Energy for Sustainable Development 27 (2015) 147–154

Contents lists available at ScienceDirect

Energy for Sustainable Development

Economic and environmental analyses of Iranian energy subsidy reform using Computable General Equilibrium (CGE) model

Zakariya Farajzadeh *, Mohammad Bakhshoodeh

Department of Agricultural Economics, College of Agriculture, Shiraz University, Shiraz, Iran

ARTICLE INFO

Article history:
Received 18 May 2013
Revised 23 May 2015
Accepted 12 June 2015
Available online 23 June 2015

JEL classification:
Q4
Q5
D5

Keywords:
Energy subsidy
Environmental impact
CGE model

ABSTRACT

This study analyzes economic and environmental implications of the elimination of energy subsidies in Iran applying a CGE model. The subsidy reform was investigated under two scenarios namely, redistributing total subsidy revenue back to households (complete payment) and allocating it to households and producers (half payment) proportionally (50% and 30% respectively). The results show that elimination of energy subsidies via resource reallocation causes a fall in GDP relative to the initial equilibrium by at least 15%, while the general level of prices (CPI) tends to increase by more than 10% compared to the initial level. However, redistributing a part of the subsidies revenue back to households increases overall welfare. Eliminating energy subsidies induces emission reduction of most of the pollutants. Considering the economic, welfare and environmental aspects, half payment scenario is preferred compared to complete payment option.

Introduction

Subsidized energy is a measure to ensure low income groups' access to modern energy utilization (Liu and Li, 2011). Protecting a particular domestic industry against international competition, avoiding potential unemployment, and making modern energy services more affordable for specific social groups are some aims of subsidizing (Lin and Jiang, 2011; UNEP and IEA, 2002). However, energy subsidies cause the price of energy products to deviate from their true costs. Moreover, some studies suggest that many subsidies failed to make energy affordable to the poor, and non-poor household gains are significantly more than that of the poor (Dube, 2003; Gangopadhyay et al., 2005; Kebede, 2006).

Based on the literature, energy has a central role in economic growth. Positive impact of energy consumption in economic growth is indicated for China (Wang et al., 2011); South Africa (Menyah and Wolde-Rufael, 2010); the newly industrialized countries (NIC[1]) (Sharif Hossain, 2011); Russia (Pao et al., 2011) and Greece (Tsani, 2010). Furthermore, cutting energy subsidies and increasing prices of energy products cause economic production to shrink. Using multi-country general equilibrium, Burniaux et al. (1992) concluded that subsidy reform would reduce world annual real income by 0.7%. Liu and Li (2011) also demonstrated that removing oil and coal subsidies would trigger a fall in China's GDP by 3.80% and 0.52%, respectively. Lin and Jiang (2011) analyzed the impact of removing the energy subsidies in China; they concluded that, without redistribution of subsidy revenue, China's GDP would decrease by 1.56%. Empirical work of Jensen and Tarr (2002) also showed that energy subsidy reform in Iran would reduce output in most of the energy and manufacturing sectors. Contrary to the above-mentioned works, the International Energy Agency (IEA, 1999) demonstrated that removing energy subsidies in the eight biggest non-OECD countries would increase their GDP by 1%. It showed that the efficiency gain of subsidy removal in Iran was equivalent to 2.22% of the Iranian GDP. When energy is sold below its true opportunity costs, its use imposes a burden on the economy. This burden can be expressed as potential gains or increase in growth that would occur if subsidies are removed (IEA, 1999). Based on the literature, the negative impacts of energy subsidy elimination on output are more likely than its positive impacts. However, GDP is expected to fall during the adjustment period as industries respond to higher input costs and energy subsidy reform has the potential to provide substantial gains in economic efficiency (Anderson and McKibbin, 1997) since it can eliminate price distortion. Steenblik and Coroyannakis (1995) support reform in coal subsidies in Western Europe, based on promoting industrialization of the power sector and increase in coal production and exports.

In recent years, welfare and environmental concerns have become the focus of many studies on energy subsidy reform (Anderson and

* Corresponding author. Tel./fax: +98 71 32286082.
E-mail addresses: zakariafarajzadeh@gmail.com (Z. Farajzadeh), bakhshoodeh@gmail.com (M. Bakhshoodeh).

