‗high' magnitude known as ―stopping rules" (OECD, 2008). Here, ‗variance explained criteria' are implemented based on the rule of keeping enough PCs to account for 90% of the variation.

Before finalizing the analysis, we need to track the PCs to identify outliers. An outlier is an observation that lies an abnormal distance from other values in a random sample from a population. Outliers are deviating factor loadings and make the PCs biased. If outliers are found in the analysis, PCA should be repeated after omitting the outliers. In this way, five countries were omitted and the analysis was repeated. The final selected PCs based on stopping rules were aggregated across countries and used as the sustainability indicator.

A comparison of rankings for three normalized input data reveals a high degree of similarity among them. Because of the 99% correlation between the three ranking matrices, we can take arithmetic mean of the inputs and repeat the ranking procedure. Table 2.3 illustrates the ranking of countries based on the derived PCs of 131 countries that are grouped for two sequential years. A ranking for total sustainability was done after rescaling of scores from 0 to 100 representing the worst and best performances, respectively. This process was done to weight all pillars equally.

To compare the accuracy of our PCA rankings, the average HDI ranking of countries is provided in the final column of Table 2.3. Before any comparisons, it should be mentioned that HDI consists of three (equally weighted) subindices that are aggregated by taking an arithmetic mean: Life Expectancy Index, Education Index (decomposed into an Adult Literacy Index and Gross Enrolment Ratio Index), and a GNP Index. In fact, HDI has a strong focus on the social dimension and no institutional or environmental variables can be found in it. Nevertheless, running a correlation test between our PCA and HDI rankings discloses a correlation of 87% between these two rankings.

Table 2.3

Ranking of countries based on their institutional, environmental, economic and social sustainability among 131 countries (2000–2007).

Row	Name of country	Pillars of sustainability (2000–2007)				Total sustainability				HDI
		Institut.	Enviro.	Econo.	Social	2000–1	2002–3	2004–5	2006–7	2000–7
1	Albania	64	16	71	52	41	46	49	49	47
2	Algeria	107	88	46	59	73	82	87	74	70
3	Angola	112	125	128	131	131	130	131	123	97
4	Argentina	50	111	50	48	52	65	55	43	35
5	Armenia	79	122	37	74	99	81	75	68	59
6	Australia	12	66	18	17	16	16	16	19	2
7	Austria	11	27	12	7	11	11	7	10	14
8	Bangladesh	102	57	89	101	83	93	98	99	102
9	Belgium	15	13	10	9	7	12	10	11	16
10	Benin	44	44	114	102	62	62	70	77	112
11	Bhutan	94	78	76	77	101	84	68	58	92
12	Bolivia	61	117	100	69	77	73	91	91	76
13	Bosnia and Herzegovina	66	39	75	28	48	43	35	36	51
14	Brazil	45	60	54	72	51	51	50	45	50
15	Bulgaria	46	116	47	39	60	50	42	51	42
16	Burkina Faso	97	92	113	98	106	103	102	109	126
17	Burundi	121	115	124	80	125	122	116	106	125
18	Cambodia	99	18	111	112	97	104	101	104	94
19	Cameroon	108	81	109	117	112	112	112	114	105
20	Canada	9	32	9	13	9	10	13	12	4
21	Central Afr. Rep.	109	35	122	129	109	123	117	120	128
22	Chad	116	101	121	125	116	125	124	130	123
23	Chile	20	126	41	78	46	49	58	69	31
24	China	127	112	32	93	111	108	110	108	66
25	Colombia	91	46	61	63	58	69	61	60	55
26	Congo (Brazzaville)	120	83	129	126	130	126	127	127	127
27	Costa Rica	29	25	59	44	31	29	33	32	38
28	Côte d'Ivoire	122	43	117	106	95	109	111	116	114
29	Croatia	37	55	36	24	32	33	31	31	33
30	Czech Rep.	24	24	28	23	24	22	21	20	27
31	Denmark	4	10	7	1	3	2	2	1	13
32	Dominican Rep.	49	69	72	91	55	57	64	59	62
67	Lebanon	90	80	94	58	78	90	67	72	54
68	Liberia	118	110	130	128	128	131	125	125	119
69	Lithuania	26	22	27	38	25	23	27	27	34
70	Macedonia	58	33	53	45	47	42	39	37	48
71	Madagascar	56	12	108	120	80	88	85	93	99
72	Malawi	73	26	116	57	68	60	65	56	113
73	Malaysia	62	45	22	41	35	34	34	40	46
74	Mali	48	96	112	108	92	87	88	89	129
75	Mauritania	89	130	98	114	129	128	129	129	108
76	Mexico	53	53	55	51	44	38	48	50	39
77	Moldova	74	84	62	25	64	48	40	41	80
78	Mongolia	43	129	65	49	104	64	100	100	79
79	Morocco	85	17	70	55	49	55	52	55	90
80	Mozambique	63	34	103	115	91	85	79	84	122
81	Namibia	38	37	58	79	40	41	46	46	89
82	Nepal	111	49	96	95	87	99	109	102	98
83	Netherlands	7	62	4	14	10	14	11	7	7
84	New Zealand	5	8	21	12	13	8	9	13	18
85	Nicaragua	57	21	118	67	56	58	59	65	85
86	Niger	78	94	127	124	121	115	119	115	131
87	Nigeria	104	98	73	130	113	119	122	119	109
88	Norway	8	38	1	4	2	4	4	3	1
89	Oman	76	121	33	76	67	89	83	80	40
90	Pakistan	123	104	85	104	114	113	115	118	96
91	Panama	39	20	63	65	37	37	37	38	43
92	Papua New Guinea	67	131	91	127	126	129	130	131	100
93	Paraguay	75	65	106	73	69	71	76	67	68
94	Peru	59	113	57	103	72	79	89	98	57
95	Philippines	72	64	79	94	70	63	77	82	71
96	Poland	32	56	38	31	29	28	30	30	30
97	Portugal	17	36	48	18	21	20	23	21	26
98	Romania	40	29	51	61	43	35	36	42	45

Row	Name of country	Pillars of sustainability (2000–2007)				Total sustainability				HDI	Row	Name of country	Pillars of sustainability (2000–2007)				Total sustainability				HDI
		Institut.	Enviro.	Econo.	Social	2000–1	2002–3	2004–5	2006–7	2000–7			Institut.	Enviro.	Econo.	Social	2000–1	2002–3	2004–5	2006–7	2000–7
33	**Ecuador**	71	52	77	113	74	83	80	85	52	**99**	**Russia**	106	105	29	64	88	80	86	75	49
34	**Egypt**	105	93	84	47	65	77	81	86	83	**100**	**Rwanda**	113	50	110	109	118	111	107	90	117
35	**El Salvador**	47	28	90	84	53	52	57	57	72	**101**	**Saudi Arabia**	124	119	40	36	79	92	96	83	41
36	**Ethiopia**	114	107	105	100	123	121	108	103	121	**102**	**Senegal**	52	87	107	89	89	72	73	78	116
37	**Finland**	1	4	5	10	5	5	5	4	11	**103**	**Sierra Leone**	95	97	131	119	127	127	128	128	130
38	**France**	18	2	23	8	14	13	14	14	9	**104**	**Slovakia**	25	11	25	35	27	24	22	22	32
39	**Gambia**	88	71	120	111	96	96	105	117	118	**105**	**Slovenia**	21	19	24	16	18	17	17	17	24
40	**Georgia**	84	95	60	60	85	74	60	63	63	**106**	**South Africa**	34	74	66	70	39	40	41	48	88
41	**Germany**	13	6	16	11	12	9	12	8	20	**107**	**South Korea**	33	63	19	43	30	32	29	28	22
42	**Ghana**	42	103	99	75	81	66	63	64	107	**108**	**Spain**	19	42	31	27	22	25	24	24	15
43	**Greece**	31	79	43	34	33	31	32	33	21	**109**	**Sri Lanka**	81	40	82	88	59	59	72	87	69
44	**Guatemala**	82	59	93	96	82	86	84	81	84	**110**	**Sudan**	130	67	87	122	115	120	120	122	104
45	**Guinea**	110	114	119	118	124	118	121	124	120	**111**	**Sweden**	6	1	3	3	1	1	3	2	6
46	**Guinea-Bissau**	96	86	126	116	110	117	113	121	124	**112**	**Switzerland**	3	9	6	6	4	6	6	5	8
47	**Guyana**	51	128	104	40	71	78	92	110	77	**113**	**Syria**	126	102	86	62	108	107	106	111	73
48	**Haiti**	119	51	125	123	122	124	126	113	103	**114**	**Tajikistan**	115	68	83	92	105	95	90	97	87
49	**Honduras**	65	54	92	86	61	61	69	76	74	**115**	**Tanzania**	70	73	102	110	90	91	93	96	106
50	**Hungary**	22	15	42	19	23	19	19	25	29	**116**	**Thailand**	55	58	45	71	38	39	54	71	60
51	**Iceland**	2	3	13	2	6	3	1	6	3	**117**	**Togo**	101	77	123	87	107	100	97	107	111
52	**India**	60	89	74	85	66	67	71	70	93	**118**	**Trinidad & Tobago**	36	90	17	66	34	36	47	35	44
53	**Indonesia**	86	106	88	105	100	105	103	88	75	**119**	**Tunisia**	98	47	69	33	54	54	51	53	67
54	**Iran**	128	108	44	50	93	98	104	92	61	**120**	**Turkey**	69	91	67	68	84	68	56	61	53
55	**Ireland**	10	5	20	30	15	18	18	16	5	**121**	**Uganda**	93	76	97	99	103	101	82	79	110
56	**Israel**	35	61	39	15	26	30	28	29	23	**122**	**Ukraine**	83	100	34	29	86	56	43	34	58
57	**Italy**	27	14	30	22	20	26	25	23	17	**123**	**United Arab Emirates**	68	118	8	83	57	76	66	54	28
58	**Jamaica**	41	72	56	56	45	45	45	47	65	**124**	**United Kingdom**	14	7	14	20	17	15	15	15	19
59	**Japan**	23	41	15	21	19	21	20	18	10	**125**	**United States**	16	31	11	5	8	7	8	9	12
60	**Jordan**	77	75	78	26	50	53	38	52	64	**126**	**Uruguay**	30	109	68	54	42	44	44	39	36
61	**Kazakhstan**	103	123	35	82	102	102	95	95	56	**127**	**Uzbekistan**	131	127	64	42	119	116	118	105	81
62	**Kenya**	87	30	95	90	94	75	74	66	101	**128**	**Venezuela**	92	70	49	97	63	97	78	73	86
63	**Kuwait**	54	120	2	46	36	47	53	44	25	**129**	**Vietnam**	125	82	52	81	98	106	94	94	78
64	**Kyrgyzstan**	100	48	81	53	75	70	62	62	82	**130**	**Yemen**	117	99	115	32	76	94	99	101	95
65	**Laos**	129	85	80	107	120	114	114	112	91	**131**	**Zambia**	80	124	101	121	117	110	123	126	115
66	**Latvia**	28	23	26	37	28	27	26	26	37											

2.5 Dynamics of the countries' sustainability

Normalization of the raw data based on their reference year provides an opportunity to compare the derived indicators over time. In this part, certain findings from Table 2.3 will be explained, in particular the highest versus the lowest ranked countries, the greatest versus the least progress and total and regional sustainability trends.

2.5.1. The highest versus the lowest ranked

As can be seen from Table 2.3, the top 10 countries in terms of total sustainability are Denmark, Sweden, Iceland, Norway, Finland, Switzerland, the United States, Austria, Belgium and Germany. The Scandinavian countries are the most sustainable countries in terms of all pillars and their performances are stable during the period 2000–2007. The worst ranked countries are Papua New Guinea, Mauritania, Angola, Sierra Leone, Congo (Brazzaville), Liberia, Chad, Guinea, Haiti and Sudan, which are mainly African countries. For the institutional pillar, the best performance belongs to Finland, Iceland and Switzerland. For the environmental pillar, Sweden, France and Iceland have the best performance. For the economic pillar, the best performance belongs to Norway, Kuwait and Sweden. In the last pillar, social sustainability, Denmark, Iceland and Sweden have the best performance among the 131 countries.

2.5.2. The greatest versus the least progress

The other interesting concern is the greatest and least progress. Institutionally, the highest progress from 2000 to 2007 belongs to Liberia, Bhutan and Ukraine. Liberia increased its rank from 127 in 2000 to 90 in 2007. On the other hand, Thailand, Sri Lanka and Côte d'Ivoire declined. For the environmental pillar, Ukraine, Uzbekistan and Kazakhstan increased their ranks and the positions of Zambia, Papua New Guinea and Chile deteriorated. The performances of Angola, Congo and Argentina were remarkable for the economic pillar. For instance, Angola improved its economic conditions and increased its ranking from 129 in 2000 to 59 in 2007. In contrast with these countries, Liberia, Guinea-Bissau and Yemen deteriorated. For the social pillar, Rwanda, Moldova and Burundi were the outstanding progress countries whereas Kuwait, Uzbekistan and Malaysia had the worst performances. Rwanda increased its social ranking from 121 to 72 while the performance of Kuwait decreased from 30 to 74. In total, the greatest progress was achieved by Angola, Ukraine and Bhutan whereas the greatest decline was experienced by Chad, Thailand and Guyana.

2.5.3. Total sustainability trend

Figure 2.1 shows total sustainability of countries in each sustainability pillar and Figure 2.2 shows the gap between the best and worst countries' performances for the period 2000–2007. The institutional pillar reveals a stable trend for the period. Although the total score of the institutional pillar increased slightly, the gap between the top and bottom ranked countries remains constant. Improvement in the social and especially the economic pillars is also evident, but the gaps remain stable too. No matter how performance improves particularly for the economic dimension, the gap between rich and poor countries persists. Comparison of the sustainability for the two institutional and social pillars is also interesting. As previously mentioned, some believe that the institutional dimension is embedded in the social pillar. However, separating the institutional dimension shows that countries are strengthening more in terms of their social progress, e.g., by supporting their education and health programs or removing obstacles to women‘s participation, instead of improving their institutional capacities. Unfortunately, good governance is not highlighted enough relative to other dimensions for governors and the public.

Despite the optimistic trends in these pillars, environmental sustainability has demonstrated negative trends. We see in Fig. 2.2 that the both of environmental pillar curves are downward sloping, which indicates that in addition to total sustainability, the performance of all countries has deteriorated. If we consider the environmental and economic pillars to be two sides of a coin, we can interpret these trends. Economic growth has been the primary target and has played the most critical role among sustainability variables for policy makers in most counties. Figure 2.1 supports this claim that most decision and policy makers sacrifice environmental quality to attain economic targets. However, our findings in Section 2.6 will complete this interpretation.

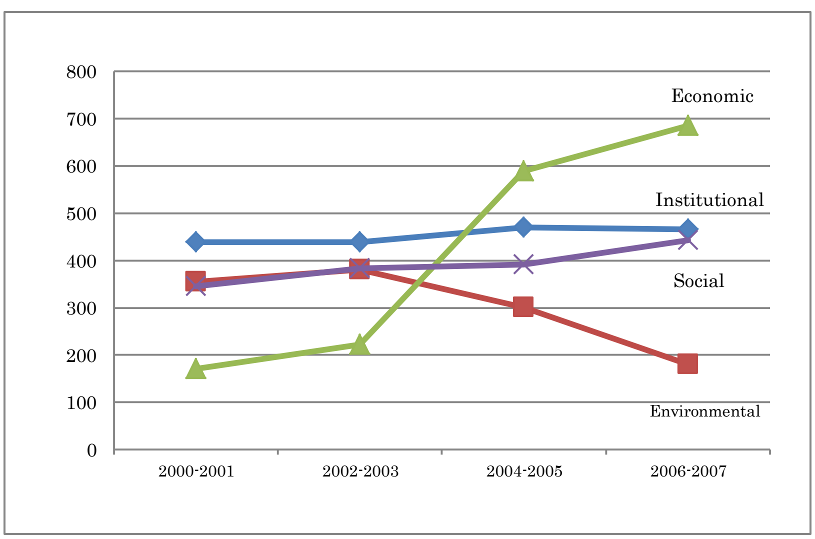


Fig. 2.1. Total trends of institutional, environmental, economic and social pillars

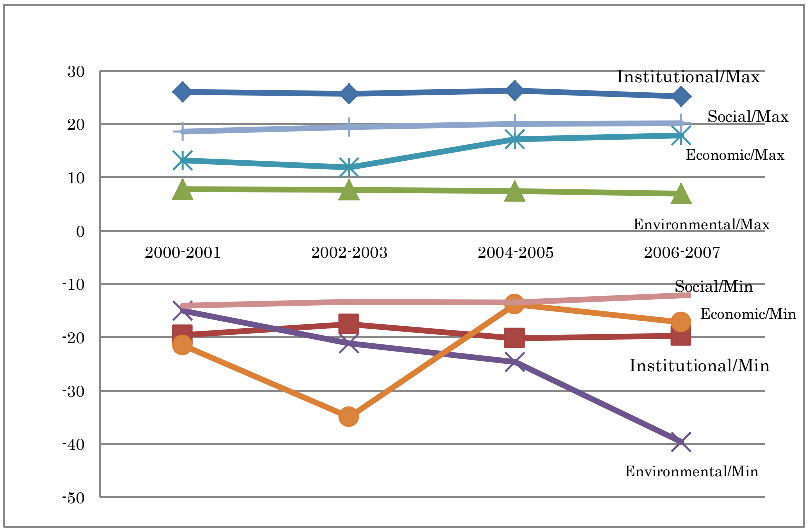


Fig. 2.2. Gaps between max and min scores in the sustainability pillars.

2.5.4. Regional sustainability trend

Figure 2.3 shows the trend in total sustainability for the studied countries based on their regional locations. Studying the trends across regions and the level of sustainability, i.e., level of PCs on the vertical axes, reveals many facts. In Africa, despite the increasing trend in the institutional, economic and social pillars, all countries have negative scores. In fact, Africa has the worst standing relative to other regions for these pillars. The only positive score belongs to the environmental pillar that is, however, declining rapidly. In Asia, only the economic pillar improved and the social and institutional dimensions have stable trends. This story repeats itself for Australia and Oceania. In Central America and the Caribbean, institutional and social pillars improved after 2005. Despite rapid economic progress in this region, environmental conditions deteriorated gradually. Regarding the level of sustainability, Europe is the best region in the world. While economic conditions improved in Europe, other institutional, environmental and social pillars had stable trends with a high level of sustainability. In the Middle East and North Africa, after frequent fluctuations, only the economic pillar improved while the other pillars deteriorated. Finally, the trends in North and South America were similar. Whereas the social and economic pillars showed an increasing trend, institutional and environmental sustainability declined.

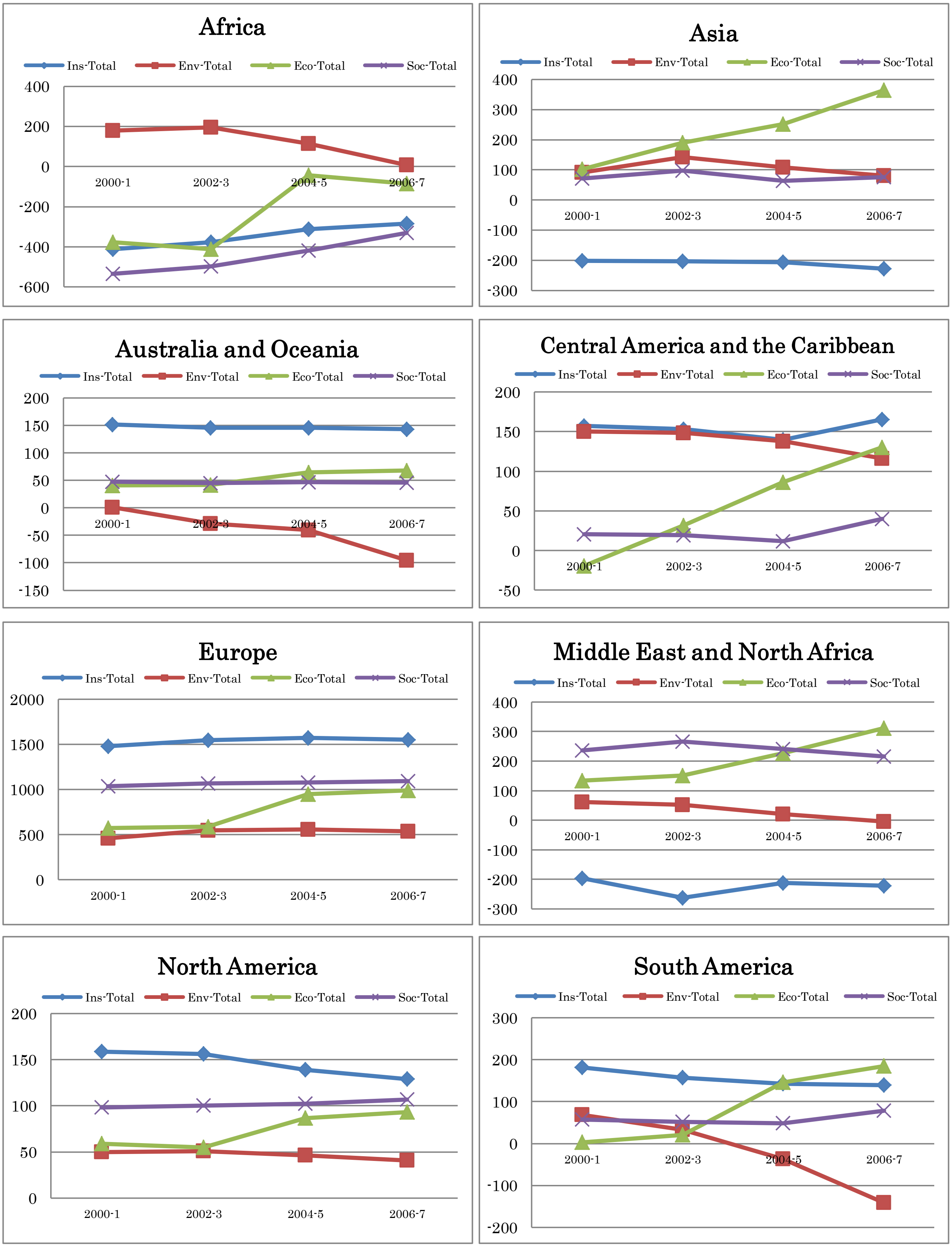


Fig. 2.3. Regional sustainability trends for institutional, environmental, economic and social pillars.

2.6 Sustainable development in Iran

The above findings pave my way to make a comparison between the sustainability of each pillar in Iran and in the other countries. Table 2.4 shows the normalized PC of each pillar in selected countries and the rank of the corresponding country across 131 countries. The selected countries are the countries with the best performance, the members of BRIC countries, Iran, and some of the neighboring countries of Iran.

As it is clear, the lowest PC belongs to institutional pillars that put Iran at the end of the list of countries with good governance. While Finland has the best score in institutional pillar, i.e. 100, the score of Iran is only 5.63. The low quality of governance puts Iran beside the countries like China, Pakistan, and Saudi Arabia. The story is the same for the environmental development. While the global average of PCs is about 82.83 in environmental pillar, it is near to 71 for Iran, puts Iran 108th country in the global ranking. The scores in the economic and social pillars of sustainable development are more than the global average. However, there is a significant gap with the performance of Iran and the best countries.

Table 2.4

Comparison of sustainability in Iran and selected countries

Country	**Institutional**		**Environmental**		**Economic**		**Social**	
	Normal PC	**Rank**	**Normal PC**	**Rank**	**Normal PC**	**Rank**	**Normal PC**	**Rank**
Best performance	Finland (100)	1	Sweden (100)	1	Norway (100)	1	Denmark (100)	1
Brazil	57.12	45	89.33	60	67.23	54	46.90	72
China	5.80	127	70.37	112	76.11	32	35.99	93
India	48.67	60	80.13	89	63.64	74	40.43	85
Russia	22.47	106	71.82	105	78.24	29	49.33	64
Iran	5.63	128	70.88	108	71.09	44	56.78	50
Kuwait	49.86	54	64.72	120	96.67	2	59.25	46
Pakistan	13.38	123	72.46	104	60.77	85	31.48	104
Saudi Arabia	13.09	124	64.92	119	72.42	40	64.36	36
United Arab Em.	45.09	68	65.63	118	91.28	8	40.81	83
Global average	**49.11**	**----**	**82.83**	**----**	**64.78**	**----**	**49.49**	**----**

Note: Normal PC represents normalized principal component ranging from 0 to 100.

Fig. 2.4 represents the trend of sustainability in each pillar over the period 2000-2007. On the other hand, while the PCs are normalized, it shows the gap between the score of Iran and the best performances in the world. As it is clear, except the environmental pillar, sustainability remained unchanged or deteriorated. Totally, it can be concluded that the sustainability has reduced over the period of study.

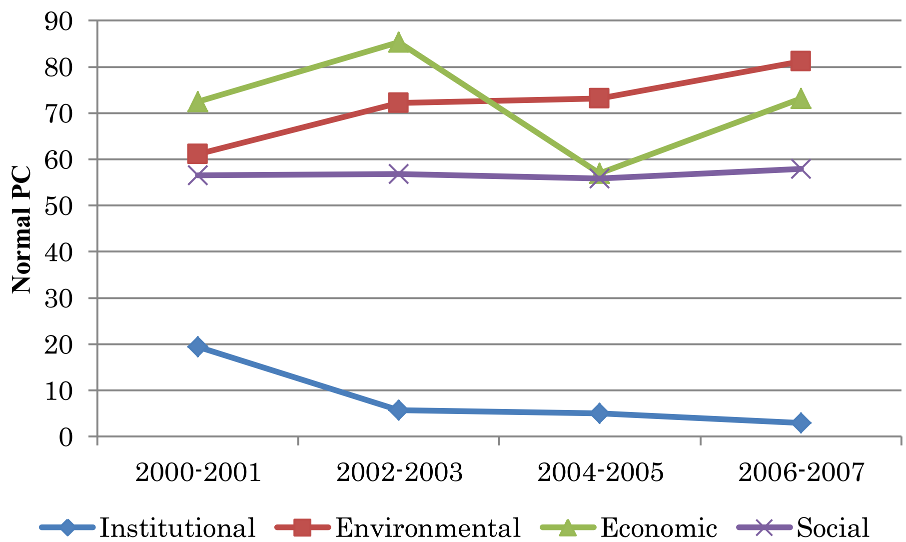


Fig. 2.4. Gaps between SDIs of Iran and the best performers

The above analysis shows that the main challenge of Iranian society is its institutional development. The next would be social development that guarantees more balanced growth. The third and fourth are economic and environmental development. The above analysis can make a guideline for policymakers to set their targets and design their policies to address the main development gaps. Indeed, this guarantees the society to achieve more balanced development.