[1] Namely, Brazil, China, India, Malaysia, Mexico, Philippines, South Africa, Thailand and Turkey.

http://dx.doi.org/10.1016/j.esd.2015.06.002
0973-0826/

McKibbin, 1997). However, the mechanism of the subsidy reform seems rather important. While removing energy subsidies without income transfer scheme may result in declining welfare (Lin and Jiang, 2011; Liu and Li, 2011) and increasing households' expenditure (Saboohi, 2001), redistribution of the subsidy revenue back to the households may increase their welfare (Jensen and Tarr, 2003).

In spite of economic growth and welfare, there is little doubt about the positive impacts of energy reform on pollutant emissions from energy consumption, since about 65% of the greenhouse gas (GHG) emissions are due to production and use of energy (Marrero, 2010). Moreover, the causal relationship between energy consumption and pollution has been the focus of many studies. Menyah and Wolde-Rufael (2010) found a unilateral causality running from energy consumption to CO_2 emission in South Africa and Zhang and Cheng (2009) demonstrated a unidirectional causality running from energy consumption to carbon emission for China. Similar conclusions are available for the USA (Soytas et al., 2007) and the newly industrialized countries (NIC) (Sharif Hossain, 2011). A bilateral relationship between energy consumption and CO_2 emission has been proved for Russia (Pao et al., 2011); Brazil (Pao and Tsai, 2011) and China (Wang et al., 2011). As Alam et al. (2011) pointed out for India, it is straightforward and intuitive that energy consumption drives CO_2 emissions because the main source of CO_2 emissions is the combustion of fossil fuels, however causality from CO_2 emissions to energy consumption should be considered in energy-emissions-income relation context (Pao et al., 2011). More CO_2 emissions are accompanied by higher income which in turn entails more energy use.

There are several studies which focus on the impacts of economic policies on energy consumption and emission. Liu and Li (2011) utilized a CGE model and suggested that cutting oil and coal subsidies in China would generate a fall in CO_2, SO_2, waste water and solid waste. Lin and Jiang (2011) argued that removing energy subsidies reduces CO_2 emission by 7% without the redistribution of subsidy revenue and by 4.7%–6% under alternative redistribution schemes in China. Increase in oil prices in Turkey is also expected to reduce CO_2 emissions (Aydin and Acar, 2011). Removing energy subsidies would reduce CO_2 emissions globally (Burniaux et al., 1992) as well as in OECD and non-OECD countries (Anderson and McKibbin, 1997; IEA, 1999).

Iranian consumers pay an artificially low and controlled price for energy products with the government making up the difference (subsidy) between subsidized and world prices. This energy subsidy is measured by price-gap approach. This approach has the advantage of conceptual and analytical simplicity, and is the most pervasive approach in analyzing energy subsidies (Lin and Jiang, 2011).

To the best of our knowledge, works referring to the Iranian energy subsidies scheme are limited, and the work conducted by Jensen and Tarr (2002) is unique in this context. They considered subsidy elimination under the assumption of redistributing subsidy revenue back to household, whereas the Iranian government may take an alternative option based on subsidy targeting program (STP).[2] Furthermore, environmental aspects of energy subsidy removal are not considered in this study. The IEA (1999) investigated the energy subsidy elimination in Iran and suggested that 49.45% reduction of CO_2 emissions is associated with an unexpected reduction of 47.54% in energy consumption. Subsidy rate of energy products, mechanism of the subsidy reform and analytical framework[3] could be responsible for such results. Contrary to the IEA study that expects a GDP growth of 2.22%, Jensen and Tarr (2002) and Khiabani (2008) indicate that outputs in most of the sectors decrease as a consequence of removing energy subsidies, resulting in a reduction in output of the Iranian economy as a whole. Recently, Khalili Araghi and Barkhordari (2012) have examined the welfare effects of energy price increase together with the government compensation payment applying a partial equilibrium approach. They chose three exogenous compensating payments of 4, 6 and 10 billion USD. The corresponding results show that under the above compensating payments, the Iranian household will be better off by a 100% or 200% rise in energy prices. However, their welfare will decrease with a 400% and 500% rise in energy prices, if the government payment is 4 and 6 billion USD.