2.7 Conclusion

This chapter attempted to assess the sustainable development of Iran in a comparative framework. As mentioned, PCA was applied to derive sustainability indices from 29 institutional, environmental, economic and social variables for 131 countries. The application of PCA has several advantages. First, PCA is a weighting approach that may be used as an alternative to the more subjective weighting systems like public opinion polls, and second, it is a useful tool for improving the efficiency of indicators. However, it should be mentioned that PCA is not a panacea. It is limited to ex-post analysis and is not an appropriate tool for prospective analysis. In addition, because of the statistical nature of PCA, it can produce some results that are unjustifiable for researchers. Therefore, the authors suggest using PCA as a complement to subjective methods rather than a competitor.

Tracking the dynamic performance of the selected countries, we can also assess total and regional sustainability. We showed the progress of institutional, economic and social sustainability for the period of research; however, the rate of change in these various measures is completely different. On a regional scale, although the overall trends in the economic and environmental pillars are similar for all regions, development of institutional and social pillars is dissimilar in different regions. However, when the institutional, environmental and economic pillars are strongly correlated, economic development cannot solely explain environmental deterioration. In fact, it seems that social and especially institutional pillars have a critical role in improving environmental sustainability.

For the case of Iran, we found that the main development gap exists in institutional pillar. The next belongs to social pillar which can guarantee more balanced development. The above analysis can make a guideline for policymakers to set their targets and design their policies to address the main development gaps.

Chapter 3:

Sectoral contribution in energy consumption and CO2 emissions: potentials for conservation

3.1 Introduction

Like most of the oil-exporting countries, Iran is experiencing ever-increasing domestic energy consumption and CO_2 emissions, mostly due to its price control policy. In 1967, final energy consumption was 49.58 MBOE[1], but by 2008 it had reached 993.65 MBOE (Fig. 3.1). This translates to the Iranian economy experiencing, on average, a 7.73% increase in final energy consumption per year over the last four decades. The same pattern exists for CO_2 emissions. CO_2 emissions rose 5.61% annually over the same period, from 67.94 MT[2] in 1967 to 537.40 MT in 2008 (Ministry of Energy, 2012; World Bank, 2012).

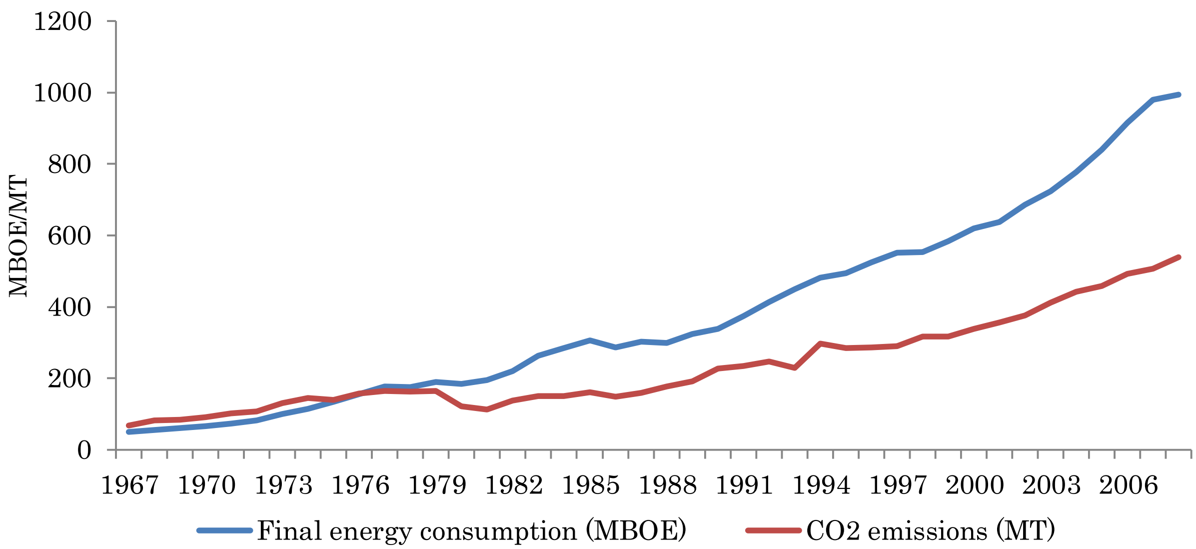


Fig. 3.1 The trend in final energy consumption and CO_2 emissions in Iran (1967–2008)

Since the 1980s, the main contributors to total energy consumption have been the residential, public and commercial (RPC) sector and the transportation sector. As Fig. 3.2 shows, the energy consumption pattern has not altered in Iran in terms of the main contributors over the last few decades. The RPC and transportation sectors accounted for 39% and 29% of

[1] Million Barrels Oil Equivalent
[2] Million Tons

final energy consumption in 1980, respectively; by 2009, their respective shares were 41% and 30%. Indeed, the main change occurred as a result of a change in fuel consumption from refined petroleum to natural gas, especially in the RPC and industrial sectors. Whereas refined petroleum comprised 80% of total energy consumption in the RPC and industrial sectors in 1980, it accounted for only 17% and 25%, respectively, of the required energy for these sectors in 2009. On the other hand, the share of natural gas used by these sectors increased from 7% (for both) to 68% and 61%, respectively, over the same period (Ministry of Energy, 2012)

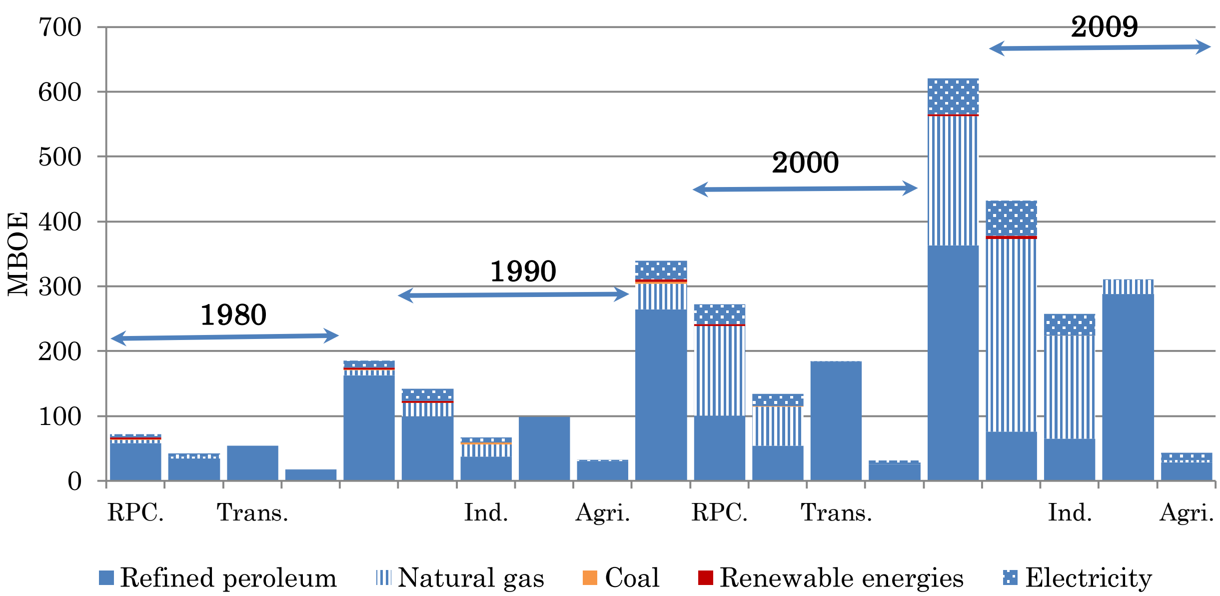


Fig. 3.2 Decomposition of final energy consumption by sector and fuel type in Iran (1980, 1990, 2000 and 2009)

An international comparison of patterns of energy consumption shows that one of the main reasons for the tremendous and seemingly uncontrollable upward trend in energy consumption and CO_2 emissions in Iran is high energy intensity. When the average global primary and final energy intensities were 189 and 118 TOE[1]/million USD (PPP) in 2009, the respective energy intensities in the same year were about 374 and 245 in Iran, almost twice the global averages (IEA, 2011). Fig. 3.3 depicts the trend in energy and CO_2 intensities in Iran over the period 1980–2008. It is obvious that energy and CO_2 intensities have risen rapidly, from 1.12 BOE[2]/million IRR and 0.73 tons/million IRR in 1980, respectively, to 2.20 and 1.26, respectively, by the middle of the 1990s, and so far they remain unchanged. It is noteworthy that in the calculation of the above intensities, the value addition of the oil and natural gas sector was deducted from GDP to provide a more realistic picture of the Iranian economy (Ministry Of Energy, 2010; Statistical Center of Iran, 2012).

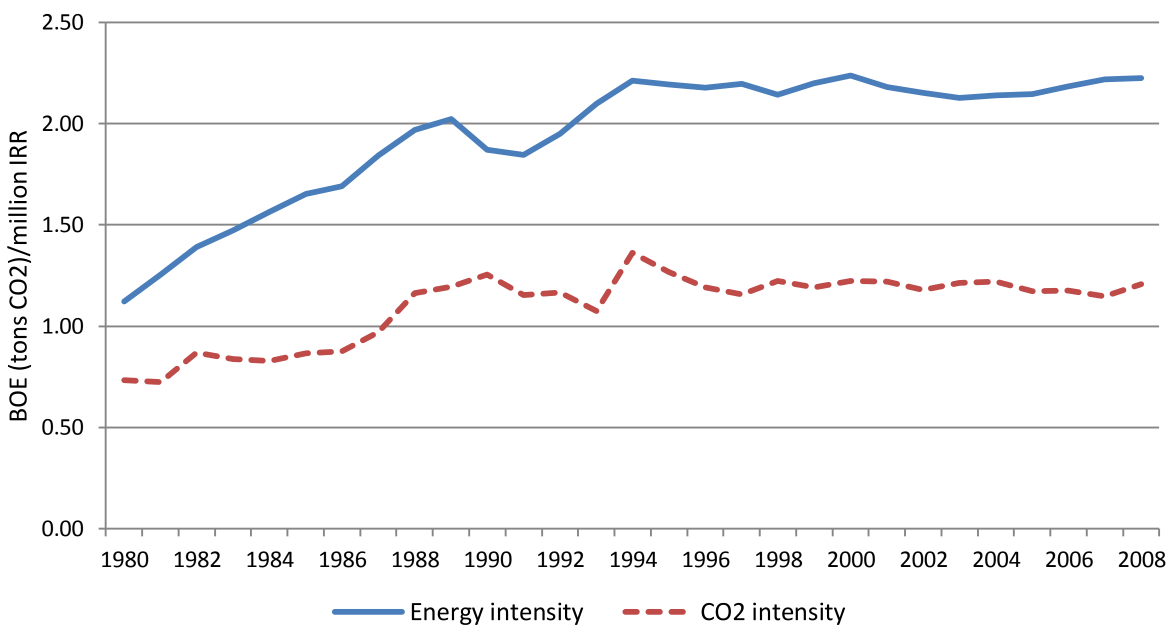


Fig. 3.3 Trend in energy and CO_2 intensities in Iran (1980–2008)

Different studies have been carried out to find out the determinants of the high energy and CO_2 intensities in Iran. Using an index decomposition analysis (IDA), Sharifi et al. (Sharifi et

[1] Tons Oil Equivalent
[2] Barrels Oil Equivalent

al., 2008) showed that structural changes have had little effect in decreasing the energy intensity in the manufacturing industries in Iran. Behboudi et al. (Behboudi et al., 2012) attempted to identify the key factors affecting energy intensity in Iran by applying an IDA over the period 1968–2006. Their results indicated that increasing energy intensity was the result of the reduction of productivity and changes in the structure of economic activities. In addition, they found that energy prices play a critical role in determining energy intensity in Iran. The results of the study of Fotros and Barati (2011) indicated that economic activities have had the largest positive effect on CO_2 emissions in the economy, with the exception of the industrial and transportation sectors. For these two sectors, structural changes have been the main driver of CO_2 emissions. Sadeghi and Sojoodi (2011) studied the determinants of energy intensity in Iranian manufacturing firms. A firm‘s size, ownership type, capital intensity and the wage level have significant impacts on energy intensity.

The first step in designing any conservation policy is the quantification of sectoral total, direct and indirect energy intensities to track the sectors or commodities responsible for increasing energy consumption and CO_2 emissions. The energy consumed by each sector and the pollutants they emit are referred to as the direct energy and pollution requirements. When a sector consumes goods and services, it causes environmental pressures and resource depletion through indirect consumption of energy and the emission of pollutants to produce corresponding commodities. The sum of these direct and indirect requirements of resources and pollutants is referred to as the sector‘s total requirements (Lenzen et al., 2004). By determining the direct and indirect requirements, the amounts of required direct and indirect energy use for producing one unit of value added can be measured in each sector, known as the direct and indirect energy intensity of that sector. Understanding energy and CO_2 intensities paves the way to assessing the effectiveness of any conservation policies at national, regional, or firm levels.

Energy input–output (E-IO) analysis is a frontier method that is popular among researchers for assessing resource and pollutant embodiments in goods and services on a macroeconomic scale. Using IO analysis, Lenzen (1998) examined the direct and indirect primary energy and GHG requirements for a given set of Australian final consumption. Lababderira and Labeaga (2002) used the IO method to obtain the energy-related CO_2 intensity for the Spanish economy in 1992. Using the estimated CO_2 intensities, they performed a structural decomposition and estimated the price effect of several hypothetical carbon taxes levied on fossil fuel consumption. Lenzen et al. (2004) used IO analysis and detailed household expenditure data to yield comprehensive energy use breakdowns for the 14 statistical subdivisions of Sydney. They used multivariate regression and structural path analysis to interpret the results. Cohen et al. (2005) used a generalized input–output model in order to calculate the energy embodied in goods and services purchased by Brazilian households of different income levels in 11 major cities in Brazil.

Using a uniform energy price, Park and Heo (2007) transformed monetary IO tables to energy IO tables and studied the direct and indirect energy requirements of Korean households over the period 1980–2000. Limmeechokchai and Suksuntornsiri (2007) quantified the embedded energy and total GHG emissions in final consumption in Thailand. Tarancón and González (2007) and Tarancón and Río (2012) proposed a combined IO and sensitivity analysis approach to determine the most CO_2-emission-intensive productive relationships. Chung et al. (2009) used a hybrid E-IO table to calculate sectoral energy and GHG emission intensities caused by energy use in Korea. Chung et al. (2011) decomposed energy and emission factors derived from Korean E-IO tables into three affecting factors, i.e., an energy consumption effect, a social effect and a technological effect, over the period 1980–2005.

Kerkhof et al. (2009) employed an environmentally extended IO table for the Netherlands and combined it with household expenditure data to evaluate the relationships between household expenditures and multiple environmental impacts, i.e., climate change, acidification, eutrophication and smog formation. Zhou et al. (2010) used an ecological IO table for Beijing to estimate the resource use and GHG emissions in the Beijing economy in 2002. Chen and Zhang (2010) employed an inventory and IO analysis to measure the GHG emissions embodied in the final consumption and international trade of the Chinese economy in 2007. Using an ecological endowment inventory and ecological IO model, Chen and Chen (2011) investigated GHG emissions and natural resources used in the global economy in 2000. Finally, Cellura et al. (2011) introduced an energy and environmental extended IO model and combined it with a Life Cycle Assessment methodology to study the energy and environmental impacts of Italian households' consumption. This chapter is the first attempt to quantify sectoral energy and CO2 emission intensities for the Iranian economy, and to detect the sectors with the highest potential in terms of reducing energy consumption and CO_2 emissions.

3.2 The methodology of energy input–output analysis

Increasing oil prices during the late 1960s and the 1970s drew the attention of researchers and policy makers to studying the role of energy in the economy. IO models were appropriate tools to study the role of energy and the impact of energy conservation policies at the macro level. The traditional approach to E-IO analysis was developed by Strout (1967) and Bullard and Herendeen (1975). They included energy in the traditional IO analysis by defining a matrix of direct energy coefficients (D). Matrix D is the amount of energy type k required directly to produce a dollar's worth of each producing sector's output. This matrix could be derived by calculating $D=AP^{-1}$, where P is the implied energy price and A is the technical coefficient matrix. Therefore, total interindustry energy coefficients can be obtained from $D(I-A)^{-1}$. The deficiency of this approach is that it provides internally consistent results only when these energy prices are the same across all consuming sectors (including final energy) for each energy type (2009). It is obvious that the condition of uniform prices does not hold in most countries.

As Chapman (1974) and Wright (1974) pointed out, matrices expressed in purely monetary terms do not correctly reflect supplies from the energy industries if the energy prices vary across different industries. This problem can be overcome if the monetary values in the IO table rows for the energy sectors are replaced by values expressed in energy units. Therefore, the new E-IO table is composed of ―hybrid units" whereby energy flows are expressed in convenient energy units (such as MBTU[1]) and nonenergy flows are expressed in monetary units (such as million IRR).

Our E-IO table in this study was constructed in four steps. First, the last monetary IO table in Iran, published in 2001, was obtained from the Statistical Center of Iran (2005). The IO table of 2001 is a commodity table consisting of 91 sectors, including five energy sectors, i.e., crude oil and natural gas, coal, electricity, natural gas and refined petroleum products. Using the use table, the energy sectors were extended to 10 sectors. When the energy prices have been set by the government in Iran, they can be used for our preliminary conversion of monetary units to energy units (million BTU) (MOE, 2010). To obtain more accurate results, all available reports were used, such as the Energy Balances of Iran and Transportation Energy Data, to replace the more accurate energy flow data with energy flows obtained from unit conversion by average energy prices (MOE, 2003, 2010; MOP, 2009, 2010). Data for energy

[1] Million British Thermal Units

prices in 2001 are reported in Table 3.1.

Table 3.1

Domestic prices for different final energies in 2001

Row	Energy type	Price in 2001
1	Coal (IRR/Kg)	620
2	Electricity (IRR/kWh)	Residential: 72.93; Public: 99.59; Commercial: 273.86; Industrial: 133.58; Agricultural: 11.5
3	Natural gas (IRR/m3)	Power plant: 22; Commercial and public: 133; Industrial: 115; Education and sport: 81; Residential (average): 60.5; Transport: 60.5; Refinery plant: 22; Petrochemical plant: 66.66
4	Gasoline (IRR/Liter)	450
5	Kerosene (IRR/Liter)	120
6	Gas oil (IRR/Liter)	120
7	Fuel oil (IRR/Liter)	64.2
8	LPG (IRR/Liter)	150

Note: The official and market exchange rates were 1755 and 7925 IRR/USD in 2001, respectively.

In the second step, and following the energy conservation condition, energy use of all energy sectors was set to zero to avoid double counting (Kok et al., 2006) and energy consumption of nonenergy sectors was multiplied by energy loss coefficients (Miller and Blair, 2009). It is noteworthy that from the authors' point of view, knowing the sectors that are really responsible for energy consumption and CO_2 emission is more important than determining those that directly consume energy and emit pollutants. As Labanderia and Labeaga (2002) mentioned, for instance, electricity-related energy consumption and CO_2 emissions should not be exclusively imputed to the electricity industry, because nonenergy sectors that are consumers of electricity are indeed responsible for production of electricity directly and, consequently, responsible for the consumption of primary energy and CO_2 emissions indirectly. Calculating the energy and CO_2 emission intensities of the final energies makes it possible to recognize actual responsibility for increasing energy consumption and CO_2 emissions.

In the third step, the Hawkins–Simon (H-S) conditions should be checked (Hawkins and Simon, 1949). The H-S conditions ensure that, to obtain a nonnegative solution in a Leontief model (Miller and Blair, 1985): 1) all the diagonal elements in the matrix (I-A) must be positive, and all the off-diagonal elements must be nonpositive; and 2) the determinants of all leading principle submatrices (minors) in the matrix (I-A) should be positive (Chung et al., 2009). The E-IO table constructed in our study satisfied both conditions.

In the last step, the E-IO analysis is performed to derive the energy intensity of each sector stemming from the direct and indirect domestic consumption of the energy carriers. Then, the CO_2 intensities can be calculated by multiplying energy intensities of the sectors to their respective CO_2 emissions factors. The procedure for estimating energy and CO_2 emission intensities is described in the next section.

3.2.1 Estimation of energy and CO_2 emission intensities

In this section, we first explain the basic and original procedure for estimation of energy and CO_2 emission intensities, and then apply our modifications to it. Although monetary and energy units exist in an E-IO table simultaneously, we have to redefine the conventional IO matrices. The basic procedure for performing an E-IO analysis was introduced by Miller and Blair (1985). Whereas n is the number of all sectors and k is the number of energy sectors, Z^* (n×n), x^* (n×1) and y^* (n×1) are the new transaction matrix, the new total output vector and the new final demand vector, respectively. f^* (n×1) is an artificial vector that is used to isolate the energy rows during matrix manipulation. These matrices are defined as follows:

$$Z^* = \begin{cases} z_j & \textit{for nonenergy rows} \\ e_k & \textit{for energy rows} \end{cases}$$

$$x^* = \begin{cases} x_j & \textit{for nonenergy rows} \\ f_k & \textit{for energy rows} \end{cases} \qquad (3.1)$$

$$y^* = \begin{cases} y_j & \textit{for nonenergy rows} \\ e_k & \textit{for energy rows} \end{cases}$$

$$f^* = \begin{cases} 0 & \textit{for nonenergy rows} \\ f_k & \textit{for energy rows} \end{cases}$$

In Eq. (3.1), z_j, x_j and y_j are expressed in monetary terms and e_k and f_k are expressed in energy units. Therefore, the above matrices have the following format:

$$Z^* = \begin{bmatrix} MBTU & MBTU \\ Mil.IRR & Mil.IRR \end{bmatrix}; \quad x^* = \begin{bmatrix} MBTU \\ Mil.IRR \end{bmatrix}; \quad y^* = \begin{bmatrix} MBTU \\ Mil.IRR \end{bmatrix}; \quad f^* = \begin{bmatrix} MBTU \\ 0 \end{bmatrix} \quad (3.2).$$

The new technical coefficient matrix (A*) and the new Leontief matrix (L*) can be defined as usual:

$$A^*=Z^*(\hat{x}^*)^{-1} = \begin{bmatrix} \frac{MBTU}{MBTU} & \frac{MBTU}{Mil.IRR} \\ \frac{Mil.IRR}{MBTU} & \frac{Mil.IRR}{Mil.IRR} \end{bmatrix}; \quad L^*=(I-A^*)^{-1} \qquad (3.3).$$

By using the A* and L* matrices, the sectoral direct energy coefficients (EI_δ) and the sectoral total or embodied energy coefficients (EI_α) can be calculated by the following equations:

$$EI_\delta=\hat{f}^*(\hat{x}^*)^{-1}A^*; \quad EI_\alpha=\hat{f}^*(\hat{x}^*)^{-1}(I-A^*)^{-1} \qquad (3.4).$$

In the above coefficient matrices, the values of the energy sectors are expressed in terms of MBTU/MBTU, which is the energy ratio of k energy sectors. What are important for us are the values of the nonenergy sectors, expressed in terms of MBTU/million IRR, which are in fact the energy intensities in the nonenergy sectors. Using a symmetric matrix of CO_2 emission factors (M (n×n)), the sectoral direct CO_2 emission coefficients (GI_δ) and the sectoral total or embodied CO_2 emission coefficients (GI_α) can be calculated as follows (Chung et al., 2009):

$$GI_\delta=\hat{f}^*(\hat{x}^*)^{-1}MA^*; \quad GI_\alpha=\hat{f}^*(\hat{x}^*)^{-1}M(I-A^*)^{-1} \quad (3.5).$$

We have made three modifications to the above procedure:

1- As mentioned before, one of our targets is recognizing the sources of ever-increasing energy consumption and CO_2 emissions in Iran. Therefore, we made the above analysis for the final energies consumed by utilizers.

2- To avoid the double counting problem, the energy consumption of the energy sectors was set to zero. While the crude oil and natural gas products are consumed by all the other energy sectors or exported to the global market, this sector was dropped from the analysis.

3- The assumption behind Eqs. (3.4) and (3.5) is equal energy and CO_2 intensities of domestic and imported commodities. A problem with this assumption is that many of the countries from which the imports originate face different energy and CO_2 intensities (Lenzen, 1998). To solve this problem, the energy coefficients are purified by using the import coefficient matrix ($\hat{M}^*=I\hat{M}(\hat{x}^*)^{-1}$) and calculating the direct and embodied domestic energy coefficients (EI_δ^d and EI_α^d) as follows:

$$EI_\delta^d=\hat{f}^*(\hat{x}^*-\hat{M}^*)^{-1}(I-\hat{M}^*)A^*; \quad EI_\alpha^d=\hat{f}^*(\hat{x}^*-\hat{M}^*)^{-1}(I-(I-\hat{M}^*)A^*)^{-1} \quad (3.6).$$

The same analysis was carried out to calculate the domestic CO_2 emission coefficients. All of the intensities that will be reported in this study are domestic intensities.

3.3 Results and discussion

As explained before, the E-IO analysis was applied to the 95×95 IO table for the 2001 Iranian economy. Table 3.2 presents the descriptions and categorization of sectors. In the IO table, the first nine sectors are energy sectors providing final energies for domestic utilizers. The agricultural and mining sectors contain six and five subsectors, respectively. The most elaborate sectors in the IO table are the industrial and service sectors, consisting of 29 and 46 subsectors, respectively.

In 2001, the gross domestic product (GDP) of Iran was 737,909 billion IRR (92.61 billion USD) including the oil sector or 614,177 billion IRR (77.50 billion USD) excluding the oil sector. Producing 10.40 billion USD, the agricultural sector accounted for 11.27% of total GDP. The share of the mining and industrial sector was 34.70%, while its production was valued at 32.01 billion USD. The biggest economic sector in Iran is the service sector, which produced 48.02 billion USD and accounted for 52.05% of the total economy in 2001.