Having the second largest oil and gas reservoirs in the world, Iran is the fourth largest producer and consumer of gas and holds the same position in the world in producing and exporting oil (Central Bank of Iran, 2009). The original intention of the Iranian government was to approach a higher level of employment and economic growth, stabilizing prices as well as achieving social equality. However, no compelling evidence exists to support achieving these objectives (Basranzad and Nili, 2005). From the environmental perspective, Iran faces tremendous pressures as pollutant emissions are higher than the global average. On average, per capita CO_2 emission in Iran is around 6.5 metric tons, much higher than the corresponding world figure, i.e. 4.5 metric tons (UN data, 2008). The considerable amount of energy subsidies in the country (12.42% of its GDP in 2009) has resulted in increasing government financial burden as well as GHG emissions due to years of overconsumption of energy (Iran's Energy Balance, 2009; UN data, 2008).

The average subsidy[4] rate in Iran was estimated to be 80.42% in 1997 (IEA, 1999), accounting for the highest energy subsidy rates among the eight largest non-OECD[5] economies. This figure reached nearly 75% in 2008. As shown in Table 1, subsidy at its lowest rate for electricity accounts for 58.2%, while the highest rate is attributed to kerosene, of which more than 96% of the international price is paid as subsidy.

Although the real prices of some energy products have slightly increased, those of gasoil, gasoline and electricity decreased between 1991 and 2008 (Iran's Energy Balance, 2009), leaving a significant gap between domestic and world prices. Energy use per USD 1000 output (constant 2000 PPP$) increased from 201 kg oil equivalent in 1990 to 269 kg in 2008. The corresponding value among all countries as a whole is also less than one-half of that for Iran (UN data, 2008).

Oil products, natural gas and electricity respectively account for 46.2%, 44.6% and 8.6% of total energy consumption in the country. The corresponding figures for transportation system and industrial activities are 26.5% and 22.1% respectively. The households, public sector, as well as business services consume 36.8% of energy in total, and 3.7% is devoted to the agriculture sector (Iran's Energy Balance, 2009).

As the Iranian government is facing greater challenges from the financial burden of the energy subsidies and pollutant emissions, energy subsidies have become a matter of great debate. The government has recently commenced reforming the energy subsidy system and redistributing it as a part of the STP. Two options are likely to be chosen for the additional revenue received by the government. The first choice is to redistribute it back to all households in equal absolute amounts similar to that assumed by Jensen and Tarr (2003). Another option is to redistribute the revenue based on the STP. According to the STP, 50% of the additional revenue is assumed to be received by the household in equal absolute amount and 30% transferred to producers as production subsidy. These options are respectively called hereafter *Complete Payment* (CP) and *Half Payment* (HP) scenarios.

Regarding the wide range of the energy subsidies and dependence of activities on low price energy, cutting energy subsidies is expected to exert some vague impacts on economic and environmental variables.

[2] This program was passed on February, 2010 by the Iranian Guard Council and it was started to perform from 2011. As a main part of this program it was supposed to eliminate petroleum product subsidies gradually. It was also supposed to transfer the subsidy revenue back to the households in equal amounts. This is examined in this study. However, it is important to note that the program failed to be performed completely since it faced some problems.

[3] IEA projections are derived from application of IEA's large-scale World Energy Model.

[4] Energy product prices are initially subsidized by the government such that the price to domestic consumers is fixed. Domestic consumers include both producers who use energy products as intermediate input in production process and consumers who demand it for final consumption. In the same way, energy subsidy elimination implies that subsidy will be abolished for these two groups.

[5] The eight non-OECD countries are China, India, Indonesia, Iran, Kazakhstan, Russia, South Africa and Venezuela.

Table 1
Domestic and international prices for energy products in 2008.