Table 3.2

Description of the 95 sectors in the input–output table for Iran

Sector categories	Name and code of sectors		
Energy sectors	1- Coal	2- Electricity	3- Natural gas
	4- Gasoline	5- Kerosene	6- Gas oil
	7- Fuel oil	8- LPG	9- Other refined petroleum products
Agricultural sectors	10- Agricultural products	11- Horticulture and market gardening products	12- Live animals and animal products
	13- Products of bees and silkworms	14- Forestry and logging products	15- Fish and other fishing products
Mining and industrial sectors	16- Iron ores and concentrates	17- Copper, ores and concentrates	18- Stone, sand and clay
	19- Other minerals	20- Water	21- Animal and vegetable oils and fats
	22- Other foods and beverages	23- Tobacco products	24- Textiles
	25- Wearing apparel	26- Leather and leather products; footwear	27- Products of wood, cork, straw and plaiting materials
	28- Pulp, paper and paper	29- Basic chemicals and chemical	30- Rubber and plastics products

	products; printed matter and related articles	products	
	31- Glass and glass products	32- Other mineral products	33- Furniture
	34- Basic iron and steel and their products	35- Other metals	36- Metal products
	37- General-purpose machinery	38- Special-purpose machinery	39- Domestic appliances and parts thereof
	40- Office, accounting and computing machinery	41- Electrical machinery and apparatus	42- Radio, television and communication equipment and apparatus
	43- Medical and surgical equipment and orthopedic appliances	44- Optical and measurement instruments, watches and clocks	45- Motor vehicles, trailers and semi-trailers
	46- Other vehicles	47- Jewelry and other unclassified products	48- Residential construction
	49- Other constructions		
Service sectors	50- Wholesale and retail trade services	51- Lodging services	52- Food and beverage serving services
	53- Railway transport	54- Road passenger transport	55- Road freight transport
	56- Pipeline transport	57- Water transport	58- Air transport
	59- Supporting and auxiliary transport services	60- Postal and telecommunication services	61- Banking services
	62- Investment banking and financial intermediation services	63- Insurance and pension services	64- Renting services of own residential construction
	65- Renting services of rental residential construction	66- Renting services of rental nonresidential construction	67- Trade services of real states
	68- Leasing or rental services without operator	69- Research and development services	70- Computer and information services
	71- Other professional, technical and business services	72- Agriculture, raising livestock and mining services	73- Maintenance, repair and installation (except construction) services
	74- News agency services	75- Administrative services of the government	76- Military and civil defense services
	77- Police and fire protection services	78- Social security services	79- Public primary education services
	80- Private primary education services	81- Public secondary education services	82- Private secondary education services
	83- Public university education services	84- Private university education services	85- Other education and training services
	86- Hospital services	87- Medical and dental services	88- Other human health services
	89- Veterinary services	90- Social services	91- Religious services (Masjids, etc.)
	92- Arts-related services	93- Recreational and sporting services	94- Museum and library services
	95- Other services		

3.3.1 Direct and indirect energy intensities by sector

Fig. 3.4 represents the energy intensities of the Iranian nonenergy sectors in 2001. Furthermore, Table 3.3 shows the energy intensities of the top 20 sectors. As is obvious, the highest energy intensity belongs to the ―pipeline transport” sector, which consumes 90.26 BTU/IRR (or 715,310 BTU/USD). This sector is a relatively small sector that contributes less than 1% to the total GDP. However, the importance of this sector is due to its strong backward linkage (the backward linkage multiplier is about 1.89), in particular, the role of the sector in transportation of raw crude oil, natural gas and refined petroleum products in this energy exporting country. The second-highest energy intensity is for the ―other mineral products” sector. This sector, producing ceramic ware, clay products, cement, lime, plaster, concrete, building stone, nonmetallic mineral products and prefabricated buildings, consumes 22.54 BTU for production of one rial of value added in this sector (or 178,629 BTU/USD). As for the transportation sector, the ―other mineral products” sector consumes most of its required energy directly. The third place is owned by the ―road freight transport” sector, which has an energy intensity of around 15.51 BTU/IRR (or 122,916 BTU/USD). The size of the last two sectors is substantial, accounting for 1.96% and 2.49% of total GDP in 2001, respectively. This means there is an opportunity for the Iranian economy to mitigate the energy consumption of the corresponding sectors by reducing their direct energy intensities. A list of the direct and indirect energy intensities of the sectors can be found in Appendix 3.1.

As Fig. 3.4 shows, most of the nonenergy sectors consumed their required energy directly. The main exceptions are some service and industrial sectors. The services of rental own, residential and nonresidential constructions have negligible direct energy consumption and thus consume energy mostly through their nonenergy inputs. The next main exclusions are the construction sectors, which consume close to 95% of their required energy indirectly. Out of a total of 86 nonenergy sectors, 32 sectors have indirect energy intensities that exceed their direct intensities. The sectors ―office, accounting and computing machinery”, ―insurance and pension services” and ―radio, television and communication equipment and apparatus” had the lowest energy intensities of all the sectors. The total energy intensities of these sectors were 0.14, 0.56 and 0.65 BTU/IRR, respectively.

Generally, taking a macro view, most of the fuels (except coal) were being consumed directly in the nonenergy sectors in 2001. As shown in Table 3.4, 59.88% of total energy was consumed directly by sectors, while 40.12% was consumed through the consumption of nonenergy inputs. Kerosene has the highest share of direct consumption, with 66.59% of total kerosene consumed directly, mostly by ―basic chemicals and chemical products” (20.28%), ―pipeline transport” (8.60%) and ―maintenance, repair and installation services” (7.35%). The ratio of direct consumption for gasoline was 63.21%, with the main direct sectoral consumers being ―road freight transportation” (42.77%) and road passenger transportation (30.12%). Electricity had a direct consumption share of 62.56%. The main sectoral direct utilizers of electricity were ―agricultural products” (16.33%), ―horticulture and market gardening products” (16.08%) and ―wholesale and retail trade services” (11.08%). The share of direct consumption for natural gas is 60.17%, with the sectors ―basic chemicals and chemical products” (21.21%), ―basic iron and steel and their products” (18.16%) and ―wholesale and retail trade services” (14.30%) being the main direct consumers. In terms of the total sectoral consumption of gas oil, 57.84% of it is consumed directly. The main consumers are ―road freight transport” (55.61%), ―wholesale and retail trade services” (7.65%) and ―road passenger transport” (6.68%). The share of direct consumption of fuel oil is 54.46%. The major part of this fuel was directly consumed by ―other mineral products” (61.51%).

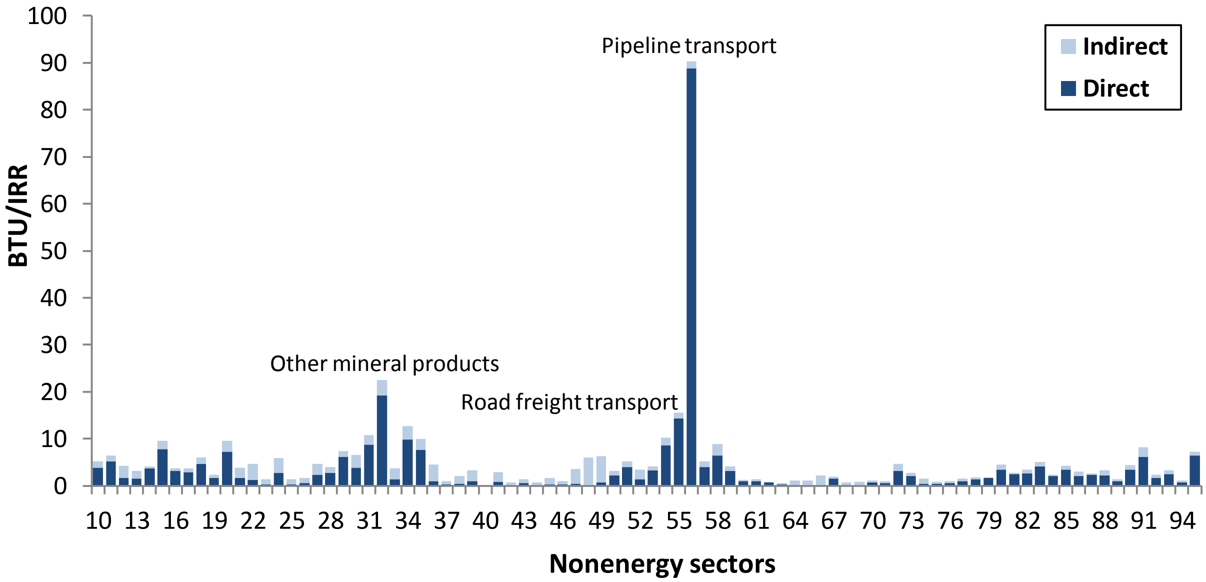


Fig. 3.4 Direct and indirect energy intensities of nonenergy sectors in Iran

Table 3.3

Top 20 sectors in terms of energy intensities in the Iranian economy

Code	Sector name	Category	Energy intensity (BTU/IRR)		
			Total	Direct	Indirect
56	Pipeline transport	Ser.	90.26	88.80	1.45
32	Other mineral products	Ind.	22.54	19.27	3.27
55	Road freight transport	Ser.	15.51	14.33	1.17
34	Basic iron and steel and their products	Ind.	12.70	9.88	2.82
31	Glass and glass products	Ind.	10.77	8.67	2.10
54	Road passenger transport	Ser.	10.22	8.57	1.65
35	Other metals	Ind.	9.96	7.59	2.36
20	Water	Min.	9.60	7.31	2.29
15	Fish and other fishing products	Agri.	9.59	7.79	1.80
58	Air transport	Ser.	8.92	6.46	2.46
91	Religious services (Masjids, etc.)	Ser.	8.25	6.21	2.03
29	Basic chemicals and chemical products	Ind.	7.33	6.09	1.24
95	Other services	Ser.	7.22	6.48	0.74
30	Rubber and plastics products	Ind.	6.51	3.77	2.73
11	Horticulture and market gardening products	Agri.	6.46	5.20	1.26
49	Other constructions	Ind.	6.27	0.70	5.58
48	Construction of residential buildings	Ind.	5.97	0.08	5.89
18	Stone, sand and clay	Min.	5.97	4.69	1.28
24	Textiles	Ind.	5.83	2.71	3.12
57	Water transport	Ser.	5.24	3.93	1.31

Note: Agri. = Agricultural, Min. = Mining, Ind. = Industrial, Ser. = Service

3.3.2 Total energy intensities by fuel type

Fig. 3.5 depicts the composition of sectoral energy intensities in Iran by their fuels. The main contributors to the energy consumption of the pipeline transportation sector are natural gas (37% of the sector's energy intensity), fuel oil (26%), electricity (15%) and kerosene (12%). The energy consumption pattern of the ―other mineral products" sector is simpler, with 54% of total energy consumption in this sector due to the consumption of fuel oil. The next main energy carriers are electricity, natural gas and gas oil, accounting for 18%, 11% and 9% of the total energy intensity of this sector, respectively. Gas oil and gasoline are the main energies consumed in the ―road freight transport" sector.

The main energy carriers consumed in the nonenergy sectors were electricity, gas oil and natural gas. The total amount of sectoral electricity consumption was 1,326.55 TBTU, which accounted for 27.46% of total energy consumption by the nonenergy sectors in 2001. When the sectors consumed 1,272.85 TBTU, they covered 26.35% of their total energy requirements by consumption of gas oil directly and indirectly. Natural gas is the third most used energy carrier consumed by different nonenergy sectors. In 2001, the amount of natural gas consumption reached 886.82 TBTU, accounting for 18.36% of total energy consumption by the sectors.

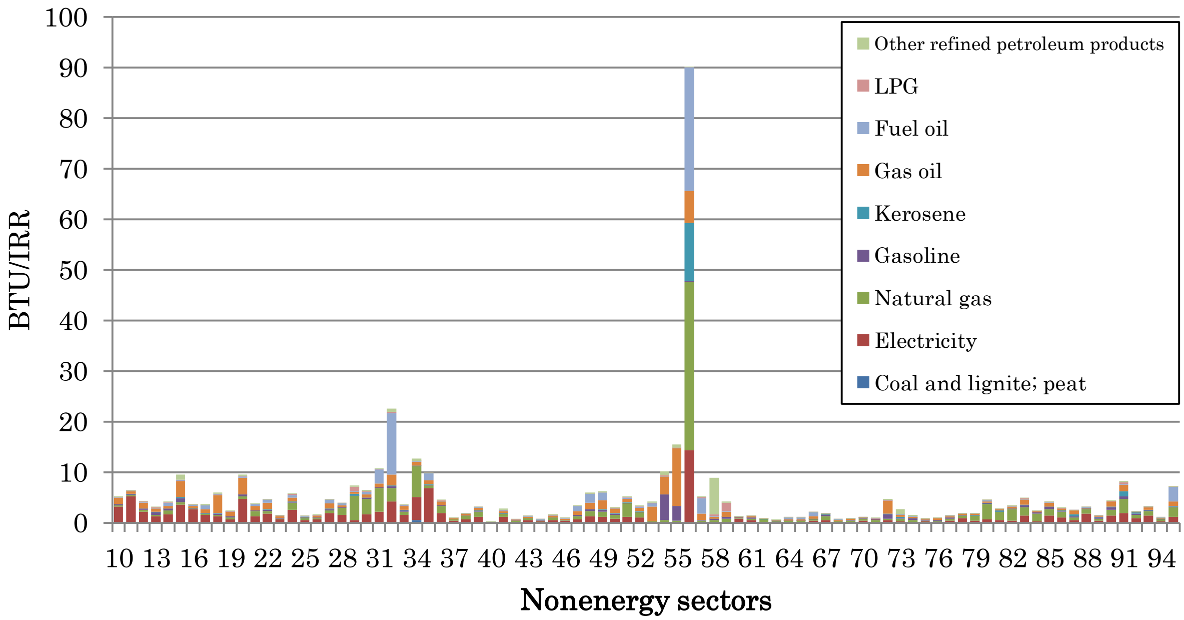


Fig. 3.5. Total energy intensity of the nonenergy sectors by fuel types

Table 3.4

Direct and indirect energy consumption and CO_2 emissions by fuel type and their shares in Iran (2001)

Energy type	Direct energy consumption		Indirect energy consumption		Total energy consumption		Shares of direct and indirect energy consumption			Direct CO_2 emissions		Indirect CO_2 emissions		Total CO_2 emissions		Shares of direct and indirect CO_2 emissions		
	Direct (TBTU)	Share of fuel (%)	Indirect (TBTU)	Share of fuel (%)	Total (TBTU)	Share of fuel (%)	Direct (%)	Indirect (%)	Total (%)	Direct (MT)	Share of fuel (%)	Indirect (MT)	Share of fuel (%)	Total (MT)	Share of fuel (%)	Direct (%)	Indirect (%)	Total (%)
Coal and lignite; peat	9.36	0.32	9.80	0.51	19.16	0.40	48.85	51.15	100.00	0.93	0.48	0.98	0.74	1.91	0.58	48.85	51.15	100.00
Electricity	829.84	28.69	496.71	25.63	1,326.55	27.46	62.56	37.44	100.00	50.40	25.74	30.17	22.85	80.57	24.58	62.56	37.44	100.00
Natural gas	533.57	18.45	353.25	18.23	886.82	18.36	60.17	39.83	100.00	31.85	16.26	21.09	15.98	52.94	16.15	60.17	39.83	100.00
Gasoline	239.89	8.29	139.62	7.21	379.51	7.86	63.21	36.79	100.00	17.76	9.07	10.20	7.73	27.96	8.53	63.52	36.48	100.00
Kerosene	47.19	1.63	23.68	1.22	70.88	1.47	66.59	33.41	100.00	3.34	1.71	1.68	1.27	5.02	1.53	66.59	33.41	100.00
Gas oil	736.16	25.45	536.68	27.70	1,272.85	26.35	57.84	42.16	100.00	54.42	27.79	39.67	30.05	94.09	28.70	57.84	42.16	100.00
Fuel oil	313.77	10.85	262.42	13.54	576.19	11.93	54.46	45.54	100.00	22.82	11.65	19.09	14.46	41.90	12.78	54.46	45.54	100.00
LPG	47.49	1.64	36.32	1.87	83.81	1.74	56.66	43.34	100.00	3.21	1.64	2.44	1.85	5.65	1.72	56.76	43.24	100.00
Other refined petroleum products	135.09	4.67	79.25	4.09	214.34	4.44	63.03	36.97	100.00	11.11	5.67	6.70	5.07	17.81	5.43	62.39	37.61	100.00
Total	2,892.36	100.00	1,937.74	100.00	4,830.11	100.00	59.88	40.12	100.00	195.85	100.00	132.01	100.00	327.86	100.00	59.74	40.26	100.00

3.3.3 CO_2 emission intensities and the contribution of fuels

Table 3.5 shows the top 20 sectors that had the largest CO_2 emission intensities in 2001. The sectors are virtually identical to the top 20 sectors with the highest energy intensities, with only small differences in the ranking. This is a reasonable finding given that most final energies in Iran have a hydrocarbon base. Out of a total nominal capacity of 34,222 MW of electricity production in 2001, the capacity of the hydropower plants was only 1,999 MW, about 5.84% of the total capacity. The remainder belonged to diesel, natural gas and steam power plants, all of which consume hydrocarbon fuels.

The ―pipeline transport”, ―other mineral products” and ―road freight transport” sectors have the highest sectoral CO_2 emission intensities. ―Pipeline transport” emits 5.94 tons of CO_2 for production of one million IRR. In other words, for production worth one USD, it emits 47.12 kg of CO_2. The intensities for ―other mineral products” and ―road freight transport” sectors are 1.56 and 1.15 tons CO_2/million IRR, respectively, or 12.38 and 9.11 kg CO_2/USD, respectively. In a similar pattern to the sectoral ranking for energy intensities, the sectors ―office, accounting and computing machinery”, ―insurance and pension services” and ―radio, television and communication equipment and apparatus” have the lowest CO_2 emission intensities, i.e., 0.009, 0.037 and 0.042 tons CO_2/million IRR, respectively. The list of CO_2 emission intensities of the Iranian nonenergy sectors can be found in Appendix 3.2.

Table 3.5

Top 20 sectors in terms of CO_2 emission intensities in the Iranian economy

Code	Sector name	Category	CO_2 emission intensity (kg/million IRR)		
			Total	Direct	Indirect
56	Pipeline transport	Ser.	5,945.90	5,844.35	101.55
32	Other mineral products	Ind.	1,563.26	1,332.32	230.94
55	Road freight transport	Ser.	1,150.22	1,068.33	81.89
34	Basic iron and steel and their products	Ind.	811.98	625.10	186.88
54	Road passenger transport	Ser.	756.04	638.76	117.28
31	Glass and glass products	Ind.	696.79	556.76	140.03
15	Fish and other fishing products	Agri.	663.05	539.95	123.10
58	Air transport	Ser.	650.47	477.27	173.21
20	Water	Min.	641.65	486.19	155.45
35	Other metals	Ind.	636.44	478.40	158.04
91	Religious services (Masjids, etc.)	Ser.	542.98	406.76	136.21
95	Other services	Ser.	488.20	438.46	49.75
29	Basic chemicals and chemical products	Ind.	457.63	377.37	80.26
49	Other constructions	Ind.	435.31	51.07	384.24
18	Stone, sand and clay	Min.	421.70	332.92	88.77
30	Rubber and plastics products	Ind.	413.89	234.40	179.50
48	Construction of residential buildings	Ind.	410.93	6.09	404.85
11	Horticulture and market gardening products	Agri.	403.35	318.54	84.81
57	Water transport	Ser.	380.41	286.67	93.74
24	Textiles	Ind.	375.23	173.74	201.49

Note: Agri. = Agricultural, Min. = Mining, Ind. = Industrial, Ser. = Service

Fig. 3.6 shows the contribution of fuels to the emissions of CO_2 pollutants in Iran in 2001. As is obvious, the main sources of CO_2 emissions across the sectors are gas oil, electricity, natural gas, fuel oil and gasoline. In total, 29% of CO_2 pollutants were emitted as a result of the consumption of gas oil. About 58% of this amount was produced by direct gas oil consumption, with the remainder emitted through the consumption of nonenergy inputs for which gas oil was a production input. Following gas oil, electricity is the second-highest contributor to emissions of total CO_2, accounting for 25% of total emissions. From a primary energies perspective, the role of gas oil and natural gas should be given more consideration, given that the main primary energies used for generation of electricity are gas oil and natural gas. However, as we mentioned before, one of the main reasons for substituting final energies with primary energies is to find the sectors and fuels responsible for the increasing trend in energy consumption and CO_2 emissions in Iran. Therefore, the role of electricity is similar to that of gas oil. In terms of total CO_2 produced by electricity, 62.56% was emitted through direct electricity consumption and 37.44% emitted via the consumption of electricity to produce other nonenergy inputs. The share of natural gas in total emissions is about 16%, with 60.17% of these emissions due to direct consumption and 39.83% due to indirect use. Consumption of fuel oil and gasoline account for 13% and 8%, respectively, of the total sectoral CO_2 emissions. As for the other energies, the largest proportion of emitted pollutants is due to direct consumption of them.

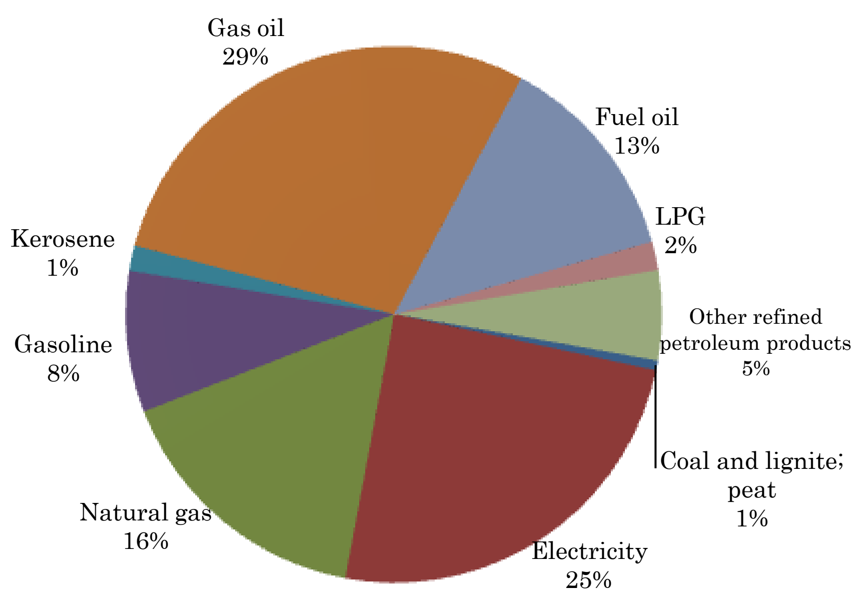


Fig. 3.6. Contribution of the final energy carriers to CO_2 emissions across the nonenergy sectors

3.3.4 Opportunities to reduce sectoral energy and CO_2 emission intensities

Having gained an understanding of the size of the energy and CO_2 emission intensities in Iran, we next need to determine which sectors can be targeted to reduce energy consumption and CO_2 emissions. Undoubtedly, the sectors that are simultaneously the main consumers of energy and have the highest energy intensities should be considered first. Because identifying the sectors in terms of energy consumption or CO_2 emissions gives us the same policy implications, we just explain the potential for CO_2 emission mitigation in this section.

Fig. 3.7 depicts the volume of CO_2 emissions in each sector against their CO_2 emission intensities. To ensure plausibility, we assumed that a conservation policy could mitigate the sectoral CO_2 emission intensities by 10%. Applying this assumption into the model, we calculated the total mitigation of CO_2 emissions that would occur in each sector. The sectors that could experience significant reductions in CO_2 emissions, e.g., more than 1 MT, are listed in descending order as follows: “road freight transport”, “other mineral products”, “wholesale and retail trade services”, “other constructions”, “other foods and beverages”, “agricultural products”, “basic iron and steel and their products”, “construction of residential buildings”, “live animals and animal products”, “basic chemicals and chemical products”, “road passenger transport” and, finally, “horticulture and market gardening products”. From the above list, three subsectors are from the agricultural sector, three are in the service sector and the remaining six are in the industrial sector.

Undoubtedly, conservation policies and plans should target transportation first, given that it is the main consumer of gas oil and gasoline. Increasing the share of public transportation, reducing the price gap between Iranian and international markets for gas oil and gasoline, and renovation fleet vehicles are the key policies that can strongly affect the energy consumption pattern in this sector. A reduction of only 10% in the CO_2 intensities of the road freight and passenger transportation sectors could mitigate total CO_2 emissions by close to 4.5 MT. The next target for conservation policies and plans should be the producers of basic products, such as basic mineral, metal and chemical products. Most of these sectors were developed under the import substitution policy and they were fundamentally established and developed in an inefficient manner. The target of the import substitution policies influencing these industries was to make the country independent of imports of such strategic products. To attain this goal in an oil-exporting country, the energy efficiency criterion had the lowest importance. A 10% reduction in the CO_2 emissions intensities of the sectors “other mineral products”, “basic iron and steel and their products” and “basic chemicals and chemical products” would reduce CO_2 emissions by about 2.5 MT, 1.5 MT and 1.2 MT, respectively. The construction and trade sectors are the other energy intensive activities in Iran. If any policy can mitigate 10% of the total CO_2 intensities of these sectors, the amount of CO_2 emissions would be reduced by 3.8 MT in the construction sector and by 2.5 MT in the trade sector. The food industry is also an energy inefficient industry in Iran, because applying the same policy would reduce CO_2 emissions by 2.4 MT in this sector. Agricultural and livestock could experience a 3.9 MT reduction in CO_2 emissions under such a policy.

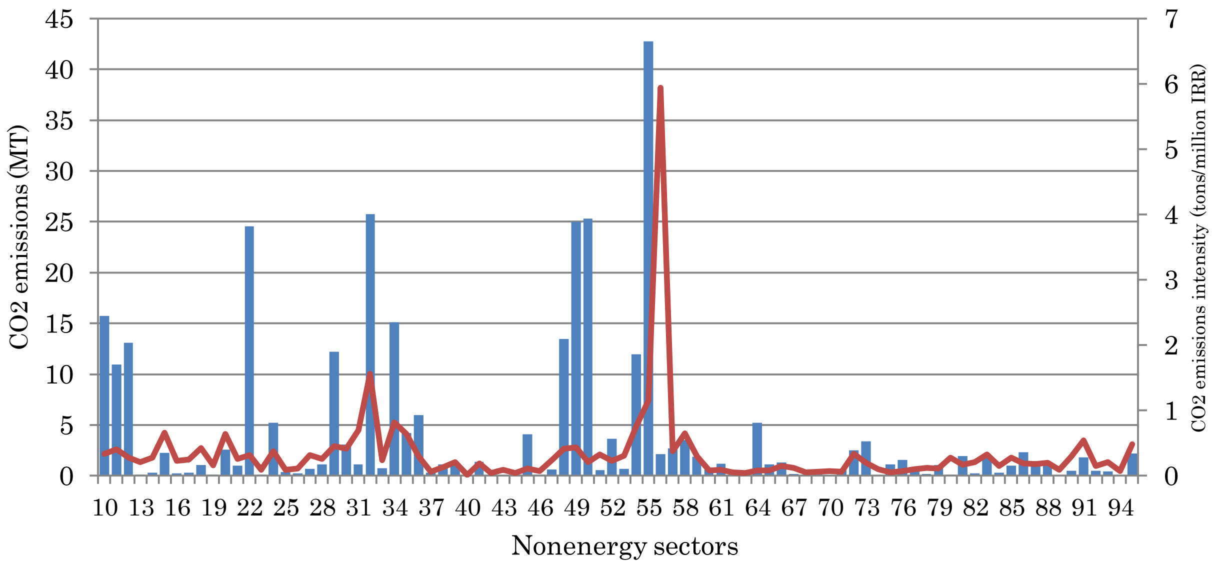


Fig. 3.7. Total sectoral CO_2 emissions against sectoral emissions intensities in Iran

3.3.5 Energy consumption and economic value in Iran

Following Costanza and Herendeen (1984), in this section, we will test the energy theory of value in Iran. An economy can be said to operate on an energy theory of value if economic value can be shown to be proportional to an appropriate energy indicator. Costanza and Herendeen (1984) show that one of the best indicators is sectors' direct plus indirect (embodied) energy consumption. To examine the theory, the logarithms of the embodied energy consumption of 86 Iranian nonenergy sectors are plotted and regressed against the logarithms of their total output. The results are depicted in Fig. 3.8 As the figure shows, there is a relatively strong relationship between sectoral embodied energy consumption and the sectors' production. While the simple regression results in a relatively high R^2 (0.75), the covariance and Pearson's r of these two variables are also high, i.e., 2.32 and 0.86, respectively. The results of our study confirm the results of previous studies regarding the strong cross-sectional relationship between embodied energy and economic value.

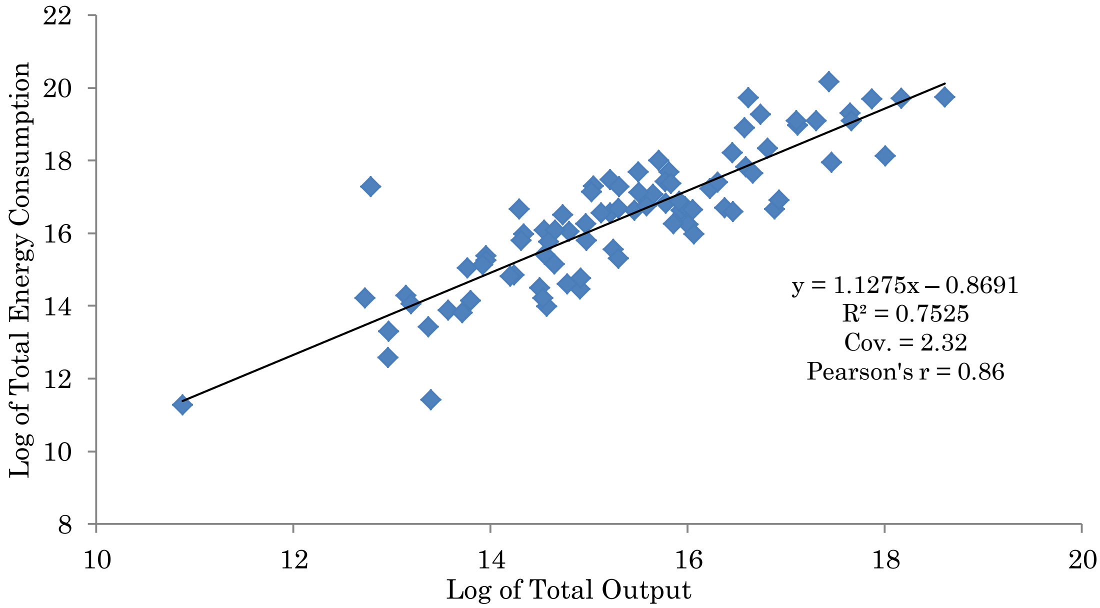


Fig. 3.8 Log-log plot of total energy consumption vs. total output of 86 nonenergy sectors in Iran

3.4 Conclusion

The aim of this chapter was to quantify the energy and CO_2 emissions intensities across the nonenergy sectors in the Iranian economy. For this purpose, E-IO analysis was applied to the 95×95 IO table of Iran in 2001. Then, the sectors that had the potential to experience a significant reduction in energy consumption and CO_2 emissions were identified. As explained above, the sectors with the highest potential to reduce energy consumption and emissions are the road transportation sectors, the sectors which produce basic mineral, metal and chemical products, the construction sectors, the food industry and the agricultural and livestock sectors. Although the energy consumption pattern is distorted by cheap energy prices, our study shows that the energy theory of value still applies in Iran. The next step should be to identify the policies that reduce energy and CO_2 emissions intensities in these sectors. While the price gap between domestic and international markets is immense in Iran, removing the energy subsidies should be considered first.

However, it is of course necessary to note that we should interpret the results of this analysis with some caution. First, the input–output table used is from 2001. This raises concerns about the rigidity of the economic structure in Iran after a decade. Second, as for other quantitative approaches, E-IO has some limitations, such as price distortion during the process of unit conversion, aggregation errors in composing sectors and missing necessary products or services in the candidate sectors. However, it is widely used, especially because it provides reliable results from a macroeconomic perspective.

Appendix 3.1

Energy intensities of sectors in the Iranian economy (BTU/IRR)

Code	Sector name	Energy intensity			Code	Sector name	Energy intensity		
		Total	Direct	Indirect			Total	Direct	Indirect
10	Agricultural products	5.23	3.85	1.38	**53**	Railway transport	4.16	3.26	0.90
11	Horticulture and market gardening products	6.46	5.20	1.26	**54**	Road passenger transport	10.22	8.57	1.65
12	Live animals and animal products	4.25	1.60	2.65	**55**	Road freight transport	15.51	14.33	1.17
13	Products of bees and silkworms	3.15	1.56	1.59	**56**	Pipeline transport	90.26	88.80	1.45
14	Forestry and logging products	4.17	3.65	0.52	**57**	Water transport	5.24	3.93	1.31
15	Fish and other fishing products	9.59	7.79	1.80	**58**	Air transport	8.92	6.46	2.46
16	Iron ores and concentrates	3.64	3.15	0.49	**59**	Supporting and auxiliary transport services	4.18	3.21	0.96
17	Copper, ores and concentrates	3.68	2.83	0.85	**60**	Postal and telecommunication services	1.28	0.93	0.35
18	Stone, sand and clay	5.97	4.69	1.28	**61**	Banking services	1.40	0.93	0.47
19	Other minerals	2.36	1.68	0.68	**62**	Investment banking and financial intermediation services	0.85	0.69	0.16
20	Water	9.60	7.31	2.29	**63**	Insurance and pension services	0.56	0.26	0.31
21	Animal and vegetable oils and fats	3.85	1.66	2.19	**64**	Renting services of own residential construction	1.14	0.00	1.14
22	Other foods and beverages	4.70	1.20	3.49	**65**	Renting services of rental residential construction	1.14	0.00	1.14
23	Tobacco products	1.42	0.31	1.10	**66**	Renting services of rental nonresidential construction	2.14	0.00	2.14
24	Textiles	5.83	2.71	3.12	**67**	Trade services of real states	1.86	1.56	0.30
25	Wearing apparel	1.36	0.28	1.08	**68**	Leasing or rental services without operator	0.74	0.09	0.64
26	Leather and leather products; footwear	1.64	0.57	1.08	**69**	Research and development services	0.87	0.15	0.72
27	Products of wood, cork, straw and plaiting materials	4.72	2.39	2.33	**70**	Computer and information services	1.10	0.72	0.38
28	Pulp, paper and paper products; printed matter and related articles	3.99	2.69	1.30	**71**	Other professional, technical and business services	0.92	0.53	0.39
29	Basic chemicals and chemical products	7.33	6.09	1.24	**72**	Agriculture, raising livestock, and mining services	4.70	3.16	1.53
30	Rubber and plastics products	6.51	3.77	2.73	**73**	Maintenance, repair and installation (except construction) services	2.70	2.06	0.64
31	Glass and glass products	10.77	8.67	2.10	**74**	News agency services	1.51	0.37	1.14
32	Other mineral products	22.54	19.27	3.27	**75**	Administrative services of the government	0.81	0.37	0.44

33	Furniture	3.68	1.37	2.31	**76**	Military and civil defense services	0.99	0.54	0.45
34	Basic iron and steel and their products	12.70	9.88	2.82	**77**	Police and fire protection services	1.49	0.97	0.52
35	Other metals	9.96	7.59	2.36	**78**	Social security services	1.85	1.41	0.44
36	Metal products	4.57	0.93	3.63	**79**	Public primary education services	1.82	1.60	0.21
37	General-purpose machinery	1.01	0.33	0.68	**80**	Private primary education services	4.48	3.49	0.99
38	Special-purpose machinery	2.00	0.47	1.53	**81**	Public secondary education services	2.74	2.44	0.30
39	Domestic appliances and parts thereof	3.24	0.97	2.28	**82**	Private secondary education services	3.37	2.56	0.81
40	Office, accounting and computing machinery	0.14	0.03	0.11	**83**	Public university education services	5.03	4.15	0.88
41	Electrical machinery and apparatus	2.87	0.80	2.07	**84**	Private university education services	2.38	2.04	0.35
42	Radio, television and communication equipment and apparatus	0.65	0.13	0.52	**85**	Other education and training services	4.21	3.48	0.73
43	Medical and surgical equipment and orthopedic appliances	1.37	0.60	0.78	**86**	Hospital services	3.02	2.04	0.98
44	Optical and measurement instruments, watches and clocks	0.69	0.20	0.49	**87**	Medical and dental services	2.61	2.32	0.29
45	Motor vehicles, trailers and semi-trailers	1.63	0.24	1.38	**88**	Other human health services	3.23	2.24	0.99
46	Other vehicles	1.01	0.34	0.67	**89**	Veterinary services	1.41	0.98	0.43
47	Jewelry and other unclassified products	3.50	0.39	3.11	**90**	Social services	4.45	3.48	0.97
48	Construction of residential buildings	5.97	0.08	5.89	**91**	Religious services (Masjids, etc.)	8.25	6.21	2.03
49	Other construction	6.27	0.70	5.58	**92**	Arts-related services	2.30	1.66	0.65
50	Wholesale and retail trade services	3.13	2.20	0.93	**93**	Recreational and sporting services	3.29	2.51	0.78
51	Lodging services	5.19	4.03	1.17	**94**	Museum and library services	1.05	0.72	0.33
52	Food and beverage serving services	3.44	1.36	2.09	**95**	Other services	7.22	6.48	0.74

Appendix 3.2

CO_2 emission intensities of sectors in the Iranian economy (kg/million IRR)

Code	Sector name	CO_2 emissions intensity			Code	Sector name	CO_2 emissions intensity		
		Total	Direct	Indirect			Total	Direct	Indirect
10	Agricultural products	340.28	245.39	94.89	**53**	Railway transport	306.05	242.47	63.58
11	Horticulture and market gardening products	403.35	318.54	84.81	**54**	Road passenger transport	756.04	638.76	117.28
12	Live animals and animal products	280.25	100.75	179.50	**55**	Road freight transport	1150.22	1068.33	81.89
13	Products of bees and silkworms	211.23	102.00	109.22	**56**	Pipeline transport	5945.90	5844.35	101.55
14	Forestry and logging products	274.93	237.81	37.12	**57**	Water transport	380.41	286.67	93.74
15	Fish and other fishing products	663.05	539.95	123.10	**58**	Air transport	650.47	477.27	173.21
16	Iron ores and concentrates	231.17	198.21	32.96	**59**	Supporting and auxiliary transport services	300.13	229.03	71.10
17	Copper, ores and concentrates	249.22	190.94	58.28	**60**	Postal and telecommunication services	83.38	58.89	24.50
18	Stone, sand and clay	421.70	332.92	88.77	**61**	Banking services	92.49	59.98	32.52
19	Other minerals	159.57	112.76	46.81	**62**	Investment banking and financial intermediation services	53.75	43.26	10.49
20	Water	641.65	486.19	155.45	**63**	Insurance and pension services	37.77	17.07	20.70
21	Animal and vegetable oils and fats	253.30	106.32	146.98	**64**	Renting services of own residential construction	78.69	0.00	78.69
22	Other foods and beverages	315.51	81.98	233.53	**65**	Renting services of rental residential construction	79.05	0.00	79.05
23	Tobacco products	94.50	20.78	73.72	**66**	Renting services of rental nonresidential construction	148.85	0.00	148.85
24	Textiles	375.23	173.74	201.49	**67**	Trade services of real states	118.44	97.90	20.54
25	Wearing apparel	88.06	17.16	70.90	**68**	Leasing or rental services without operator	50.55	6.99	43.56
26	Leather and leather products; footwear	109.56	38.25	71.31	**69**	Research and development services	58.28	10.43	47.85
27	Products of wood, cork, straw and plaiting materials	314.69	157.62	157.07	**70**	Computer and information services	70.66	44.83	25.83
28	Pulp, paper and paper products; printed matter and related articles	254.82	168.63	86.19	**71**	Other professional, technical and business services	60.57	33.80	26.77
29	Basic chemicals and chemical products	457.63	377.37	80.26	**72**	Agriculture, raising livestock, and mining services	336.65	230.50	106.15
30	Rubber and plastics products	413.89	234.40	179.50	**73**	Maintenance, repair and installation (except construction) services	198.07	154.81	43.26
31	Glass and glass products	696.79	556.76	140.03	**74**	News agency services	105.60	24.87	80.72
32	Other mineral products	1563.26	1332.32	230.94	**75**	Administrative services of the government	53.63	23.64	29.99
33	Furniture	242.38	88.03	154.34	**76**	Military and civil defense services	69.58	38.80	30.78
34	Basic iron and steel and their	811.98	625.10	186.88	**77**	Police and fire protection	99.98	64.47	35.51

	products					services			
35	Other metals	636.44	478.40	158.04	**78**	Social security services	117.98	87.77	30.21
36	Metal products	297.20	58.52	238.68	**79**	Public primary education services	114.18	99.80	14.38
37	General-purpose machinery	66.45	21.63	44.82	**80**	Private primary education services	279.43	211.20	68.23
38	Special-purpose machinery	132.34	31.72	100.63	**81**	Public secondary education services	171.83	151.61	20.22
39	Domestic appliances and parts thereof	210.80	60.88	149.92	**82**	Private secondary education services	210.62	155.46	55.16
40	Office, accounting and computing machinery	9.20	1.82	7.38	**83**	Public university education services	330.88	270.73	60.16
41	Electrical machinery and apparatus	191.66	55.79	135.88	**84**	Private university education services	150.45	127.19	23.26
42	Radio, television and communication equipment and apparatus	42.54	8.27	34.26	**85**	Other education and training services	274.04	223.60	50.43
43	Medical and surgical equipment and orthopedic appliances	89.33	38.02	51.31	**86**	Hospital services	192.94	128.39	64.55
44	Optical and measurement instruments, watches and clocks	44.51	12.69	31.82	**87**	Medical and dental services	177.64	158.22	19.43
45	Motor vehicles, trailers and semi-trailers	107.44	15.29	92.15	**88**	Other human health services	201.98	136.60	65.38
46	Other vehicles	67.84	22.45	45.39	**89**	Veterinary services	93.77	64.97	28.79
47	Jewelry and other unclassified products	238.69	27.57	211.12	**90**	Social services	293.64	227.30	66.34
48	Construction of residential buildings	410.93	6.09	404.85	**91**	Religious services (Masjids, etc.)	542.98	406.76	136.21
49	Other construction	435.31	51.07	384.24	**92**	Arts-related services	148.28	103.75	44.53
50	Wholesale and retail trade services	210.63	144.01	66.62	**93**	Recreational and sporting services	211.75	158.28	53.47
51	Lodging services	330.17	250.54	79.63	**94**	Museum and library services	68.84	46.47	22.37
52	Food and beverage serving services	225.94	84.30	141.64	**95**	Other services	488.20	438.46	49.75

Chapter 4:

The impact of energy subsidy reform on producer costs and household expenditure in Iran

4.1 Introduction

Despite some limited and specific benefits, energy subsidies impose substantial costs on modern societies, of which several studies overview the economic, environmental, and social impacts (UNEP, 2003, 2008; Ellis, 2010). In developing countries, Gupta et al. (2002) found that oil-exporting countries were the main net subsidizers of energy. Their study demonstrated that implicit energy subsidies in major oil-exporting countries averaged approximately 3.0% of GDP and 15.2% of explicit government expenditures in 1999. The IEA (2007) also concluded that oil exporters were major energy subsidizers. For instance, in 2005, Russia paid the largest subsidies in dollar terms, amounting to about 40 billion USD, most of which went to natural gas. Second placed in terms of subsidization, Iran subsidized mostly oil products, amounting to some 37 billion USD in the same year. China, Saudi Arabia, India, Indonesia, Ukraine, Egypt, Venezuela, and Kazakhstan are in order the world‘s next largest energy subsidizers, many of which are also major oil producers.

After decades disputing the necessity of subsidy reform, the Iranian parliament approved the Reform Act on January 5, 2010. The Reform Act envisaged the replacement of product subsidies with targeted transfers to the population, with some assistance to Iranian companies and the government. The Reform Act stipulated that households would receive at least 50% of the increase in revenues derived from the reform. Initially, the payment of benefits was to be in cash, while in a second phase, some of the additional revenues would support higher social benefits and public goods. Thirty percent of the additional revenues were to be used to assist Iranian companies to restructure to adjust to the new, dramatically higher, energy costs. The remaining 20% of additional revenues would go to the government to cover the government‘s own higher energy bill. Article 15 of the Reform Act authorized the government to establish a new Subsidy Targeting Organization to ensure the efficient centralized management of the reform process.[1] On December 19, 2010, Iran increased domestic energy and agricultural prices up to twentyfold, making it the first major oil-exporting country to reduce substantially its system of implicit energy subsidies. In the next phase, prices would increase progressively until the removal of all subsidies. Since the start of the first phase, the government has compensated for the burden of increased energy prices by transferring 450,000 IRR (nearly 40 USD) per person to Iranian household heads.

As the reform is relatively new, it is still too early to evaluate its effects on the Iranian economy, especially in terms of producer costs and household expenditures. However, the published official data show that the first phase of the reform increased the Iranian monthly inflation rate by approximately 1%. Fig. 4.1 plots the Consumer Price Index (CPI) in urban areas in the months preceding and following the start of reform (CBI, 2011). Such graphical analysis is of course limited; the aim of this chapter therefore is to investigate in more detail the inflationary impact of the energy subsidy reform on different nonenergy sectors and urban and rural households in Iran. For this purpose, we construct an input–output price model for Iran and use this to derive the energy cross-price effects of the nonenergy sectors in Iran. The results evidence well the substantial impact of the complete program of energy subsidy reform on production and consumption prices.

[1] The Reform Act is available in Appendix 1.

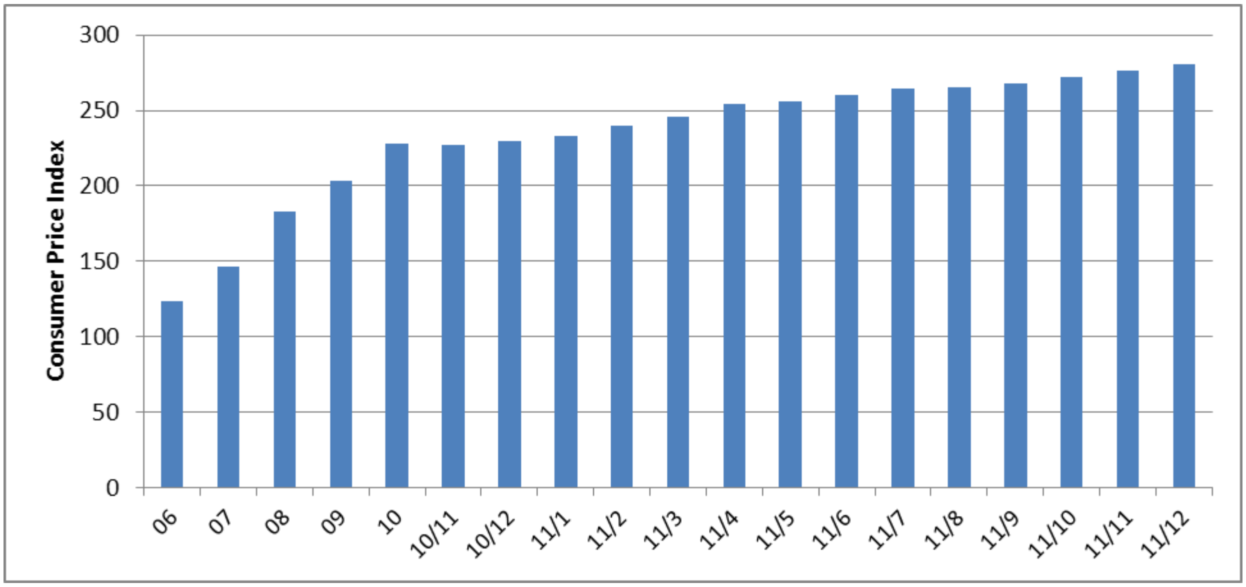


Fig. 4.1. Iranian urban area CPI before and after the start of reform (2004/05 = 100)

4.2 Literature review

Several studies have considered the impact of new energy prices on total prices at the production and consumption levels. The input–output price model is one of the approaches used to analyze the effects of the fluctuations in energy prices. For instance, Llop and Pié (2008) analyzed the effects of a tax on intermediate energy use and a reduction in intermediate energy demand on production and consumption prices in Catalonia, Spain. Using a competitive and a markup price formulation in the framework of an input–output model, they found a tax on intermediate energy uses increases the consumer price index, and this in turn decreases the intermediate demand for energy and has a negative effect on private real income.

However, levying a tax combined with a reduction in the intermediate demand for energy use not only reduces energy consumption, but also has no effect on prices and a positive impact on private real income. Llop (2008) used the same research questions and methodology in an examination of the Spanish water sector. The results of this particular analysis are similar to those found earlier. Nguyen (2008) also studied the impact of increasing electricity tariffs on long-run marginal cost on the prices of other products in Vietnam using a static input–output approach. He ascertained that such an increase would drive up prices in all other sectors. Given it would be difficult to implement this increase altogether, Nguyen (2008) recommended it would be better to increase the electricity tariff only gradually.

Liu et al. (2009) evaluated how alternative policies, such as increasing the prices of intermediate electricity use and implementing energy-saving projects and reducing intermediate electricity use, may also affect production prices, consumption prices, and real income in rural and urban households in China. Applying an adjusted input–output price model, Liu et al. (2009) found that the increase in the energy price accounted for a general increase in production and consumption prices, but decreased household real income, especially in urban areas. A combination of two complementary policies was found to somewhat reduce prices. Combining the portfolio and input–output approaches, Suzuki and Uchiyama (2010) measured the risk of an increase in the producer price in Japanese nonenergy sectors associated with an increase in the price of imported fossil fuels. Using an input–output price model, they also measured the energy cross-price effects in nonenergy sectors. The results in Suzuki and Uchiyama (2010) indicate that almost all nonenergy sectors have reduced the risk of an increase in producer prices because of improvement in energy usage by upstream sectors.

A number of international studies have already investigated the effects of subsidy phase out in the Iranian economy (Birol et al., 1995; Jensen and Tarr, 2003; AlShehabi, 2011). For instance, Birol et al. (1995) attempted to quantify the potential gains from both the removal of energy subsidies and an improvement in autonomous energy efficiency in Iran and two other oil-exporting countries. In a scenario where domestic energy prices meet international prices and energy efficiencies improve toward some autonomous rate of energy-efficiency improvement, Birol et al. (1995) found the economic savings in Iran could be as high as 20% over the period 1993–2005. Using a multisector computable general equilibrium (CGE) model, Jensen and Tarr (2003) estimated the gains in Iran from ‗tariffication' of nontariff barriers, the lowering of tariffs, the unification of the exchange rate for import purchases, and energy pricing reform. Regarding the relative importance of these several reforms, Jensen and Tarr (2003) found that the largest potential gains were from energy pricing reform, especially as this reform alone resulted in an estimated gain of 32% of consumption.

Also in Iran, AlShehabi (2011) considered the effects of eliminating crude and fuel oil subsidies on the labor market using two alternative policy options. The first option redistributed additional revenues as extra income to households, while the second directed revenue into increased investment. AlShehabi (2011) found that even though real GDP and household welfare increased in the first scenario, wages and the quantity of labor employed both fell because of the Dutch disease effect and the increased costs of inputs. In the second scenario, and in the short run, the variation in the channeling of revenues accounted for a contraction in the labor market, though it would also continue to expand the market over time because of capital accumulation effects and shifts in the structure of the economy.

The main pitfall of these studies is that they disregard the negative effects of policy reform that may slow the pace of reform or, in extreme cases, negate the policy itself. Several domestic studies have estimated the economic effects of energy subsidy reform in Iran. For instance, Khiabani (2008) employed a standard CGE model to examine the effects of an increase in the price of energy carriers on production costs, inflation, and economic welfare across different income deciles. The results indicate that if domestic fuel prices increased to their international level, the inflation rate would increase by 35%, output and employment would respectively decrease by 4.5% and 6.8%, and government revenue would increase by

40%. As an alternative approach, Ghaderi and Estedlal (2009) employed an autoregressive distributed lag model (ARDL) to measure the effects of an increase in the price of electricity by quantifying the compensating variation (CV) and deadweight loss (DWL) of Iranian residential consumers. They show that although CV and DWL increased in high-income groups, there was a more pronounced effect in low-income groups because of the typically larger expenditure share of electricity.

Applying a CGE model and using a micro-consistent matrix, Manzoor et al. (2010) examined the effects of implicit and explicit energy subsidy phase out in Iran. They concluded that the policy would increase the inflation rate by between 57.9% and 69.07%, reduce total output from 2.11% to 2.22%, and decrease household welfare between 11.80% and 12.62%. Akhoond zade et al. (2011) used an Almost Ideal Demand System (AIDS) to appraise the welfare effects of energy price reform in the Iranian construction and transportation sectors. The results showed that the share of energy costs in total expenditure in the transportation sector was concentrated in middle-income groups, and declined as income grew. They also found that the CV was generally larger in higher-income groups and more significant in urban areas.