	Subsidy (Rials/l)	Domestic prices (Rials/l)	International prices (Rials/l)	Subsidy share (%)
Gasoline	3986.6	986.0	4972.7	80.2
Kerosene	6057.9	237.3	6295.2	96.2
Gasoil	5036.5	644.4	5681.0	88.7
Fuel oil	2276.3	1545.3	3821.6	59.6
Liquid gas	3093.2	616.5	3709.8	83.4
Natural gas	358.6	102.9	461.5	77.7
Electricity	735.0	528.6	1263.7	58.2

Note: International prices are converted to Rials at the market exchange rate on the Tehran Stock Exchange of 9428.5 Rials per Dollar in 2008.

It has been more than 10 years since the IEA and the Jensen and Tarr studies, and there has been very little research focused on the impacts of elimination of energy subsidies on the macroeconomic as well as environmental aspects. Khalili Araghi and Barkhordari (2012) examined welfare effects of energy price increase in Iran applying a partial equilibrium approach and covering only consumption side of a two-sector economy, i.e. energy and non-energy, while it assumes an exogenous compensating payment.[6] Another distinguishing feature of our study even in welfare context is the income group-based welfare analysis as households are considered in income deciles. Therefore, an in-depth simulation and analysis of possible impacts of energy subsidy reform is necessary. Exploring the possible sectoral, macroeconomic and environmental impacts of removing energy subsidies while the subsidies are redistributed back to the households under the two regimes is the question that the rest of this paper aims to achieve. Sectoral impacts contain output, relative price and net export changes and environmental impact is measured by selected pollutant emission.

The remainder of the paper is structured as follows: The model section introduces the model features; the Simulation results section applies the Computable General Equilibrium (CGE) model to simulate the impact of energy subsidy reform on macroeconomic and environmental variables; conclusion and policy suggestions are presented in the Conclusion section.

The contribution of this paper is threefold: First, the total emission of the selected pollutants is decomposed into energy use, production process and final non-energy use emissions. Second, to approach more precise criteria for welfare, Linear Expenditure System (LES) is used to analyze welfare changes. Third, more households' income groups and more pollutants are considered.

The model

The analytical instrument of the study is a static CGE. Our Small Open Economy (SOE) model is designed for energy policy analysis with large sectors. The model is a constant return to scale general equilibrium and uses Social Accounting Matrix (SAM) data. Explanations of the equations may be found in de Melo and Tarr (1992, ch. 3); McDonald et al. (2007); and Beghin et al. (2002). However, the model is designed specifically for Iran, having some features such as energy subsidies and trade distortions that are compatible with the reality of the Iranian economy. Although the trade policies are not our focus, we incorporate the trade distortion caused by non-tariff barriers. Here, the general features of the model are described. In the model, 26 sectors that can be divided into some main groups including agriculture, agricultural industries, manufacturing, mining, energy, services and transportation sectors were considered. Agricultural industries are food, beverage and tobacco industries, textile, leather and clothing industries, and wood and paper industries. For brevity, the first two sectors are called food and textile sectors, respectively. Manufacturing includes all industrial sectors except for agricultural industries. Services accounts for all service sectors except transportation. Energy sectors also contain crude oil and gas and their products including gasoline, kerosene, fuel oil, gasoil, liquid gas, natural gas as well as electricity.

As Table 2 shows, services (including transportation) have the highest contribution to the Iranian economy, accounting for around 40%. Crude oil and gas and their products also contain 30.6% of the GDP. Manufacturing sector including mainly metal, industrial machinery, and chemical industries shares about 13.3% of the GDP followed by agriculture as a whole, with a GDP share of 11.8%. Agricultural industries include food, beverage and tobacco industries, textile, leather and clothing industries, and wood and paper industries and account for GDP share of about 4.5%.

Goods are produced using primary factors and intermediate inputs. Primary factors involve unskilled labor, skilled labor and capital. Labor and capital are perfectly mobile and are capable of floating among sectors, which yields unique wage rate and rental rate on capital for the entire economy. The value added is produced by primary factors via constant elasticity of substitution (CES) production function. The value added makes up total production function with intermediate inputs using Leontief production function. Production also exhibits constant return to scale and individual firms behave competitively, selecting output levels such that the marginal cost at those output levels equals the given market price. Goods used as intermediates are an Armington composite of domestic and imported goods. The world prices of imported and exported goods are fixed, which implies the absence of any terms-of-trade effects. Based on Euler's theorem, payments to primary factors exhaust value-added. This model uses a constant elasticity transformation (CET) function to allocate total domestic output of sectors between exports and domestic sales.