Some studies have also examined the effects of energy subsidy reform in Iran using input–output and social accounting matrix (SAM) price models. For example, Perme (2005) concluded that removing the subsidies on refined petroleum products, natural gas, and electricity would increase their respective average national price indexes by 19.52%, 11.07%, and 4.83%, respectively. Moreover, if the removal of all energy subsidies took place simultaneously, the price index would increase by 35.4%. In other work, Sharifi et al. (2008) showed that the sectors most affected by energy subsidy reform would be nonferrous mineral products, forestry, and refined petroleum products. They also found that electricity had the highest inflationary impact among the energy carriers. Similarly, Shahmoradi et al. (2010) found that increasing inland fuel prices to their international level would increase consumer and producer price indices by 108% and 118%, respectively, while prices for freight and passenger rail transportation would experience an extraordinary 263% increase in service prices. In the absence of any protection program, social welfare would then deteriorate by 79%, especially in rural areas. Finally, Heydari and Perme (2010) provided evidence that removing the fuel and bread subsidies would potentially increase the related expenditures by urban and rural households by at least 33% and 40%, respectively.

4.3 Methodology

4.3.1 Input–output price model

The input–output price model, or more typically, the Leontief price model, is an analytical framework used to examine the effects of energy price fluctuations in a static manner. The starting point in the derivation of the model is summing the *j*th column in a standard input–output table:

$$x_j = \sum_{i=1}^{n} z_{ij} + v_j \quad ,$$

or

$$x' = i'Z + v' \tag{4.1}$$

where x, Z, and v are the total outlay, transaction, and value-added matrices and *i* indicates the unity vector. Substituting $Z = A\hat{x}$ and postmultiplying by $\hat{x}^{-1}$ yields:

$$\begin{aligned} x'\hat{x}^{-1} &= i'Ax'\hat{x}^{-1} + v'\hat{x}^{-1} \\ i' &= i'A + v'_c \end{aligned} \quad , \tag{4.2}$$

where $v'_c = v'\hat{x}^{-1}$. The right-hand side of Eq. (4.2) is the cost of inputs per unit of output. Output prices are set equal to the total cost of production, so each price equals unity. The vector *i* can be interpreted as the index prices in the base year. If we denote these base-year index prices using the vector p, the input–output price model is as Eq. (4.3) (Miller and Blair, 2009):

$$p' = p'A + v'_c \quad \text{or} \quad p = A'p + v_c \tag{4.3}$$

Following Suzuki and Uchiyama (2010), we make two modifications to Eq. (4.3). First, we externalize energy prices by decomposing Eq. (4.3) into energy (e) and nonenergy sectors (n):

$$\begin{bmatrix} p_e \\ p_n \end{bmatrix} = \begin{bmatrix} A'_{ee} & A'_{ne} \\ A'_{en} & A'_{nn} \end{bmatrix} \begin{bmatrix} p_e \\ p_n \end{bmatrix} + \begin{bmatrix} v_{ce} \\ v_{cn} \end{bmatrix} \tag{4.4}$$

In Eq. (4.4), p_e and p_n are the respective index prices in energy and nonenergy sectors, v_{ce} and v_{cn} are the value-added of the energy and nonenergy sectors per unit of production, and as an example in the technical matrix (A), A_{en} provides the share of energy input transferred to nonenergy sectors in the total outlays of the nonenergy sector. In a country like Iran where energy prices are set administratively, the price of energy is an exogenous variable. While the prices of energy carriers can influence the production costs of nonenergy products, the only significant equation that can be derived from Eq. (4.4) is as follows:

$$\begin{aligned} p_n &= A'_{en} p_e + A'_{nn} p_n + v_{cn} \\ [I - A'_{nn}] p_n &= A'_{en} p_e + v_{cn} \\ p_n &= [I - A'_{nn}]^{-1} A'_{en} p_e + [I - A'_{nn}]^{-1} v_{cn} \end{aligned} \tag{4.5}$$

We can use Eq. (4.5) to examine the impact of an exogenously given change in energy prices. The assumption $\Delta v_{cn} = 0$ yields the general form of the price model:

$$\Delta p_n = [I - A'_{nn}]^{-1} A'_{en} \Delta p_e \tag{4.6}$$

The second modification involves the extraction of imported nonenergy commodities from the price model. This is because domestic energy prices do not determine the prices of imported nonenergy products. For this purpose, we need to modify Eq. (4.6) using the import coefficient vector of nonenergy products ($\hat{m}_n$), where the elements indicate the ratio of the imported nonenergy products to the total demand of the respective sector:

$$\Delta p_n = \left[I - \{(I - \hat{m}_n).A_{nn}\}' \right]^{-1} A'_{en} \Delta p_e , \qquad (4.7)$$

where $B_{nn} = (I - \hat{m}_n).A_{nn}$. Eq. (4.7) can be rewritten as Eq. (4.8):

$$\Delta p_n = \left[I - B_{nn}' \right]^{-1} A'_{en} \Delta p_e \qquad (4.8)$$

In addition to analyzing the effects on production prices, we can examine the impact of the reform of energy subsidies on consumption prices. Consumption prices are conventionally defined endogenously using a normalized basket of goods, which define the weights of final prices (Llop and Pié, 2008):

$$p_C = \sum_{j=1}^{n} p_j . \frac{c_j}{c} , \qquad (4.9)$$

where p_j are production prices and c_j/c represents the share of final consumption for each good with respect to all goods consumed. We can also obtain an approximation of the influence of the revised energy prices on consumer real income. In particular, the changes in private real income (Δi) can be calculated using Eq. (4.10):

$$\Delta i = i - i^R = \sum_{j=1}^{n} p_j c_j - \sum_{j=1}^{n} p_j^R c_j = \sum_{j=1}^{n} (p_j - p_J^R) c_j , \qquad (4.10)$$

where p_j and $p^R{}_j$ respectively indicate the consumption price of good j before and after the reform. These results will assist us in estimating an approximation of the compensatory payments the government should transfer to consumers to cover any increased expenditure, at least in the short run.

4.3.2 Decomposition of the price model

While the Leontief price model assumes that the economic structure does not alter over time, Eq. (4.8) links the price change of nonenergy products to the price change in energy carriers. If we decompose Eq. (4.8) into its constituent parts, we can individually track the impact of each part. Given our purpose is to consider the impact of energy subsidy reform on the price of nonenergy products, we restrict the decomposition in our analysis to the price of energy carriers. Therefore, we decompose Δp_e into the increase in the prices of each of the final energies as:

$$\Delta p_e = \Delta p_{ELE} + \Delta p_{NG} + \Delta p_{GA} + \Delta p_{KE} + \Delta p_{GO} + \Delta p_{FO} + \Delta p_{LPG}\,, \qquad (4.11)$$

where ELE, NG, GA, KE, GO, FO, and LPG denote electricity, natural gas, gasoline, kerosene, gas oil, fuel oil, and LPG, respectively. Substituting Eq. (4.11) into Eq. (4.8) yields:

$$\Delta p_n = (I - B'_{nn})^{-1} A'_{en} \left[\Delta p_{ELE} + \Delta p_{NG} + \Delta p_{GA} + \Delta p_{KE} + \Delta p_{GO} + \Delta p_{FO} + \Delta p_{LPG}\right]. \qquad (4.12)$$

Multiplication of the first term in Eq. (4.12) reveals by how much the rate of producer prices in nonenergy sectors would increase given the change in the price rate of each fuel. When all the diagonal elements in Δp_e are set equal to one, Δp_n represents the cross-price effect of each fuel in the nonenergy sectors. We can then decompose the elasticities obtained from Eq. (4.12) into their direct and indirect impacts by substituting the Leontief inverse matrix with the equivalent power series. For instance, the first term in Eq. (4.13) indicates the direct impact of any electricity price change, whereas the remaining terms in Eq. (4.13) reflect any price effects in subsequent rounds (Suzuki and Uchiyama, 2010):

$$\Delta p_{n.ELE} = (I - B'_{nn})^{-1} A'_{en} \Delta p_{ELE} = (I + B_{nn} + B_{nn}^{2} + \ldots) A'_{en} \Delta p_{ELE} \quad (4.13)$$

4.4 Empirical results

The last published survey-based input-output table is for 2001, issues by Statistical Center of Iran (SCI, 2005). The above symmetric table contains 91 commodities complemented by supply, use, import, and value added tables. The classification of commodities in this table is based on System of National Account 1993 (SNA93) and Central Product Classification Version 1.0 (CPC.V.1.0).

To simplify the analysis, we aggregate the original table of 91 commodities into 37 sectors. Table 4.2 depicts the structure of our aggregated input–output table comprising primary energy products (crude oil and natural gas), final energy products (Sectors 2–10), and nonenergy products (Sectors 11–37). Because of the relatively low production share of coal as a final energy in Iran, we include this particular sector (11) among the nonenergy sectors. In addition, given the focus of our analysis is energy subsidy reform, we assume the prices in sectors (3) and (10), i.e. water and the other refined petroleum products, remain unchanged.

Table 4.2
Introduction of primary energy, final energy, and nonenergy sectors in Iranian input–output

Sector No.	Energy sectors	Sector No.	Nonenergy sectors	Sector No.	Nonenergy sectors
1	Crude oil and natural gas (primary energy)	11	Coal and lignite; peat	25	Jewelry and other products
2	Electricity	12	Other ores and minerals	26	Construction
3	Water	13	Agriculture, forestry and fishery products	27	Wholesale and retail services
4	Natural gas	14	Food products	28	Lodging and serving services
5	Gasoline	15	Textiles and leather products	29	Transport services
6	Kerosene	16	Pulp, paper and wood	30	Communication and

			products		financial services
7	Gas oil	17	Chemical products	31	Real estate and rental services
8	Fuel oil	18	Glass and glass products	32	Research, development and technical services
9	LPG	19	Basic metals and metal products	33	Production and maintenance services
10	Other refined petroleum products	20	General and specific purpose machinery	34	Public administration
		21	Electrical machinery	35	Education
		22	Media equipment	36	Health services
		23	Medical appliances	37	Other services
		24	Transport equipment		

4.4.1 Direct and indirect elasticities of fuels in nonenergy sectors

Using the decomposition methodology of the input–output price model, we are able to calculate the total, direct, and indirect cross-price effects of electricity, natural gas, gasoline, kerosene, gas oil, fuel oil, and LPG for all of the nonenergy sectors. Fig. 4.6 and Table 5.3 detail the cross-price effects by fuel and sector.

As explained earlier, we calculate the elasticities by equalizing the rate of price increase of each fuel to unity. Therefore, we interpret the elasticities as indicating by how many percent the price of a specific nonenergy sector would increase if the price of a specific fuel were to double. For instance, the results in Table 4.3 show that the price elasticity of electricity in the construction sector (Sector 26) is 1.54. This means that if the price of electricity per kWh doubled, prices in the construction sector would increase by 1.54% per unit of output. Of this total elasticity measure, only 0.05% stems from the increase in electricity prices consumed directly in the construction sector with the remainder (1.49%) associated with the increasing prices of other inputs associated with the indirect impact of the same electricity price increase.

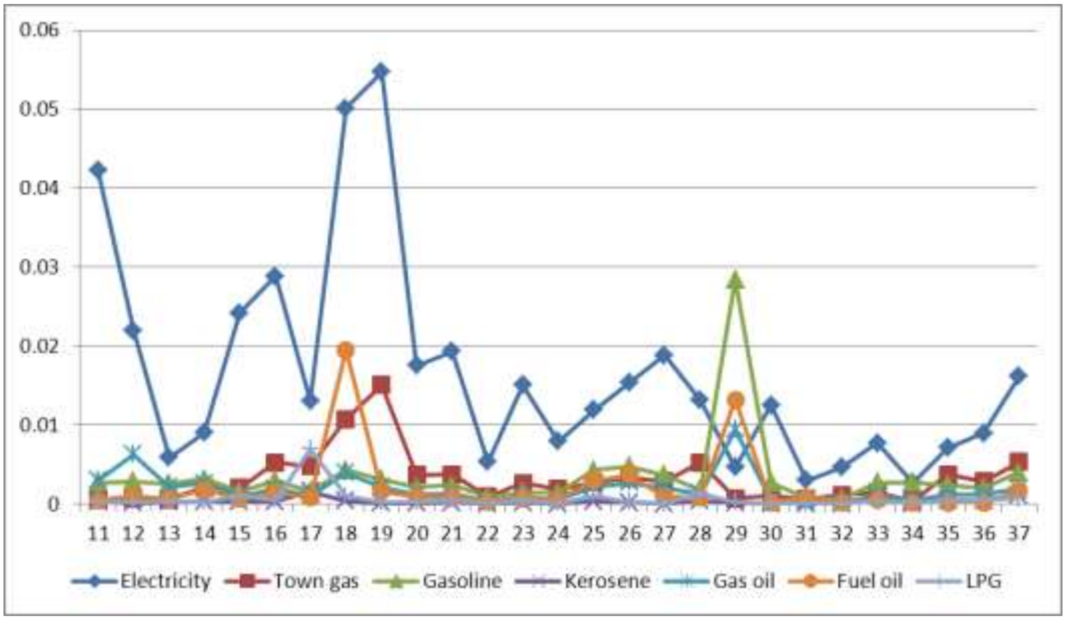


Fig. 4.2. Comparison of total cross-price effects of fuels in Iranian nonenergy sectors

From Fig. 4.2, it is clear that except in the transportation sector (29), electricity has the highest cross-price effect of all of the final energies. In other words, an increase in the price of electricity can increase production costs, and consequently, the total inflation rate, relatively more than any other fuel. The highest price elasticities of electricity are in basic metals and metal products (5.47%), glass and glass products (5%), and coal and lignite (4.22%). In these sectors, the price increase is usually because of the direct consumption of electricity. The highest indirect elasticities are in basic metals and metal products (1.67%), construction (1.49%), and electrical machinery (1.30%).

The results for natural gas are similar in that the total elasticities of natural gas are higher in the same sectors that are the largest consumers of electricity, i.e. basic metals and metal products (1.50%) and glass and glass products (1.07%). As with electricity, the price changes in these sectors are significant because of the enormous direct consumption of natural gas in these sectors. In addition, the greatest indirect elasticities of natural gas are in basic metals and metal products (0.39%), construction (0.33%), and electrical machinery (0.32%).

Because 99% of gasoline consumption occurs in the transportation sector, it is not surprising that an increase in the price of gasoline mainly affects prices in this sector. Put simply, if the price of gasoline were to double, the prices of transport services would increase by 2.85%. The respective direct and indirect elasticities of gasoline in the transportation sector are 2.53% and 0.30%, respectively. The next two sectors most affected by an increase in the price of gasoline are the construction and glass and glass products sectors with total cross-price effects of 0.48% and 0.43%, respectively. In sharp contrast, the price of kerosene has one of the lowest impacts on production prices, with the largest cross-price effects in chemical products, other services, and production and maintenance services.

Because of their substantial direct consumption of gas oil, transport services, other ores and minerals, and glass and glass products have the largest cross-price effects of 0.94%, 0.62%, and 0.39%, respectively. The largest indirect effects of an increase in the price of gas oil are in the food products and jewelry and other products sectors, with cross-price effects of 0.19 and 0.17%, respectively. The highest cross-price effects for fuel oil are glass and glass products (1.95%) and transport services (1.32%), mainly because of its direct impact. In terms of indirect price elasticities, the price of fuel oil mainly affects construction, jewelry and other products, and glass and glass products indirectly. Finally, doubling the price of LPG increases the prices of chemical products and lodging and serving services by 0.70% and 0.13%, respectively. This is mainly associated with the direct consumption of LPG in these sectors. The highest indirect impact of an increase in the price of LPG appears in chemical products and textile and leather products.

Table 4.3

Total, direct, and indirect cross-price effects of fuels in nonenergy sectors in Iran (%)

Sec. no.	Electricity			Natural gas			Gasoline			Kerosene			Gas oil			Fuel oil			LPG		
	Tot.	Dir.	Ind.	Tot.	Dir.	Ind.	Tot.	Dir.	Ind.	Tot.	Dir.	Ind.	Tot.	Dir.	Ind.	Tot.	Dir.	Ind.	Tot.	Dir.	Ind.
11	4.23	3.99	0.24	0.06	0.01	0.05	0.27	0.16	0.11	0.03	0.02	0.01	0.30	0.26	0.05	0.05	0.00	0.05	0.03	0.01	0.02
12	2.20	1.99	0.20	0.06	0.02	0.05	0.29	0.16	0.12	0.02	0.01	0.01	0.63	0.58	0.05	0.10	0.04	0.06	0.03	0.01	0.02
13	0.59	0.28	0.31	0.06	0.00	0.06	0.26	0.10	0.16	0.02	0.01	0.01	0.22	0.14	0.08	0.07	0.00	0.06	0.03	0.01	0.02
14	0.90	0.27	0.63	0.21	0.12	0.09	0.32	0.02	0.30	0.03	0.01	0.02	0.27	0.08	0.19	0.18	0.07	0.12	0.03	0.00	0.02
15	2.42	1.71	0.71	0.20	0.07	0.13	0.16	0.01	0.15	0.03	0.00	0.03	0.10	0.01	0.08	0.07	0.01	0.06	0.11	0.00	0.10
16	2.89	2.30	0.59	0.53	0.40	0.13	0.30	0.11	0.20	0.03	0.02	0.01	0.19	0.10	0.09	0.15	0.07	0.09	0.05	0.01	0.04
17	1.31	0.83	0.48	0.48	0.35	0.13	0.16	0.03	0.13	0.16	0.13	0.03	0.11	0.04	0.06	0.08	0.02	0.06	0.70	0.60	0.11
18	5.01	4.26	0.74	1.08	0.94	0.13	0.43	0.10	0.33	0.04	0.03	0.01	0.40	0.23	0.17	1.95	1.72	0.23	0.10	0.08	0.02
19	5.47	3.79	1.68	1.51	1.11	0.40	0.32	0.03	0.29	0.01	0.00	0.01	0.22	0.06	0.16	0.17	0.03	0.13	0.03	0.01	0.02
20	1.76	0.65	1.11	0.37	0.08	0.29	0.21	0.03	0.18	0.01	0.00	0.01	0.12	0.03	0.09	0.09	0.01	0.08	0.03	0.01	0.02
21	1.93	0.63	1.30	0.38	0.05	0.33	0.24	0.04	0.20	0.02	0.00	0.01	0.13	0.03	0.10	0.09	0.00	0.09	0.05	0.01	0.05
22	0.53	0.27	0.26	0.10	0.02	0.07	0.09	0.01	0.08	0.01	0.00	0.00	0.04	0.01	0.04	0.04	0.00	0.04	0.02	0.00	0.01
23	1.50	0.94	0.57	0.27	0.11	0.16	0.15	0.03	0.12	0.02	0.00	0.01	0.09	0.03	0.06	0.07	0.01	0.06	0.05	0.01	0.04
24	0.79	0.17	0.62	0.19	0.04	0.15	0.14	0.01	0.13	0.00	0.00	0.00	0.07	0.01	0.06	0.06	0.00	0.06	0.01	0.00	0.01
25	1.19	0.00	1.19	0.27	0.04	0.23	0.43	0.17	0.26	0.03	0.01	0.02	0.22	0.04	0.18	0.30	0.03	0.27	0.10	0.03	0.07
26	1.54	0.04	1.50	0.34	0.00	0.34	0.48	0.13	0.35	0.02	0.01	0.01	0.27	0.09	0.18	0.37	0.01	0.36	0.02	0.00	0.02
27	1.88	1.76	0.13	0.29	0.26	0.03	0.37	0.20	0.17	0.01	0.00	0.00	0.20	0.14	0.06	0.10	0.01	0.08	0.01	0.00	0.01
28	1.31	0.91	0.40	0.53	0.44	0.08	0.17	0.02	0.16	0.04	0.03	0.01	0.14	0.03	0.10	0.09	0.00	0.09	0.14	0.12	0.01
29	0.47	0.24	0.23	0.07	0.03	0.05	2.84	2.54	0.30	0.02	0.00	0.01	0.94	0.84	0.11	1.32	1.19	0.13	0.03	0.00	0.03
30	1.25	1.05	0.20	0.10	0.07	0.03	0.28	0.21	0.06	0.01	0.00	0.00	0.05	0.03	0.02	0.02	0.00	0.02	0.01	0.00	0.00
31	0.30	0.02	0.29	0.07	0.01	0.06	0.07	0.00	0.07	0.00	0.00	0.00	0.04	0.00	0.04	0.09	0.00	0.09	0.01	0.00	0.01
32	0.46	0.32	0.14	0.11	0.08	0.03	0.07	0.02	0.05	0.01	0.00	0.00	0.02	0.00	0.02	0.02	0.00	0.02	0.01	0.00	0.01
33	0.77	0.53	0.24	0.15	0.10	0.05	0.27	0.19	0.08	0.10	0.09	0.01	0.11	0.07	0.04	0.05	0.01	0.04	0.03	0.02	0.02
34	0.27	0.23	0.04	0.04	0.03	0.01	0.28	0.24	0.04	0.01	0.00	0.00	0.05	0.03	0.01	0.02	0.00	0.02	0.02	0.02	0.00
35	0.71	0.59	0.13	0.38	0.35	0.03	0.25	0.20	0.04	0.05	0.04	0.00	0.12	0.10	0.02	0.02	0.00	0.02	0.04	0.03	0.01
36	0.90	0.78	0.12	0.28	0.25	0.03	0.20	0.17	0.04	0.05	0.04	0.01	0.12	0.10	0.02	0.02	0.00	0.02	0.04	0.02	0.03
37	1.62	1.37	0.24	0.53	0.47	0.06	0.40	0.32	0.08	0.11	0.10	0.01	0.19	0.16	0.04	0.16	0.12	0.04	0.07	0.06	0.02

4.4.2 Price effects on producers and consumers

Estimation of the cross-price effects of these several fuels paves the way to examine the impact of energy subsidy reform on production costs and household expenditures and real incomes in Iran. Table 4.4 provides information on domestic and regional energy prices before and after the reform. Clearly, the gap in prices between domestic and regional prices in Iran has been considerable for much of recent history. Before implementation of the reform, the ratios of international prices to domestic prices for electricity, natural gas, gasoline, kerosene, gas oil, fuel oil, and LPG were 4.68, 22.96, 5.36, 38.7, 37.81, 41.49, and 11.49, respectively. In the first phase of the reform from December 2010, the government increased the domestic prices of these same fuels by 172%, 569%, 300%, 506%, 809%, 201%, and 223%, respectively. Article 1 of the Subsidy Reform Law requires that the domestic sale prices of energy carriers should adjust gradually until the end of the Fifth Five-Year Development Plan (2010–15) to a level not less than 90% of Persian Gulf FOB[1] prices. However, it is not clear when and in how many steps the next phases of reform will proceed.

Table 4.4

Domestic and regional energy prices before and after the reform (IRR)

	Domestic energy prices in 2008/09 – before reform	Average regional market prices in 2008/09	Domestic energy prices in 2010 – after reform
Electricity	165	773[a]	450
Natural gas	104.5	2400[b]	700
Gasoline	1000	5362[c]	4000
Kerosene	165	6392[c]	1000
Gas oil	165	6239[c]	1500
Fuel oil	94.5	3921[c]	2000
LPG	309.1	3605[c]	1000

[a] Export price (IRR/kWh), [b] Export price (IRR/m^3), [c] FOB price of refined petroleum products in Persian Gulf (IRR/liter)
Source: MoE (2010) and MoP (2009). Note: 1 USD = 9,917 IRR in 2008.

Because of some ambiguity about the phases of reform and the market prices of fuels in 2015, we examine the impact of the subsidy reform on production and consumption prices using two scenarios. The first scenario is where the price changes correspond to the first phase of reform in 2010. This is because analyzing the price impact of the first reform phase is

[1] Freight on Board (FOB)

essential from a policy viewpoint, particularly as we can compare the results with the real initial increase in prices as reported by CBI. The second scenario assumes that domestic energy prices increased immediately to average regional market prices in 2008/09. In practical terms, the results of this second scenario can improve our understanding about the overall inflationary impact of a full energy price adjustment in Iran.

Table 4.5, Fig. 4.3 and Fig. 4.4 detail the total, direct, and indirect impact of energy subsidy reform under these two alternative scenarios. It is apparent that the removal of energy subsidies principally affects the glass and glass products, transport services, and basic metals and metal products sectors. While the first phase of reform respectively increased the production prices of these sectors by 59%, 44%, and 24%, the removal of energy subsidies would increase production prices in these same sectors by 140%, 105%, and 70%, respectively. Four sectors are relatively unaffected by the increase in energy prices, i.e. research, development and technical services, public administration, media equipment, and real estate and rental services. We expect that by removing all or some energy subsidies in Iran, the increase in production prices in these sectors would not exceed 8% and 3%, respectively.

Table 4.5

Effects of energy subsidy reform on producer prices (%)

Sector number	Scenario 1: First phase			Scenario 2: Complete reform		
	Total	Direct	Indirect	Total	Direct	Indirect
11	12.09	9.70	2.39	32.62	26.10	6.52
12	12.25	9.54	2.71	38.83	31.79	7.04
13	5.42	2.01	3.40	16.61	7.19	9.42
14	9.78	3.26	6.53	28.09	9.80	18.29
15	8.38	3.75	4.62	22.72	9.04	13.68
16	13.86	8.88	4.98	38.75	25.09	13.66
17	10.39	6.28	4.11	36.82	24.72	12.10
18	59.10	50.02	9.08	140.30	117.24	23.07
19	24.22	14.14	10.07	70.16	42.29	27.87
20	8.72	2.19	6.53	24.32	6.20	18.12
21	9.34	1.83	7.51	26.29	5.12	21.17

22	2.89	0.70	2.18	7.88	1.86	6.02
23	6.91	2.82	4.09	19.34	7.72	11.61
24	4.63	0.61	4.02	12.82	1.81	11.01
25	13.01	1.82	11.19	34.42	5.08	29.34
26	15.78	1.44	14.33	40.95	4.82	36.13
27	9.59	6.54	3.05	26.43	18.93	7.50
28	9.17	4.87	4.30	28.68	16.90	11.78
29	44.26	39.02	5.24	105.19	91.87	13.32
30	4.38	3.12	1.26	10.88	7.61	3.27
31	3.25	0.08	3.17	8.16	0.24	7.92
32	2.32	1.12	1.20	6.52	3.30	3.22
33	5.45	3.34	2.11	17.26	11.56	5.71
34	2.32	1.62	0.70	5.97	4.13	1.84
35	5.86	4.74	1.12	19.46	16.48	2.98
36	5.44	4.32	1.13	17.76	14.40	3.35
37	12.67	10.42	2.25	38.30	32.07	6.23

As with the cross-price effects, comparison of the total and direct effects for both scenarios reveals that the sectors experiencing the largest total impact are the main consumers of energy, mostly because of their large energy input shares. However, the picture for indirect effects differs. The main increase in the price of nonenergy inputs resulting from the increase in energy prices occurs in the construction, jewelry and other products, and basic metals and metal products sectors. While increasing energy prices in the first phase respectively increases production prices in these sectors by only 1%, 2%, and 14%, it also increases production prices via an increase in the prices of the other inputs by 14%, 11%, and 10%, respectively. The indirect impacts in the second scenario for these sectors are 36%, 29%, and 28%, respectively.

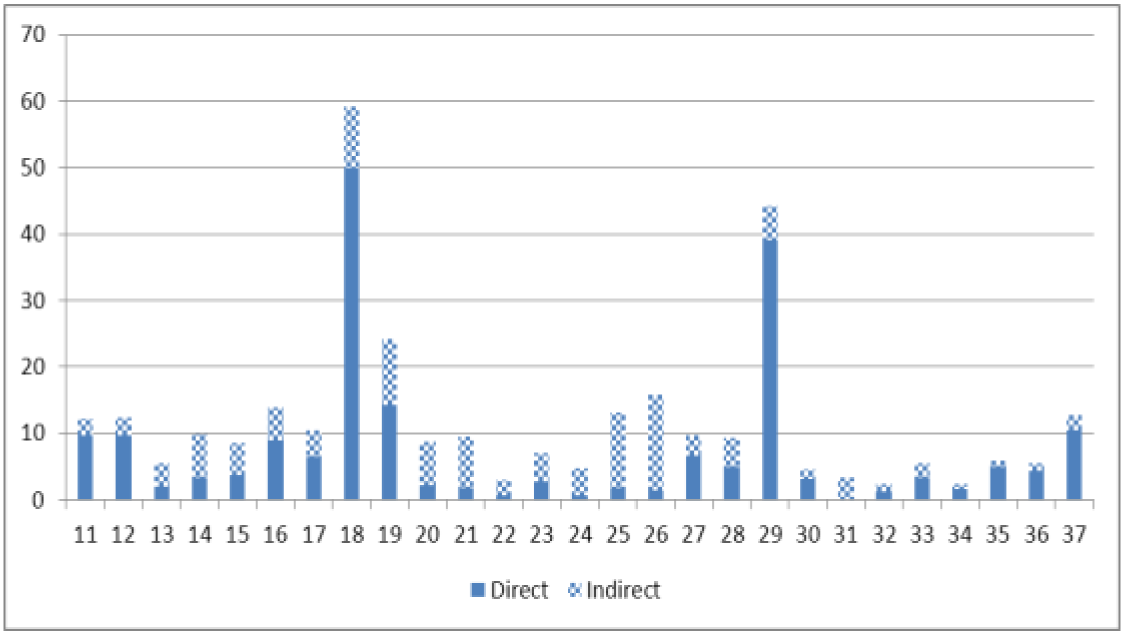


Fig. 4.3. Direct and indirect impacts on production prices of the first phase (Scenario 1**)**

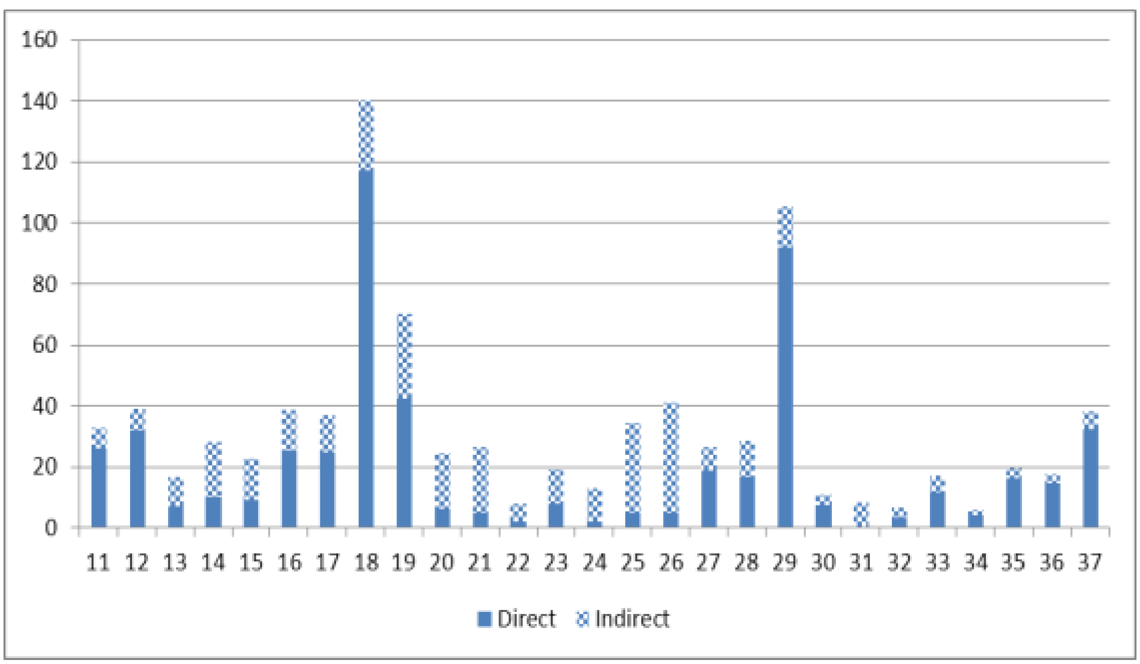


Fig. 4.4. Direct and indirect impacts of complete energy subsidy reform on production prices (Scenario 2)

To understand the impact of the reform on Iranian households, we estimate the changes in consumption prices and real incomes of urban and rural households. For this purpose, we are using the detailed data for household final consumption exists in the original IO table. Through the aggregation process, the sectoral data of household consumption are aggregated at the same way to ensure consistency in the analysis.

Fig. 4.5 and Table 4.6 show that by removing all energy subsidies in Iran, consumption prices would increase by 45.7%, representing a strong and highly destructive shock for most Iranian households. The results also reveal that rural families will suffer the burden of inflation more than urban families. For example, we expect consumption prices to increase by 42.8% in urban areas and 55.5% in rural areas. Comparison of the change in consumption prices across the first and the second scenarios reveals that the gradual phasing out of energy subsidies can control and reduce the impact of these potentially devastating shocks on households, especially poor households. Overall, the results from the first scenario show that the first phase of reform will increase consumption prices by 16.4% nationwide. In the second scenario, inflation would hit rural households particularly hard relative to their urban counterparts, i.e. 17.5% vs. 16%.

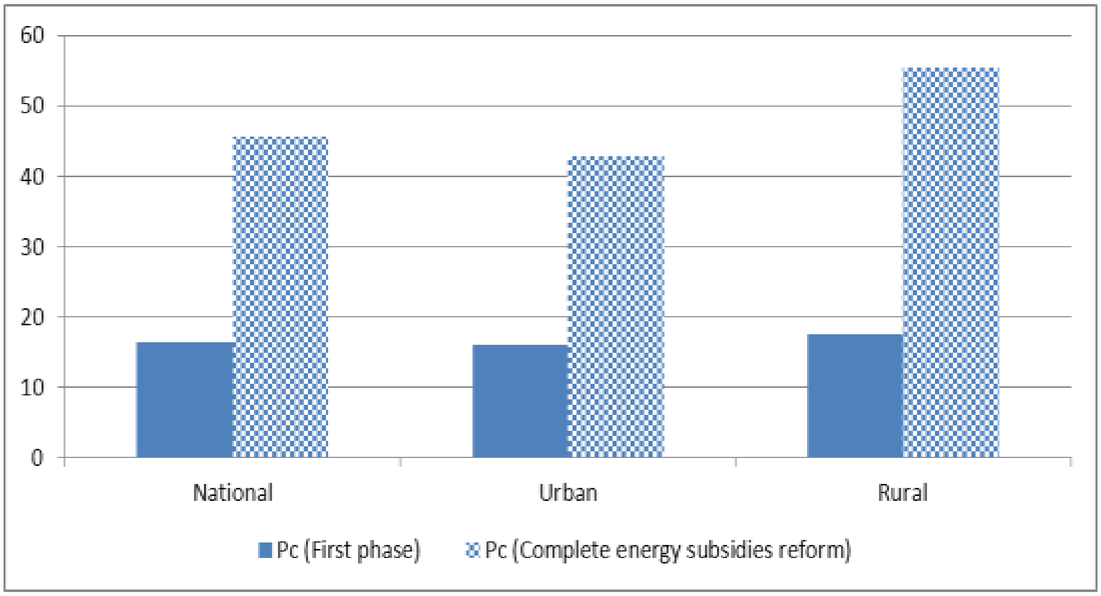


Fig. 4.5. Impact of energy subsidy reform on consumption prices

The loss in household annual real income under the two scenarios would be in the order of more than 238,000 billion IRR (about 21 billion USD) in the first scenario and 664,000 billion IRR in the second scenario (some 60 billion USD). Because of the relatively greater expenditures of urban households, urban households stand to lose between 1.46 and 1.23 more under the reform scenarios than would rural households. Because the Reform Law requires the government to compensate for the increased burden of charges, we calculate the compensatory payments per person in Table 4.6. As shown, if the government were to remove all energy subsidies, it would need to transfer 9.495 million IRR to each person annually, whereas the required amount is close to 3.405 million IRR in the first phase of the reform only. We can see a sizeable difference between what has been already transferred to households and that inferred by our model. At present, the government pays 450,000 IRR to each registered person per month, while the model instead proposes 283,750 IRR. In addition, the model suggests that the payments to urban residents per month should exceed those for rural residents, i.e.

315,000 IRR vs. 215,000 IRR. This lies counter to the currently equal compensatory payment to all Iranians, regardless of income or residence.

Table 4.6

Effects on consumption prices and real incomes

	National	**Urban**	**Rural**
Household consumption price changes: Scenario 1 (%)	16.37	16.04	17.52
Household consumption price changes: Scenario 2 (%)	45.66	42.84	55.47
Change in household annual real income at 2010 prices: Scenario 1 (IRR millions)	–238,333,589	–181,428,899	–56,904,689
Change in household annual real income at 2010 prices: Scenario 2 (IRR millions)	–664,677,472	–484,519,372	–180,158,100
Compensatory payment per person at 2010 prices: Scenario 1 (IRR millions)	3.405	3.780	2.587
Compensatory payment per person at 2010 prices: Scenario 2 (IRR millions)	9.495	10.094	8.189

4.5 Conclusion

The study examined the impact of energy subsidy reform in Iran under two alternate reform scenarios. The first scenario represents in fact what begun as the first phase of reform in December 2010, whereas the second scenario represents the removal of all energy subsidies at once in 2008/09 prices. We employed an input–output price model to consider the impact of the energy pricing reform on consumption and production prices in Iran, along with a decomposition model for deriving the cross-price effects of fuels in the nonenergy sectors.

Our analysis revealed the tremendous inflationary impact of a complete energy subsidy reform on the production and consumption prices. The results showed that full reform would increase consumption prices by 45.7%. Further, although the increase in consumption prices affected rural households more, families in urban areas potentially lose greater real income because of their higher level of expenditure. In the reform procedure, the glass and glass products, transport services, and basic metals and metal products sectors would experience the largest increase in production prices. Consideration of the sector cross-price effects confirms that of all of the fuels, electricity and gasoline have the largest impact on production prices.

We now propose some policy implications. First, a gradual and phased reform process imposes lower inflation on producers and households and provides sufficient room for policy makers to modify any succeeding phases to help alleviate any negative effects. Second, given that the real income losses of households differ according to income and geographic location, the Iranian government should compensate for losses in a discriminatory manner with some households receiving relatively more (less) compensation for the increase in consumption prices. Finally, because the increases in the prices of some fuels, such as electricity and gasoline, have a potentially greater inflationary impact, the pace of the reform for these fuels should be more gradual.

However, it is of course essential to note that we should interpret the results of this analysis with some caution. First, the input–output table used is from 2001. This raises concerns about the rigidity of the economic structure in Iran after a decade. Second, the Leontief price model has some deficiencies because of its relatively restrictive assumptions concerning the lack of substitution between factors and the null role of final demand in the economy price setting. Nevertheless, the general equilibrium nature of the model has a number of advantages over alternative partial equilibrium analyses, and thereby provides a better understanding of the possible negative consequences of energy subsidy reform at both the producer and consumer level.

Chapter 5:

The impact of energy subsidy reform on energy conservation and CO_2 mitigation

5.1 Introduction

Iran is one of the main oil exporting countries, but has recently encountered the problem of large increases in energy consumption and CO_2 emissions. The growth in energy consumption has been so strong that Iran has recently become a net importer of refined oil products. Iran consumed 325 MBOE[1] of energy carriers in 1989, but this increased to more than 1000 MBOE in 2009. On a per capita basis, final energy consumption was 6.10 BOE in 1989, increasing to 14.15 BOE in 2009. The trend is similar for environmental emissions. In total, 602 MT of CO_2 were emitted in 2009, compared with only 191 MT in 1989. Since the 1980s, the main contributors to energy consumption and CO_2 emissions have been the residential, public and commercial sectors and the transportation sector (MoE, 2011).

The growth in energy consumption is a result of various structural and economic changes. In the last two decades, annual gross domestic product (GDP) growth in Iran has average 5% per year (Table 1). Oil revenues have accounted for a significant share of total GDP, meaning that fluctuations in global oil prices are transmitted to the domestic economy. The recent boom in the world oil market has provided significant financial resources to the Iranian government, encouraging it to adopt expansionary fiscal and monetary policies. This explains why GDP and the oil revenues are procyclical. Thanks to abundant oil and gas reserves, income per capita has increased considerably in recent decades. While the average income in Iran was more than 6000 USD (PPP) at the beginning of the 1990s, it almost doubled in the following two decades (World Bank, 2012). As energy products are normal goods, the increase in real income can explain the increase in energy consumption in Iran.

[1] Million barrels oil equivalent.

The energy and CO_2 intensities reveal other facts. Table 1 shows that whereas 1.08 BOE of energy carriers were consumed to produce 1000 USD of value additions (PPP) in 1989, energy intensity increased to 1.36 BOE/1000 USD in 2009, indicating 25% growth in two decades. Furthermore, CO_2 emission intensity increased from 0.64 tons/1000 USD in 1989 to 0.79 tons/1000 USD in 2009. Different studies have attempted to identify the determinants of the higher energy and CO_2 intensities in Iran. Using an index decomposition analysis (IDA), Sharifi et al. (2008) showed that structural changes have had little effect in reducing the energy intensity of the manufacturing industries in Iran. Behboudi et al. (2010) attempted to identify the key factors affecting energy intensity in Iran by applying an IDA over the period 1968–2006. Their results indicated that increasing energy intensity was the result of a reduction of productivity and changes in the structure of economic activity. In addition, they found that energy prices play a critical role in determining energy intensity in Iran. The results of the study of Fotros and Barati (2011) indicated that the structure of economic activity has had the largest positive effect on CO_2 emissions, with the exception of the industrial and transportation sectors. For these two sectors, structural changes have been the main driver of CO_2 emissions. Sadeghi and Sojoodi (2011) studied the determinants of energy intensity in Iranian manufacturing firms and found that a firm's size, ownership type, capital intensity and the wage level have significant impacts on energy intensity.

The energy pricing system is the other determinant of ever-increasing energy consumption in Iran. Domestic energy prices have historically been set administratively in Iran at significantly lower levels than international or regional prices. Unsurprisingly, the government has filled the energy price gaps by paying enormous implicit subsidies. IEA (2010) reported that total energy subsidies exceeded 66 billion USD in Iran in 2009, the highest of any country in the world. In other words, each Iranian received an annual energy subsidy of 895 USD, equal to 20% of GDP.

Table 5.1

Gross domestic product and energy consumption in Iran (1989–2009)

Year	Real GDP, PPP (billion USD)	Real GDP per capita, PPP	GDP growth (%)	Energy consumption (MBOE)									Energy intensity (BOE/1000 USD, PPP)	CO_2 intensity (tons/1000 USD, PPP)
				Residence, public, commerce	(%)	Industry	(%)	Transportation	(%)	Agriculture	(%)	Total		
1989	299.27	5600.36	6.18	140.72	43.39	63.26	19.51	90.77	27.99	29.54	9.11	324.29	1.08	0.64
1990	340.23	6200.67	13.69	141.63	41.81	66.95	19.76	98.32	29.02	31.89	9.41	338.78	1.00	0.62
1991	383.08	6832.07	12.59	158.56	42.41	72.95	19.51	109.28	29.23	33.11	8.86	373.90	0.98	0.60
1992	399.37	6998.18	4.25	189.99	45.87	77.34	18.68	117.14	28.29	29.68	7.17	414.15	1.04	0.57
1993	393.08	6784.15	–1.58	205.90	45.85	83.37	18.57	131.35	29.25	28.40	6.32	449.02	1.14	0.60
1994	391.70	6660.56	–0.35	218.36	45.29	89.87	18.64	138.55	28.74	35.34	7.33	482.11	1.23	0.68
1995	402.09	6728.73	2.65	220.70	44.72	104.67	21.21	136.97	27.76	31.15	6.31	493.48	1.23	0.68
1996	430.64	7081.08	7.10	231.47	44.13	114.28	21.79	147.93	28.21	30.79	5.87	524.46	1.22	0.64
1997	445.22	7186.05	3.38	242.12	43.92	126.23	22.90	153.22	27.80	29.67	5.38	551.24	1.24	0.61
1998	457.42	7245.31	2.74	241.10	43.52	118.54	21.40	161.20	29.10	33.14	5.98	553.98	1.21	0.68
1999	466.26	7253.83	1.93	252.48	43.24	131.01	22.43	170.20	29.15	30.27	5.18	583.95	1.25	0.82
2000	490.24	7502.72	5.14	272.11	43.87	134.02	21.61	183.37	29.56	30.77	4.96	620.27	1.27	0.76
2001	508.24	7664.12	3.67	278.29	43.64	134.97	21.16	194.13	30.44	30.37	4.76	637.75	1.25	0.78
2002	546.43	8129.88	7.52	306.17	44.69	140.49	20.51	209.01	30.51	29.36	4.29	685.03	1.25	0.74
2003	585.31	8599.68	7.11	316.67	43.78	154.31	21.33	220.82	30.53	31.59	4.37	723.39	1.24	0.72
2004	615.07	8927.81	5.08	345.01	44.44	165.20	21.28	234.03	30.14	32.17	4.14	776.41	1.26	0.73
2005	643.50	9228.24	4.62	371.72	44.25	181.33	21.58	253.31	30.15	33.73	4.02	840.09	1.31	0.76
2006	681.43	9654.45	5.89	413.16	45.17	194.34	21.25	270.41	29.56	36.82	4.03	914.74	1.34	0.74
2007	734.75	10285.53	7.82	436.55	44.57	236.05	24.10	269.21	27.49	37.60	3.84	979.41	1.33	0.73
2008	751.65	10397.82	2.30	417.45	42.01	252.74	25.44	281.58	28.34	41.87	4.21	993.64	1.32	0.77
2009	765.18	10462.27	1.80	431.90	41.43	258.05	24.75	309.20	29.66	43.35	4.16	1042.50	1.36	0.79

Source: WDI (2012) and MoE (2011)

To stop the growth in energy consumption, the Iranian parliament approved the Reform Act on January 5, 2010. The Reform Act included the replacement of product subsidies with targeted transfers to the population, with some assistance to Iranian companies and the government. The Reform Act stipulated that households would receive at least 50% of the increase in revenues derived from the reform. Initially, the payment of benefits was to be in cash, while in a second phase, some of the additional revenues would support higher social benefits and public goods. Thirty percent of the additional revenues were to be used to assist Iranian companies to restructure and adjust to the new, dramatically higher, energy costs. The remaining 20% of additional revenues went to the government to cover the government's own higher energy bill. On December 19, 2010, Iran increased domestic energy and agricultural prices by up to twentyfold, making it the first major oil-exporting country to reduce substantially its system of implicit energy subsidies. In the next phase, prices would increase progressively until all subsidies were removed (Guillaume et al., 2011).

This chapter investigates the fuel-conservation effects of energy subsidy reform in Iran. To study the conservation effects, a translog cost function is estimated and the own- and cross-price elasticities of fuel demands are derived. Using assumptions about the effect of the reforms on fuel prices, the reduction in fuel demands is estimated.

Using translog cost or production function models, different studies have been carried out to estimate the elasticity of energy demand (as a factor of production) or the elasticities of different fuels (as constituents of the energy market) in developed and developing countries. The objective of these studies was to understand the sensitivity of consumers to fuel prices at sectoral, national, and international levels. For instance, some of the studies carried out at the sectoral level are Bölük and Koç (2010) for Turkey; Welsch and Ochsen (2005) for West Germany; Al-Mutairi and Burney (2002) for Kuwait; Christopoulos and Tsionas (2002) for Greece; and Berndt and Wood (1975), Humphrey and Moroney (1975), Lakshmanan et al. (1984), Debertin et al. (1990), Stratopoulos et al. (2000), and Urga and Walters (2003) for the United States. The national level studies are Vega-Cervera and Medina (2000) for Portugal and Spain; Ma et al. (2009) for China; Cho et al. (2004) for South Korea; Perkins (1994) for

Japan; and Magnus (1979) for the Netherlands. Some of the studies carried out at the regional or international level are Pindyck (1979), Renou-Maissant (1999), Söderholm (2001), and Roy et al. (2006).

5.2 A translog cost model

To measure the own- and cross-price elasticities of fuels, we employ the two-stage estimation of a translog cost model, suggested by Pindyck (1979). This approach is based on neoclassical theory and assumes that factor and fuel inputs are chosen to minimize the total cost of production (Renou-Maissant, 1999). We assume that aggregate production is weakly separable in the major components of capital, labor, energy, and materials. Furthermore, we assume that each of the above factors is homothetic in their components, such that we can specify a homothetic translog fuel cost-share equation. Under these assumptions, the aggregate production function is given by:

$$Y = F(K, L, E(OI, NG, EL); M), \qquad (5.1)$$

where Y is gross domestic product, and K, L, E, and M represent the quantities of capital, labor, energy, and materials. Function E is a homothetic aggregate energy input function of three fuels, i.e., oil (OI), natural gas (NG), and electricity (EL). If the factor prices and output level are exogenously determined, the above production function can be described by a cost function that is weakly separable:

$$C = C\left[P_K, P_L, P_E(P_{OI}, P_{NG}, P_{EL}), P_M; Y\right], \qquad (5.2)$$

where P_i are the prices of factors and fuels. The translog functional form can be considered as a second-order approximation to the above arbitrary twice-differentiable cost function (Christensen et al., 1973):

$$\ln C = \alpha_0 + \alpha_Y \ln Y + \sum \alpha_i \ln P_i + \frac{1}{2}\beta_{YY}(\ln Y)^2 + \frac{1}{2}\sum\sum \beta_{ij} \ln P_i \ln P_j + \sum \beta_{Yi} \ln Y \ln P_i \text{ , } \quad (5.3)$$

where i,j = K, L, E, and M. In Eq. (5.3), $\beta_{YY} = 0$ because of the assumption of homogeneity of degree one in price, $\sum \alpha_i = 1$ and $\sum \beta_{ij} = \sum \beta_{ji}$ because of the adding-up criteria, $\beta_{ij} = \beta_{ji}$ because of the Slutsky symmetry restriction, and $\sum \beta_{Yi} = 0$ because of the assumption of homotheticity in the production function (Cho et al., 2004). Using Shephard's lemma, the conditional factor demands can be obtained by differentiating Eq. (5.3) with respect to input prices:

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{\partial C}{\partial P_i}.\frac{P_i}{C} = \frac{P_i X_i}{C} = S_i^{factor} = \alpha_i + \beta_{Yi} \ln Y + \sum \beta_{ij} \ln P_j \quad (5.4)$$

The homothetic translog aggregate energy-price index (P_E) function is given by:

$$\ln P_E = \alpha_0 + \sum \alpha_i \ln P_i + \frac{1}{2}\sum\sum \beta_{ij} \ln P_i \ln P_j \text{ , } \quad (5.5)$$

where P_E is the aggregated energy price and P_i or P_j denote the prices of oil, natural gas and electricity. By differentiating Eq. (5.5) with respect to individual fuel prices, the fuel cost-share equations are derived as follows:

$$S_i^{fuel} = \alpha_i + \sum \beta_{ij} \ln P_j \qquad i = EL, NG, OI \quad (5.6)$$

It is clear that in the two-stage estimation approach, we must estimate the system of homothetic translog fuel cost-share functions first to compute the fitted aggregated energy price $(\hat{P}_E)$. Through the estimation of Eq. (5.6), the partial own- and cross-price elasticities of the fuels can be derived. In the second stage, by knowing the price indices of all factors, we can estimate the nonhomothetic translog factor cost-share equations (Eq. (5.4)). The Allen partial elasticities (σ_{ii} and σ_{ij}), and own-price and cross-price partial elasticities of fuel demands (η_{ii} and η_{ij}) are given by (Allen, 1938):

$$\sigma_{ii} = \frac{\beta_{ii} + S_i(S_i - 1)}{S_i^2} \text{ and } \sigma_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i S_j} \quad \forall i \neq j, \tag{5.7}$$

$$\eta_{ii} = \sigma_{ii} S_i \text{ and } \eta_{ij} = \sigma_{ij} S_j \quad \forall i \neq j, \tag{5.8}$$

where i and j are oil, natural gas, and electricity and S_i and S_j are the cost shares of fuels. To control for technological progress and structural change in the postwar era, two other fuel cost-share models are specified. The first is a static model with a time trend (Eq. (5.9)) and the other is the first-difference model (Eq. (5.10)). The time trend captures not only the technological progress in the economy, but also the effects of the economic reconstruction and boom that occurred after the Iran–Iraq war in 1988. While the first-difference variables reflect the changes in variables, the first-difference model can show the short-term impacts (where the economic and structural variables are relatively more stable).

$$S_i^{fuel} = \alpha_i + \sum \beta_{ij} \ln P_j + \gamma_{it} t \tag{5.9}$$

$$\Delta S_i^{fuel} = \alpha_i + \sum \beta_{ij} \Delta \ln P_j \tag{5.10}$$

5.3 Estimation results

To estimate the fuel cost-share equations, we employed annual data over the period 1989–2009. The period was shortened because of the Iran–Iraq war (the First Persian Gulf War) from September 1980 to August 1988. In this period, the Iranian economy experienced substantial damage, instability and structural breaks. To avoid estimation bias, we only measure the substitution elasticities in the postwar era. The nominal prices and final consumption of electricity, natural gas, and oil products were collected from the Energy Balance of Iran 2010 (MoE, 2011). The CPI is derived from the database of the Central Bank of Iran (CBI, 2012). The price index of oil is the weighted sum of the prices of the oil products.

5.3.1 The fuel model

Employing the seemingly unrelated regression (SUR) method, introduced by Zellner (1962), we estimate the system equations of the translog fuel cost-share function. Table 5.2 reports the estimation results of the static model without a time trend (Eq. (5.6)), the static model with a time trend (Eq. (5.9)), and the first-difference model (Eq. (5.10)). As Table 5.2 shows, all the coefficients except $\beta_{NG.OI}$ in the first model are highly significant.

Table 5.2

Parameter estimation of the translog fuel cost-share equations

Coefficient	Static model without time trend (Model 1)	Static model with time trend (Model 2)	First difference (Model 3)
α_{EL}	–0.053 (0.023)	–12.206 (0.621)	0.006 (0.002)
α_{NG}	0.317 (0.025)	–8.136 (0.404)	0.004 (0.001)
α_{OI}	0.736 (0.024)	21.342 (0.764)	0.990 (0.002)
$\beta_{EL.EL}$	0.208 (0.013)	0.235 (0.007)	0.247 (0.009)
$\beta_{EL.NG}$	–0.076 (0.011)	–0.048 (0.006)	–0.048 (0.007)
$\beta_{EL.OI}$	–0.133 (0.020)	–0.188 (0.005)	–0.200 (0.007)
$\beta_{NG.NG}$	0.085 (0.010)	0.091 (0.008)	0.076 (0.008)
$\beta_{NG.OI}$	–0.010 (0.014)	–0.043 (0.004)	–0.028 (0.005)
$\beta_{OI.OI}$	0.143 (0.028)	0.231 (0.010)	0.228 (0.012)

Note: Numbers in parentheses are the standard errors.

Table 3 represents the estimated Allen and price partial elasticities. As is obvious, the estimated elasticities in the static model without a time trend are significant at 10%. However, adding the time trend to Eq. (5.9) makes the Allen- and own-price elasticities of electricity ($\sigma_{EL.EL}$ and $\eta_{EL.EL}$) insignificant. In the last model, four out of 15 elasticities are insignificant, which are the Allen- and own-price elasticities of electricity and natural gas ($\sigma_{EL.EL}$, $\sigma_{NG.NG}$, $\eta_{EL.EL}$ and $\eta_{NG.NG}$). Among the significant own-price elasticities, the elasticities of electricity and oil are negative, whereas the elasticity of natural gas is positive. The results reveal that if the real price of electricity increases twofold, the demand for it reduces by 8.4%. The same increase in the oil price results in a 3.8% to 21.3% reduction in its demand. The story for natural gas is the opposite. If the reform raises the real price of natural gas by 100%, its demand increases by 25.3% to 33.1%. This finding is in contrast to the findings of some developing countries. For instance, Cho et al. (2004) and Ma et al. (2009) found that the own-price elasticities of all fuels are negative in Korea and China, respectively. Increasing the accessibility of users to natural gas through 189,484 km of pipelines, and relative cheapness, reliability of supply, and comfort in consumption, have been the main drivers of increasing natural gas consumption over the period of study. However, the subperiod analysis in the next section will show that the sensitivity of consumers to natural gas prices has changed. Overall, the above results show that fuel demands are inelastic with respect to their own prices.

The Allen- and cross-price elasticities suggest that electricity and natural gas were complementary and electricity and oil were substitutable over the period of study. The substitutability between oil and electricity is confirmed for most developed and developing countries (Pindyck, 1979; Cho et al., 2004; Ma et al., 2009). However, several studies carried out at the national level indicate long-run substitutability between gas (LPG and LNG) and electricity in developed countries (Renou-Maissant, 1999). For natural gas and oil, Models 1 and 3 confirm the substitutability of the fuels, while the second model suggests they are complementary. Some studies find substitutability between oil and gas (Perkins, 1994). Comparison of the cross-price elasticities reveals some interesting points. Although electricity and natural gas are complementary, the sensitivity of natural gas demand to the price of electricity is significantly higher than the sensitivity of electricity demand to the price of natural gas (e.g., –0.620 vs –0.106 in Model 1). In addition, the sensitivity of oil demand to the electricity price is almost the same as the sensitivity of electricity demand to the oil price.

Table 5.3

The Allen and price partial elasticities of fuels

Elasticity	Static model without time trend (Model 1)	Static model with time trend (Model 2)	First difference (Model 3)
$\sigma_{EL.EL}$	–0.199 (0.072)	–0.050 (0.037)	0.018 (0.048)
$\sigma_{EL.NG}$	–1.464 (0.344)	–0.554 (0.210)	–0.558 (0.238)
$\sigma_{EL.OI}$	0.378 (0.092)	0.122 (0.024)	0.065 (0.031)
$\sigma_{NG.NG}$	3.500 (1.988)	4.572 (1.559)	1.699 (1.547)
$\sigma_{NG.OI}$	0.728 (0.386)	–0.190 (0.107)	0.225 (0.130)
$\sigma_{OI.OI}$	–0.422 (0.111)	–0.075 (0.041)	–0.087 (0.048)
$\eta_{EL.EL}$	–0.084 (0.031)	–0.021 (0.016)	0.008 (0.020)
$\eta_{EL.NG}$	–0.106 (0.025)	–0.040 (0.015)	–0.040 (0.017)
$\eta_{EL.OI}$	0.190 (0.046)	0.061 (0.012)	0.033 (0.016)
$\eta_{NG.EL}$	–0.620 (0.146)	–0.235 (0.089)	–0.237 (0.101)
$\eta_{NG.NG}$	0.253 (0.144)	0.331 (0.113)	0.123 (0.112)
$\eta_{NG.OI}$	0.367 (0.195)	–0.096 (0.054)	0.114 (0.066)
$\eta_{OI.EL}$	0.160 (0.039)	0.052 (0.010)	0.028 (0.013)
$\eta_{OI.NG}$	0.053 (0.028)	–0.014 (0.008)	0.016 (0.009)
$\eta_{OI.OI}$	–0.213 (0.056)	–0.038 (0.021)	–0.044 (0.024)

Note: Numbers in parentheses are the standard errors. Elasticities are computed using the mean of each share.

5.3.2 The subperiod analysis

The subperiod analysis provides a clearer image about the behavior of energy consumers. Figure 5.1 depicts the trend in the own-price elasticities of natural gas, electricity, and oil derived from Model 1. The same trends for the other models are illustrated in Appendix 5.1. As the figure shows, the own-price elasticities of oil and electricity were extremely stable over the period of study. For almost the whole period, the elasticities were negative and close to zero. In other words, the demand for oil and electricity were inelastic with respect to their prices in the last two decades. The demand for natural gas shows a different picture. The own-price elasticity of natural gas was positive until 2007 and then completely elastic in the years following the end of war. However, the elasticity reduced over time with some fluctuations and finally became negative in the last years of our study. That is, the sensitivity of consumers to the price of natural gas has increased gradually.

As the target of this study is the assessment of the conservation effects of energy subsidy reform in Iran, the elasticities of fuels should be determined cautiously. Therefore, in addition to the average elasticities in Table 5.3, we calculate the averages of recent elasticities reflecting the shift in Iranian consumer behavior. Table 5.4 represents the average elasticities for the period 2007–2009.

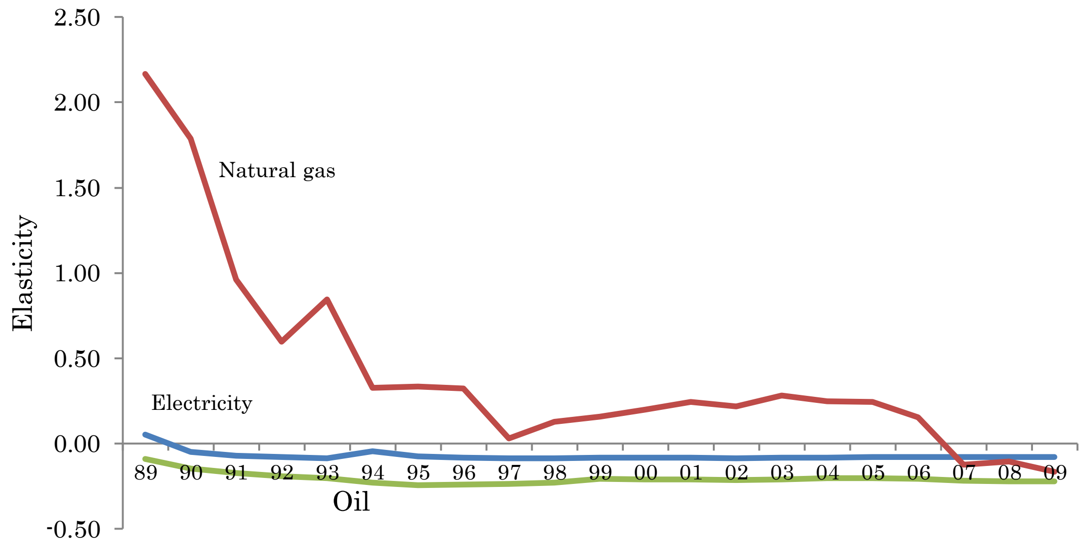


Fig. 5.1. Trend in own-price point elasticities of fuels in Eq. (5.6)

Table 5.4

Average price elasticities for the period 2007–2009

Elasticity	Static model without time trend (Model 1)	Static model with time trend (Model 2)	First difference (Model 3)
$\eta_{EL.EL}$	–0.078	–0.011	0.020
$\eta_{EL.NG}$	–0.077	–0.007	–0.007
$\eta_{EL.OI}$	0.155	0.018	–0.013
$\eta_{NG.EL}$	–0.270	–0.023	–0.024
$\eta_{NG.NG}$	–0.132	–0.082	–0.215
$\eta_{NG.OI}$	0.401	0.105	0.239
$\eta_{OI.EL}$	0.126	0.014	–0.010
$\eta_{OI.NG}$	0.093	0.024	0.055
$\eta_{OI.OI}$	–0.219	–0.039	–0.045

The temporal change in the price elasticities of fuels reflects the temporal changes in their substitutability and complementarity. Figure 5.2 illustrates the trend in Allen-point elasticities of fuels over the period of study. The results for the other models are in Appendix 5.2. The figure reveals the stable pattern of substitutability between natural gas and oil, and electricity and oil. Although natural gas and electricity were complementary over the whole period, their

Allen partial elasticities reduced gradually. Given the reducing degree of complementarity between natural gas and electricity, we can estimate that if this trend continues, these two fuels will become substitutable in coming years.

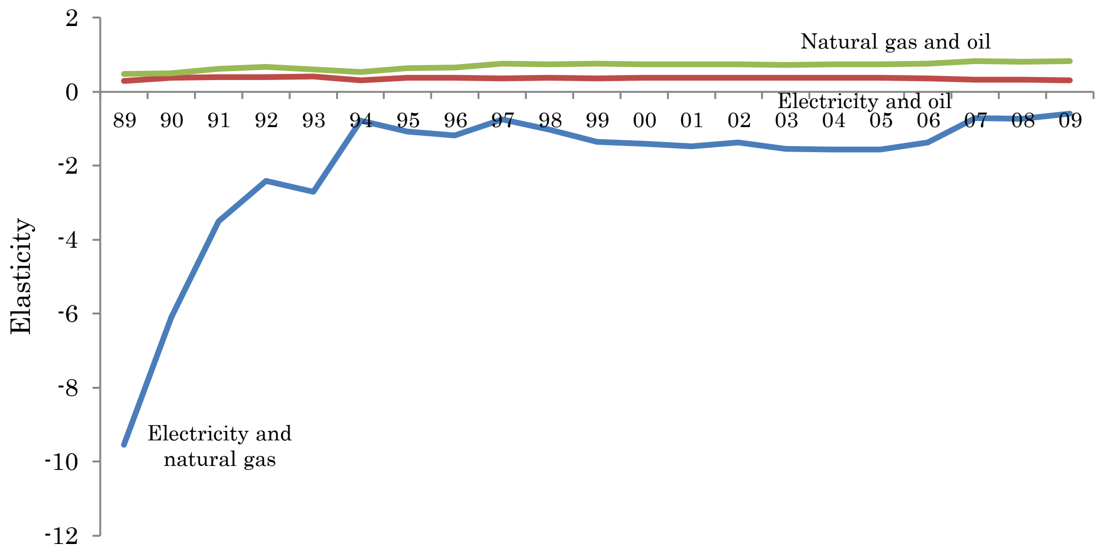


Fig. 5.2. Trend in Allen-point elasticities of fuels in Eq. (5.6)

5.4 Fuel conservation effects of the reform

As mentioned above, Iran started to remove fuel subsidies in successive phases in 2010. Article 1 of the Subsidy Reform Law requires that the domestic sale prices of energy carriers should adjust gradually until the end of the Fifth Five-Year Development Plan (2010–2015) to a level not less than 90% of Persian Gulf FOB[1] prices. However, it is not clear when and in how many steps the next phases of reform will proceed.

Table 5.5 provides information on domestic and regional retail energy prices before and after the reform. Clearly, the gap between domestic and regional prices in Iran has been considerable in recent years. Before implementation of the reform, the ratios of international

[1] Freight on board (FOB).

prices to domestic prices for electricity, natural gas, gasoline, kerosene, gas oil, fuel oil, and LPG were 4.68, 22.96, 5.36, 38.7, 37.81, 41.49, and 11.49, respectively. In the first phase of the reform, from December 2010, the government increased the domestic retail prices of these same fuels by 173%, 570%, 300%, 506%, 809%, 2016%, and 426%, respectively.

Table 5.5

Domestic and regional retail energy prices before and after the reform (IRR)

	Domestic energy prices in 2009/10 – before reform	Average regional market prices in 2009/10	Increase in nominal prices (%)	Domestic energy prices in 2010 – after reform	Increase in nominal prices (%)
Electricity	165	773[a]	368	450	173
Natural gas	104.5	2400[b]	2197	700	570
Gasoline	1000	5362[c]	436	4000	300
Kerosene	165	6392[c]	3774	1000	506
Gas oil	165	6239[c]	3681	1500	809
Fuel oil	94.5	3921[c]	4049	2000	2016
LPG	309.1	3605[c]	1066	1625	426

[a] Export price (IRR/kWh), [b] Export price (IRR/m^3), [c] FOB price of refined petroleum products in the Persian Gulf (IRR/liter)
Source: MoE (2011) and MoP (2009). Note: 1 USD = 9,917 IRR in 2009/2010.

Using the estimated own- and cross-price elasticities of fuels, we can estimate the reduction in energy demand in the next step. As explained above, the elasticities measure the percentage change in fuel demand following a 1% increase in the real price of the same fuel or of other fuels. Table 5.5 shows the percentage changes in fuel prices after implementation of the energy subsidy reform in Iran. To measure the impact of the reform on energy conservation correctly, we need to know the inflationary impact of the reform. The following example highlights the necessity of knowing the increase in the general price level of goods and services. If increasing the price vector of fuels by 10% increases the aggregate price index by the same amount, the real prices of fuels do not change and consequently the demand pattern of consumers remains unchanged.

Several studies have estimated the inflationary effects of the energy subsidy reform in Iran. For instance, using a social accounting matrix price model, Perme (2005) concluded that removing the subsidies on refined petroleum products, natural gas, and electricity would increase their respective average national price indexes by 19.52%, 11.07%, and 4.83%, respectively. Moreover, if the removal of all energy subsidies took place simultaneously, the price index would increase by 35.4%. Khiabani (2008) employed a standard CGE model and found that if domestic fuel prices increased to their international level, the inflation rate would increase by 35%. Shahmoradi et al. (2010) found that increasing inland fuel prices to their international level would increase consumer and producer price indices by 108% and 118%, respectively, while prices for freight and passenger rail transportation would experience an extraordinary 263% increase in service prices. Heydari and Perme (2010) provided evidence that removing fuel and bread subsidies would potentially increase the related expenditures by urban and rural households by at least 33% and 40%, respectively. Applying a CGE model and using a microconsistent matrix, Manzoor et al. (2010) examined the effects of implicit and explicit energy subsidy phaseout in Iran. They concluded that the policy would increase the inflation rate by between 57.9% and 69.07%. Finally, using an updated input–output price model, Hosseini and Kaneko (2012) found that the first phase of reform would increase consumption prices by 18.86% nationwide. They showed that the inflationary impact of overall subsidy removal is about 54.10%. In this study, we use the estimated CPIs in the authors‘ previous study (Hosseini and Kaneko, 2012) to calculate the real prices after the reform.

Using the estimated own- and cross-price elasticities of electricity, natural gas, and oil illustrated in Tables 5.3 and 5.4, and considering the percentage changes in real fuel prices in the first phase and overall energy subsidy reform period, we calculate the percentage changes in fuel demands in Iran. To avoid any bias in the calculations, we replace the significant elasticities of electricity and natural gas with the insignificant ones in the second and third models. Table 5.6 shows the percentage changes in fuel demands after the implementation of the reforms. Table 5.6 is divided into four parts. Parts I and II show the percentage changes in the first phase and overall reform period using the averaged elasticities over the period 1989–2009. Parts III and IV show the changes using the averaged elasticities over the period 2007–2009.

Table 5.6

Changes in fuel demands of Iranian consumers in the first phase and overall reform period (%)

	1989–2009					
	First phase			Complete reform		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Electricity	+15.430	–5.164	–16.645	–12.883	–24.053	–47.249
Natural gas	+182.579	+84.903	+131.787	+517.784	+335.536	+394.238
Oil	–39.168	–14.707	–6.266	–63.476	–38.751	–6.648
	2007–2009					
Electricity	+15.770	–6.153	–18.376	+0.887	–11.004	–35.699
Natural gas	+63.173	+0.699	+30.686	+81.595	–34.971	+2.575
Oil	–27.443	–2.229	+6.472	–19.592	+5.894	+38.986

In all parts, Model 1 shows larger changes because of the higher elasticities. In addition, the direction of changes is similar in Models 2 and 3. In Part I and Model 1, implementing the first phase would increase the demand for electricity and natural gas by 15% and 182%, respectively. It also reduces the demand for oil by 39%. In contrast, Model 2 shows that the first phase results in 5% and 15% reductions in electricity and oil demands, respectively, and an 84% increase in the demand for natural gas. Model 3 estimates a larger reduction in the demand for electricity than for oil (17% vs 6%). Adjusting the elasticities, Part 3 shows a smaller increase in the demand for natural gas. In Model 1, the demand for electricity and natural gas increases by 16% and 63%, respectively. The only conservation effect of the reform is a 27.5% reduction in oil demand. Model 2 shows minor changes in demands after controlling for any dynamic effects using a time trend. Decreases in the demand for electricity and for oil of 6% and 2%, respectively, is the only outcome of applying the fuel price changes in the first phase. Finally, Model 3 shows increases in the demand for oil and natural gas of about 6.5% and 37%, respectively, whereas the demand for electricity decreases by 18%.

Different models show contradictory results about the conservation effects of full subsidy reform in Iran. Model 1 in Part II demonstrates that the reform reduces the demand for electricity and for oil by 13% and 63.5%, respectively. However, it increases natural gas demand by about six times. Reductions of 24% and 39% in the demand for electricity and for oil, respectively, are the outcome of Model 2. On the contrary, it increases the demand for natural gas by 335%. Model 3 provides similar results, with estimates of the increase in the demand for natural gas of 394% and decreases in electricity and oil demand of 47% and 7%, respectively. If we consider the recent behavioral sensitivity of consumers in Part IV, we obtain more optimistic results. In Model 1, the full reform has no significant impact on electricity demand. In contrast, it raises the demand for natural gas by 82% and reduces the demand for oil by 20%. Model 2 provides the most optimistic results among all models. Based on the results of Model 2, the full reform reduces the demand for electricity and natural gas by 11% and 35%, respectively. In contrast, it increases the demand for oil by 6%. In Model 3, the demand for electricity falls by 36%. However, it increases the demand for natural gas and for oil by 3% and 39%, respectively.

To evaluate the results, it should be noted that electricity, natural gas, and oil account for 8.73%, 44.82%, and 46.45% of the 1160 MBOE of energy consumption in 2009, respectively. Therefore, further reductions in natural gas and oil demand would be desirable for the reform‘s designers. From a methodological point of view, the elasticities for the period 2007–2009 better reflect the actual behavior of consumers, thus providing estimates that are more accurate. Consequently, the results in Parts III and IV are superior to the results in Parts I and II. The most optimistic results in Part III are from Model 2, which estimates 6% and 2% reductions in electricity and oil demand, respectively, and a marginal increase in natural gas demand after implementation of the first phase of reform. These results show a marginal impact of the first phase on energy consumption in Iran. However, if we consider the results of Models 1 and 3, we can conclude that the reform never reduces total energy demand, but rather will increase it. The same as for Part III, Model 2 provides the most hopeful results for the overall reform scenario. It diminishes the demand for electricity and for natural gas by 11% and 35%, respectively, but increases the demand for oil by 6%. However, the results of the two other models are disappointing. They show that the full liberalization of energy prices either has no significant effects (Model 3) or it increases total energy demand (Model 1). In general, the results reveal that the reform may not be as successful as imagined previously. Under an optimistic view, it conserves energy marginally. Under a pessimistic view, it may increase energy demand because of inelastic demands and substantial substitution between fuels.

To make an image about the amount of changes in energy consumption and CO_2 emissions, we applied the above elasticities to the level of energy consumption in 2009. The results are shown in Table 5.7. Based on the price elasticities over the period 2007-2009, implementing the first phase of energy subsidy reform in Iran may reduce energy consumption about 15 MBOE under the optimistic view and increase it about 197 MBOE under pessimistic view. The same amounts for the complete reform are 161 MBOE (reduction) and 319 MBOE (increase), respectively.

If we apply the emission factors to the changes in energy consumption, we can get the amount of direct changes in energy-related CO_2 emissions in Iran. It should be noted that nationally 538 MT CO_2 emitted in 2009. As it is obvious, the first phase may decline CO_2 emissions by 11 MT or increase it by 69 MT. On the other hand, the full reform may reduce it by 61 MT or increase it by 100 MT, respectively.

Table 5.7

Estimated changes in energy consumption and direct CO_2 emissions in 2009

	First phase			Complete reform		
Energy (MBOE)	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
1989–2009	+753.53	+356.80	+634.28	+2335.97	+1510.69	+1965.15
2007–2009	+196.48	–14.60	+175.72	+319.43	–161.14	+187.18
CO_2 (MT)	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
1989–2009	+250.78	+109.56	+195.80	+747.29	+470.75	+615.06
2007–2009	+68.98	–10.96	+45.58	+100.38	–61.11	+46.76

5.5 Conclusion

In this chapter, the fuel conservation effects of energy subsidy reform in Iran were studied. To measure the impact of the first phase and overall reform on energy demand in Iran, a translog cost function of the energy market was estimated and the own- and cross-price elasticities of electricity, natural gas, and oil were derived. The results of this study can be summarized in the following points.

First, the own-price elasticities of electricity and oil are negative and the own-price elasticity of natural gas is positive over the period of study. Second, electricity and natural gas are complements and electricity and oil are substitutes over the period of study. In addition, most of the models find substitutability between natural gas and oil. Third, the own-price elasticities of oil and electricity are highly stable and close to zero over the period of study. However, the positive elasticity of natural gas declines over time and becomes negative in the last years of our study.

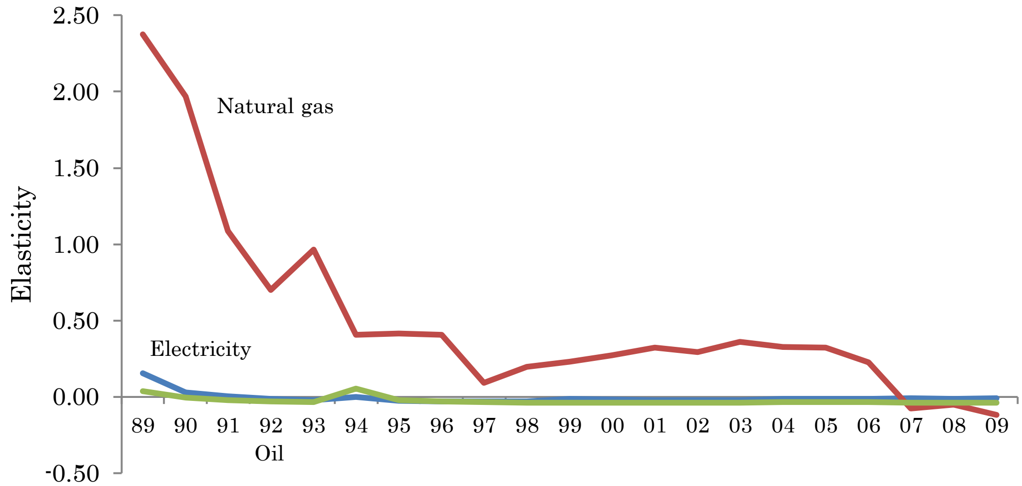
Finally, we found that the reform might not hit its targets. Under an optimistic view, the reform may conserve energy marginally, and under a pessimistic view, it may increase energy consumption because of inelastic fuel demands and substantial substitution between them. As a policy implication, the above results suggest that other conservation strategies, such as training, technological progress and regulation improvement, etc., are alternatives to the price reform policy.

From a social perspective, the unsatisfactory conservation outcome of the reform should be considered alongside the effects of the reform on key economic, social, and environmental variables. If we consider the total impact of the reform, we can evaluate its sustainability in

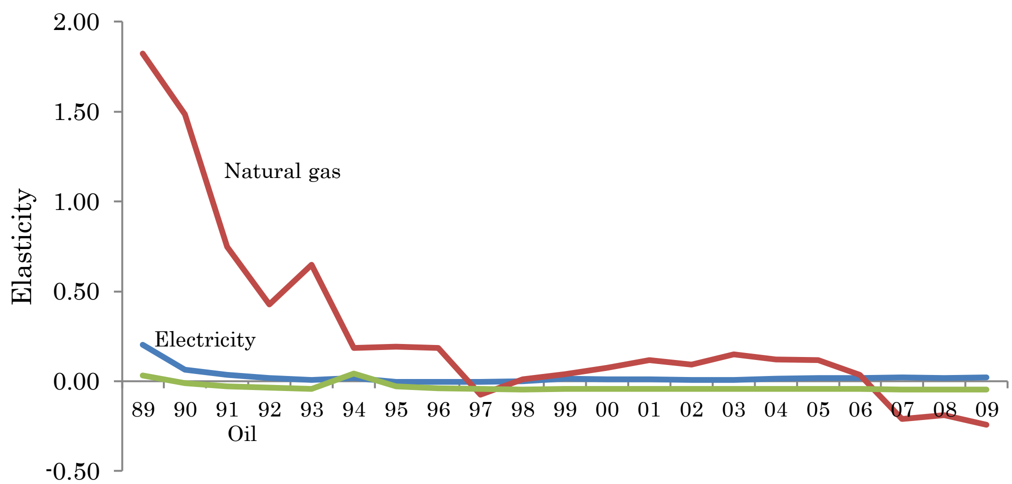
Iran. The question of the sustainability of the reform is one that will be answered in the next chapter. .

Appendix 5.1

Own-price point elasticities of fuels in the static model with trend (A) and first-difference model (B)



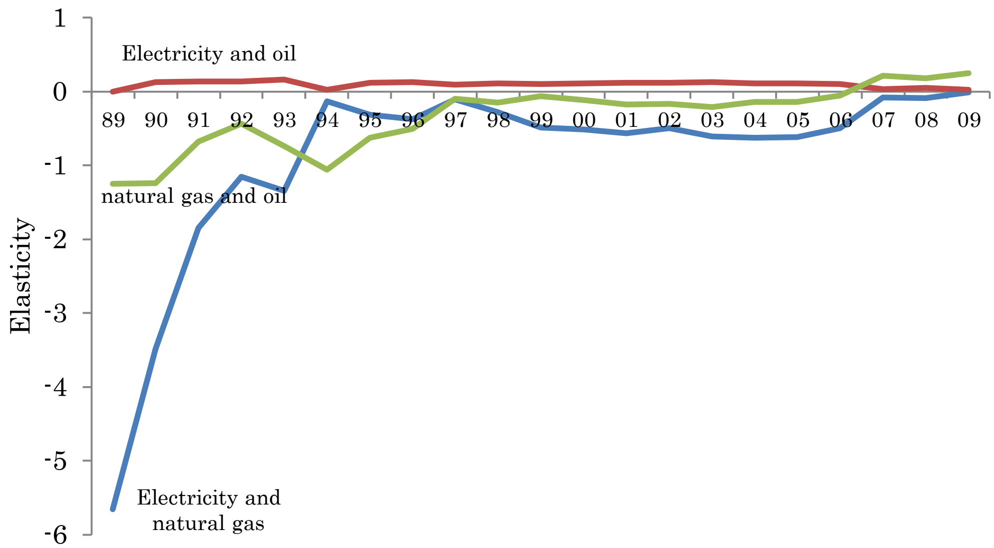
(A) Static model with time trend



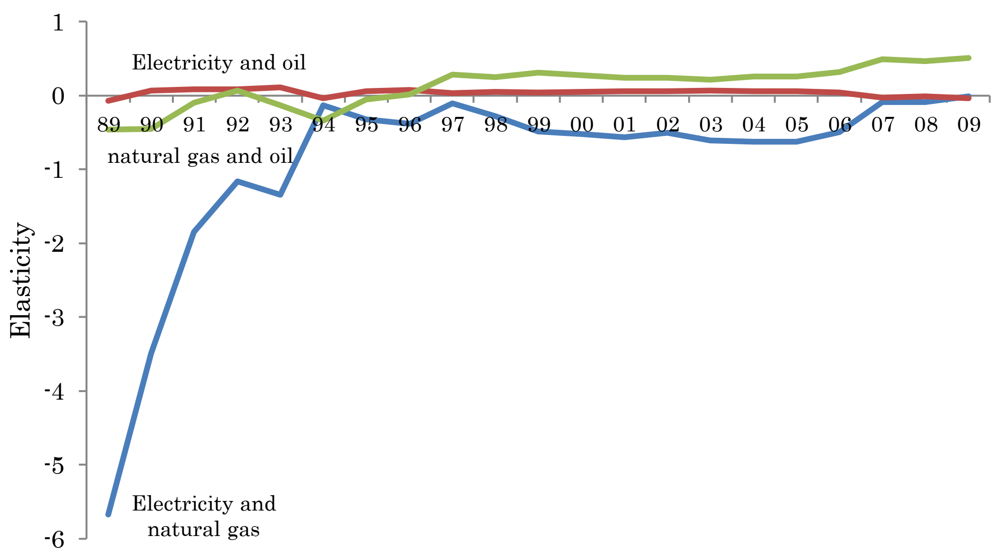
(B) First-difference model

Appendix 5.2

Allen-point elasticities of fuels in the static model with trend (A) and the first-difference model (B)



(A) Static model with time trend



(B) First-difference model

Chapter 6:

The sustainability of the reform: lessons learned and further studies

6.1 Lessons learned

In the previous chapters, the impacts of energy subsidy reform on selected variables in different pillars are studied. In the second chapter, the energy and CO_2 emissions intensities across the nonenergy sectors were quantified in the Iranian economy. Therefore, the sectors that had the potential to experience a significant reduction in energy consumption and CO_2 emissions were identified. The results showed that the sectors with the highest potential to reduce energy consumption and emissions are the road transportation sectors, the sectors which produce basic mineral, metal and chemical products, the construction sectors, the food industry and the agricultural and livestock sectors.

In the third chapter, the impact of energy subsidy reform on producer cost and consumer expenditure is examined. Our analysis revealed the tremendous inflationary impact of a complete energy subsidy reform on the production and consumption prices. The results showed that full reform would increase consumption prices by 45.7%. Further, although the increase in consumption prices affected rural households more, families in urban areas potentially lose greater real income because of their higher level of expenditure. In the reform procedure, the glass and glass products, transport services, and basic metals and metal products sectors would experience the largest increase in production prices. Consideration of the sector cross-price effects confirms that of all of the fuels, electricity and gasoline have the largest impact on production prices.

In chapter four, the impact of reform on energy demand and CO_2 emission is examined. What we found is that the reform may not hit its targets. Under the optimistic view, the reform may conserve energy marginally and under the pessimistic view, it may increase the energy demand due to inelastic fuel demand and substantial substitution between them.

6.2 Sustainability assessment

To make a final conclusion about the sustainability of energy subsidy reform in Iran, we need to remember the concept of sustainability once more. As explained before, sustainable development is addressing four pillars of sustainability (institutional, social, environmental, and economic) which are integrated and interlinked in a comprehensive manner Indeed, sustainable development that aims to restore equilibrium between institutional, environmental, economic and social values leads us to square diagrams when discrimination between pillars, i.e. non-sustainability, can be shown by rectangles or trapezoids (Fig. 6.1)

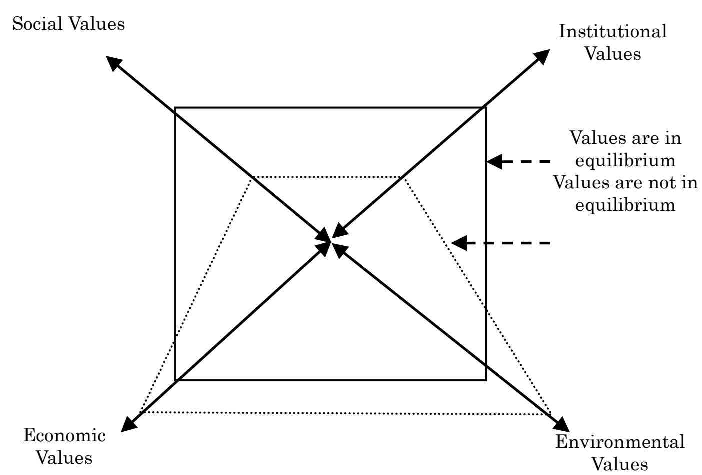


Fig 6.1. The concept of sustainability and non-sustainability

Now, let‘s compare the above figure with our findings in Chapter 2. Fig. 6.2 depicts the current situation in Iran. As it is obvious, the development in Iran could not address the equilibrium criteria. While, the country experienced somewhat progress in social, environmental, and economic pillars, the development level in institutional pillar is far behind the development frontiers. Therefore, we can conclude that the unsustainability features of Iran are more prevailing.

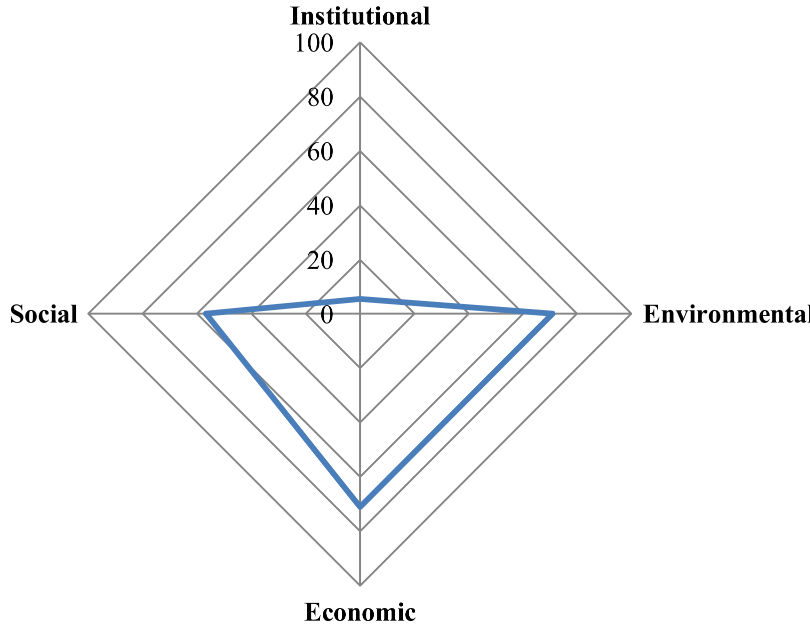


Fig. 6.2. The sustainability of Iran in institutional, social, environmental and economic pillars

What is clear from Fig. 6.2 is that institutional development should the main priority for policymakers. Institutional development not only increases the inter-pillar balance, but also may create some inter-pillar spillover effects. The next would be social development. The development without equality increases the social gaps and disparities in the country. The next priorities would be economic and environmental developments.

What does the energy subsidy reform address in Iran? Which pillars are improving and which are deteriorating? Is it basically a sustainable policy? What we studied in this thesis was the short-term impacts of energy subsidy reform on particular key social, economic and environmental variables. We did not include the institutional pillar because the short-term impact of the reform on good governance criteria is marginal. However, we may find some impacts in the long-term through the reduction of rent-seeking activities (e.g. smuggling) and increasing some financial resources for the government to supply more public goods and services. However, the reform cannot improve the quality of governance in the short-term and so it fails to address the main problematic pillar in Iran.

The other short-term impacts investigated in this thesis are shown in Table 6.1. As we mentioned before, the list of affected variables are undoubtedly more than what we studied. However, it seems that the above key variables can show the overall direction and pace of the impacts. The first impact is on the social pillar that can be represented by changing in household expenditure measured in Chapter 4. In contrary to income that can be located in economic pillar, household expenditure can be grouped in the pillar of social development. Household expenditure has direct and indirect effects on the variables mentioned in social pillar (Table 2.2). Changing the household expenditure would undoubtedly result in changing the level of health and education expenditures. Indirectly, the final impact would be on the social variables such as life expectancy at birth, mortality rate, and gender discrimination. In addition, as we learned in Chapter 4, the reform has not the same impact on the rural and urban households. The results revealed that rural families will suffer the burden of inflation more than urban families. We expect consumption prices to increase by 42.8% in urban areas and 55.5% in rural areas. This means that by increasing the household expenditure, the inequality between urban and rural households is rising that leads to more social disparities in the Iranian society.

The next impact is on the environmental sustainability. The target variable is social cost of CO_2 emission that measured in Chapter 5. The social cost of CO_2 emission is measured by multiplying the amount of CO_2 emission changes, in two optimistic and pessimistic views, by unit social cost of CO_2 emission reported by MoE (2011) (1 ton CO_2 = 80,000 IRR at prices in 2001). The same component exists in Table 2.2 that reflects the carbon dioxide damage in the selected countries.

The last impact is on economic pillar that the value of conserved energy can show it. The amount of conservation in energy consumption is derived from Table 5.7 and grouped in two optimistic and pessimistic estimations. The conserved energy is converted to the monetary term by international prices in 2010.

The estimated impacts on these three pillars, i.e. social (household expenditure), economic (energy consumption), and environmental (CO_2 emissions), are monetized and showed in Table 6.1.

Table 6.1

Some short-term costs and benefits of energy subsidy reform in Iran (Million IRR at 2010 prices)

	First Phase		Complete Reform	
	Optimistic	Pessimistic	Optimistic	Pessimistic
Social pillar (household expenditure)	-238,333,589	-238,333,589	-664,677,472	-664,677,472
Economic pillar (energy consumption)	17,473,315	-66,546,375	54,896,652	-143,933,175
Environmental pillar (CO_2 emission)	2,600,634	-10,819,655	14,507,541	-23,829,225

Note: 1 ton CO_2 emissions = 80,000 IRR at 2001 prices (MoE, 2011)

It should be mentioned that comparison between social cost and the other economic and environmental costs should be made cautiously. The reason roots in the methodology used to estimate each one. To estimate the impact of the reform on household expenditure, we employed the IO price model that assumes no substitutability between inputs. However, the main idea behind the estimation of translog cost function in Chapter 5 is the possibility of fuels to be substituted with each other. Although the assumptions in two IO price model and translog cost function are different, the both approaches are common in one point that is the short-term nature of them. IO price model assumes that the economic structure remains unchanged through the reform and the translog model assumes that the production level (i.e. GDP) in the economy remains fixed that just happens in the short term. Therefore, both of the results can be justified as the short-term impacts.

All in all, the results in Table 6.1 show that in the both of optimistic and pessimistic estimations, the energy subsidy reform is an unsustainable policy either in the first phase or in the whole of it. The negative impact on the social pillar is such drastic that fades the probable conservational benefits. Therefore, we can come into this final conclusion that Iranian society becomes a net loser after implementing the reform.

6.3 Further studies

While we just investigated the short-term impacts in this thesis, studying the long-run institutional, social, economic and environmental effects of energy subsidy reform is required. Although, it is noteworthy that these are the short-term impacts that make the long-term one. The key point in our analysis is that if the short-term impacts are not such bearable for the economy and the society, the government cannot implement all of the phases. Therefore, if the current trend continues, it is not surprising to see that the reform stopped by Iranian government or parliament.

The other interesting field of study is the political economy of the reform. The question raised for every researcher (especially Iranian economists who are suffering the consequences of the reforms) is that when the consumers and producers are the net losers and beside, the reform cannot hit its conservation targets in the short-term, why the government insists on the continuity of the reform on its original form. When the reform coincided with the tight sanctions against Iran, why the government insists on its continuity? These are the questions that should be answered in the next studies. However, the preliminary answer is that the perseverance of the government roots in its political interests rather than economic or developmental motives.

The public choice theories can explain the behavior of the Iranian government well. Public choice or public choice theory has been described as the use of economic tools to deal with traditional problems of political science. It is often used to explain how political decision-making results in outcomes that conflict with the preferences of the general public.

Public choice theory attempts to look at governments from the perspective of the bureaucrats and politicians who compose them, and makes the assumption that they act based on a budget-maximizing model in a self-interested way for the purpose of enhancing their own power and influence. The theory aims to apply economic analysis (usually decision theory and game theory) to the political decision-making process in order to reveal certain systematic trends towards inefficient government policies. The next studies should use these theories to provide a clearer picture about the motives of the government in implementing and continuing the energy subsidy reform in Iran.

Appendix 1:

Subsidy Reform Law

Article 1. The government is required to reform the prices of energy carriers in accordance with the provisions of this law:[1] [2] [3] [4]

- Domestic sale prices of energy carriers: gasoline, diesel fuel, fuel oil, kerosene, liquefied petroleum gas (LPG), and other oil condensates, inclusive of relevant costs (including transport and distribution expenses, taxes, and other legal duties) and depending on the quality of carriers, will be adjusted gradually until the end of the 5 th Five-Year Development Plan (FYDP) 2010-15, up to a level which shall not be less than 90 percent of Persian Gulf FOB prices.[5]
- Average domestic sale price of natural gas will be adjusted gradually until the end of the 5 th FYDP up to a level which shall not be less than 75 percent of average export price of natural gas, excluding transfer costs, taxes and legal duties.[6]
- Average domestic sale price of electricity will be adjusted gradually until the end of the 5 th FYDP up to a level which shall be equal to full cost price.[7]

Article 2. To manage the impact of energy carriers price fluctuations on the domestic economy, the government is authorized to keep the prices unchanged for consumers as long as Persian Gulf FOB prices fluctuate within a range of 25 percent, by paying subsidy or collecting differentials, as the case may be, and include such amounts in the account established for regulating energy carriers market, in the relevant annual budget. If price fluctuations exceed the said 25 percent range, prices will be adjusted accordingly.

Article 3. The government is authorized to adjust the price of water and the fee chargeable for sewage collection and disposal, in accordance with the provisions of this law.

- Average price of water for different uses will be adjusted gradually until the end of the 5th FYDP, up to a level which shall be equal to the cost price, considering the quality and the manner of purification. [8] [9]
- Calculation of chargeable fee for sewage collection and disposal services will be based on total costs of maintenance and operation of the sewage system, after deduction of the intrinsic value of delivered wastewater and government aids under the annual budget (in connection with incentive policies).

Article 4. The government is required to make arrangements for gradual targeting of subsidies payable on wheat, rice, cooking oil, milk, sugar, postal services, and air and rail (passenger) transportation services, until the end of the 5th FYDP.[10]

Article 5. The government is required to make available the flour and bread subsidies to consumers, who have applied, to the extent payable in accordance with the annual budget bill, through appropriate methods. [11]

Article 6. The government is required to adopt incentive and supportive policies, which are necessary to establish and expand industrial bread production units, and also to help compensate the losses to the flour and bread production units that may face difficulties as a result of implementing this law. The implementing regulations of this Article will be prepared by the Ministry of Commerce, in cooperation with relevant organizations, and approved by the Cabinet within three months after the approval of this law.

Article 7. The government is authorized to spend up to 50 percent of net proceeds resulting from the implementation of this law under the following items:

- Cash and non-cash subsidies payable to all households countrywide, considering the level of household income;

- Implementing a comprehensive social security system for the targeted population, such as: (i) Providing and expanding social insurances, health care services, ensuring and enhancing public health, and medical coverage for special and difficult-to-cure diseases; (ii) Providing assistance for financing housing costs, enhancing resistance of buildings, and creating employment; (iii) Empowering and implementing social support programs. [12] [13]

Article 8. The government is required to spend 30 percent of the net proceeds resulting from the implementation of this law to pay for grants, or subsidies on bank facility charges, or specially managed funds for implementation of the following items: [14]

- Optimizing energy consumption in production, services, and residential units, and encouraging energy savings and observing the consumption pattern introduced by the relevant implementing organization.
- Reforming technological structures of production plants, aimed at increasing efficiency of energy and water, and developing electricity generation from renewable resources. Compensating part of losses to the companies providing utility services–water and sewage, electricity, and natural gas—and oil products, and municipalities and townships, incurred as a result of implementing this law.
- Developing and improving public transportation, under the framework of Public Transportation Development and Fuel Consumption Management Law, and paying an amount up to the credit ceiling determined under Article (9) of the said law.
- Supporting the producers in agriculture and manufacturing sectors.
- Supporting production of industrial bread.
- Supporting non-oil export promotion.

- Developing interactive electronic services to eliminate or reduce need for unnecessary traffic.

Article 9. Sources discussed under Articles (7) and (8) of this law, including aid, facilities, and specially-managed funds, will be made available to the said persons through state-owned and private bank and non-bank financial institutions.

Article 10. Receipt of aids and subsidies discussed under Articles (7) and (8) of this law will be subject to providing accurate information. If the provided information proves to be inaccurate, the government is required to take necessary legal actions for refunding the amounts so paid, while preventing future payments. If the persons consider that they are eligible for receipt of the aids and subsidies discussed under Articles (7) and (8) of this law, they may submit their objection to the Commission that shall be foreseen under the implementing regulations of this Article The implementing regulations of this Article will be proposed by Ministers of Justice, Economic Affairs and Finance, Welfare and Social Security, and Head of MPO, and approved by the Cabinet within three months after the notification of this law.

Article 11. The government is authorized to spend up to 20 percent of the net proceeds resulting from the implementation of this law, to compensate its impact on spending and the acquisition of capital assets.

Article 12. The government is required to deposit all income sources resulting from implementation of this law into a special account titled subsidy targeting account with the General Treasury. 100 percent of funds so deposited will be allocated for the uses authorized under Articles (7), (8) and (11) of this law, and under the framework of annual budget laws. 15 16 17

Article 13. The petty cash needed to implement this law will be included in the petty cash of the annual budget, and will be settled from sources generated by implementation of this law during the year. 18

Article 14. The interchangeability of credits discussed in Articles (7), (8) and (11) of this law will be authorized only for a maximum of 10 percentage point in the annual budget, so that the total proceeds so resulted shall be used as provided in this law.

Article 15. The Government is authorized to establish, within one month after coming into force of this law, a new organization of public company nature named Subsidy Targeting Organization (the Organization) for implementation of this law in accordance with the FYDP Law, by using the available resources (facilities, manpower and credits) or by restructuring and merging the existing companies. The government is authorized to draw whenever needed the funds deposited to the Treasury as a result of implementation of this law, and make such amounts available to the Organization as aid, after deduction of the government's share as per Article (11) hereof, which amounts will be utilized solely for purposes and obligations specified in Articles (7) and (8) of this law. The Organization‘s administration will be centralized, and it will be authorized to have only staff, planning, and supervising units in the centre. The members of its General Assembly will comprise Ministers of Welfare and Social Security, Economic Affairs and Finance, Commerce, Roads and Transportation, Agricultural Jihad, Industries and Mines, Petroleum, Energy, and Head of MPO. The company‘s Organization‘s articles of association, including its pillars, responsibilities and powers, will be prepared by the Ministry of Economic Affairs and Finance and MPO, and approved by the Ministerial Cabinet. Funds and credits discussed in this law, including in Articles (12) and (15), will be reflected in the country‘s general budget, like those of other public companies, and changes in the company's Organization‘s credit ceilings during the year will be subject to providing a proposal by the government and its approved by Parliament, except for the cases authorized in accordance with provisions of this law, including Articles (2) and (14). The Organization‘s unutilized funds in any year could be used in the succeeding year, and in any year it may make commitments for the succeeding years under the framework of this law. Credits governed by this law are subject to the Regulations Governing Spending Credits Exempted from Observance of the Public Audit Law and Other General Government Regulations Law approved on 06/11/1364 (January 26, 1986). The Organization is required to provide reports on performance, receipts and payments related to resources from subsidy targeting, for each of Articles (7) and (8) separately, at the end of each six-month period, to Parliament‘s Planning, Budget and Audit Committee and other relevant committees. The Supreme Audit Court is required to provide semi-annual reports to Parliament on the Organizations‘ operations based on the contemplated targets as provided in this law.

Article 16. Starting from the beginning of the year 1389 (March 21, 2010), the government is authorized to increase the tax exemption level provided under Article (84) of the Direct Taxes Law, proportional to price adjustments under this law and in addition to its annual increase, subject to Ministry of Economic Affairs and Finance‘s proposal, over a period of five years and up to a maximum of 100 percent.

The above law, consisting of 16 Articles and 16 Notes, was approved by the Islamic Assembly on Tuesday, 15 Day 1388 (January 5, 2010) and was confirmed by the Guardian Council on 23 Day 1388 (January 13, 2010).

1- http://www.icana.ir/News/Parliament/2010/1/52183/0/Default.aspx.

2-With regard to electricity and natural gas prices, the government is authorized to apply preferential prices, considering geographical regions, type, amount, and time of consumption. In cases where several families or subscribers share the benefits of a single subscription, Water, Electricity, and Gas Companies are required to install additional individual meters for additional families by charging only the cost of meter and its installation expenses; and in case it shall not be possible to install additional individual meters, the number of subscribers shall be increased to the number of individual users of the shared subscription.

3- Calculation of prices of energy carriers after the first year of implementation of this law will be based on the exchange rate used in the relevant annual budget.

4- The adjustment of relevant prices in the first year of implementation of this law will be made in a manner that generate an additional aggregate amount of revenue up to RLS 200,000 billion, but not less than RLS 100,000 billion.

5- Sale prices of crude oil and gas liquids to domestic refineries will be equal to 95 percent of Persian Gulf FOB prices, and purchase prices of products from the refineries will be set in line with the said prices.

6- To encourage investment, for a period of at least 10 years from the date of approval of this law, the prices of feedstock for industrial, refinery, and petrochemical plants per cubic meter, will not exceed a level which is equal to 65 percent of a basket of gas export prices of Persian Gulf origin (excluding transfer costs).

7- Calculation of electricity cost price will be based on total costs of energy conversion, transmission and distribution, and fuel costs, with an efficiency of at least 38 percent of power plants and observance of standards; and the efficiency of the country‘s power plants shall be improved by at least 1 percent per year, so that it reach a level of 45 percent within 5 years from the date of implementation of this law, and also 2 the transmission and distribution power grid losses to be reduced to 14 percent by the end of the 5th FYDP. The government is required to make arrangements for rating of electricity producers in terms of efficiency and its distributers in terms of energy losses by establishing a work group comprising governmental and nongovernmental experts, and to adopt appropriate incentives and supportive policies.

8- The government is required to set the cost price of water by including all costs of water supply, transfer and distribution, and observing efficiency.

9- Setting preferential and multiple prices for different uses of water, in view of geographical regions, type, and amount of consumption, will be authorized.

10- Subsidies paid to producers in agriculture sector in each year should not be less than the same for the preceding year.

11- Per capita bread subsidy payable to population of villages and the cities with less than twenty thousand people, and vulnerable groups in other cities, will be at least 50 percent more than the average per capita subsidy, at the discretion of the government.

12- The implementing regulations of this Article, including how to identify the targeted population, and establish and update the needed databases; the method of payment to the targeted population; and the payments under this Article, will be proposed by Ministers of Economic Affairs and Finance, and Welfare and Social Security, and Head of Management and Planning Organization (MPO), and approved by the Cabinet, within three months after the approval of this law.

13- The government can open the subsidy targeting account in the name of the head of each eligible family, or another eligible person determined by the government. The government is authorized to exercise control over the manner in which the funds are spent under the said account, including the applicable time, type of drawings, and the refund of amounts that have erroneously been deposited.

14- The implementing regulations of this Article, including the method of supporting industries, agriculture, and services, and the manner of payments under this Article, will be proposed by Ministers of Economic Affairs and Finance, Industries and Mines, Agricultural Jihad, Commerce, Petroleum, Energy, and Interior, Chairman of the Iranian Chamber of Commerce, Industries and Mines, the Secretary General of the Chamber of Cooperatives, and Head of MPO, and approved by the Cabinet within three months after the approval of this law.

15- The government is required to present credits amounts of sources and uses discussed under the said Articles in four separate items in the relevant annual budget bill.

16- Cash and noncash aids provided to natural and legal persons as a result of implementation of this law will be exempt from income tax under the Direct Taxes Law 6 approved in Esfand 1366 (February 1988) as amended. Such aids to such persons for compensation in part or in whole of the price of goods or services provided by them will not be subject to the tax exemption provided under this note.

17 - The government is required to provide the Supreme Audit Court and Parliament with the detailed report of operations under this Article every six month.

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