There are seven energy products in the model: gasoline, kerosene, fuel oil, gasoil, liquid gas, natural gas and electricity, all of which are heavily subsidized. Following Jensen and Tarr (2002), we assume zero substitution between energy inputs as well as other intermediate inputs. This indicates that there is a roughly fixed physical relationship among the energy products (Jensen and Tarr, 2003). As Manzoor et al. (2011) showed, this can be reasonable for the Iranian case, however, it should be noted that allowing non-zero substitution elasticity among energy products may play a crucial role in carbon dioxide emission changes caused by energy tax policy (Sancho, 2010).

There are ten urban and ten rural household types in the model, grouped from the poorest to the richest with an equal number of people based on the 2008 Iranian Household Expenditure Survey. Households' income mainly comes from labor income and profit distribution from enterprises. After paying income tax and receiving transfers from government, the households receive disposable income. One part of the disposable income is devoted to savings. The other is spent on consumption of various goods, which is described with a LES. A welfare change is also measured by Hicksian equivalent variation (EV).

Government revenue is derived from rents on crude oil, mining products, import tariff revenues, and exogenous lump-sum taxes. Government expenditures which are subjected to income balance condition

Table 2
GDP share of the main sectors in Iran.

Sectors	GDP share (%)	Sectors		GDP share (%)
Agriculture	11.8	Manufacturing		13.3
Agricultural industries	4.5	Services		39.8
Crude oil, gas and their products	30.6		Transportation	5.4
			Other services	34.4

[6] The compensating payment in their study is based on energy subsidy of USD 20 billion paid in 2009 that is considered as a constant. Then, they suppose percentage payments of 20%, 30% and 50%. However, in CGE model applied to simulation we allow the subsidy revenue to be endogenously determined and redistributed by the model. Furthermore, our approach allows for examining additional effects such as changes in sectoral and total output, CPI, government expenditure, emissions, etc.

include government demand for goods and services, transfers to households, subsidies to energy products, and food subsidies. The exchange rate in the model is also fixed and foreign capital inflow adjusted such that the current account balances the value of exports and imports.

The equilibrium module includes market clearing and agents' income balance conditions including the equilibrium of commodity market, factor market, domestic transfer, international trade, and savings and investment.

Another part of the model is environmental block, which expresses a relation between total emission of the selected environmental pollutants and the pollution sources. Pollution sources are energy use including final and intermediate use, production process, and non-energy final consumption. Regarding CO_2, CH_4 and N_2O pollutant emissions measured in terms of CO_2 equivalent,[7] energy consumption and production process respectively account for about 66% and over 30% of pollution, whereas non-energy consumption process creates almost 4% of pollution. Around half of CO_2 equivalent energy consumption based emissions belongs to natural gas followed by gasoil, fuel oil and gasoline with shares of 18.7%, 12.9% and 12% respectively. In the case of production-based emissions, agriculture and agricultural industries account for 20.3% and 5.6% respectively. Manufacturing and mining also share 17.4% and 12.1% respectively. The rest of the production based emissions of the mentioned pollutants belongs to energy sectors (UNDP, 2010).

Total amount of emissions in the economy for each pollutant is determined by the following equation:

$$EN_p = \sum_a \beta_a^p QX_a + \sum_c \pi_c^p \left[\sum_a QINT_{ac} + \sum_h QCD_{ch} + \sum_f QQf_{cf} \right]$$

The first term represents what is called production process pollution (QX_a). It is the residual amount of pollution in production that is not explained by consumption of inputs (Beghin et al., 2002). The second term, presented in the brackets, is the pollution assigned to direct consumption of goods. The emission caused from the second term is derived from the use of polluting intermediate input[8] "*c*" in the production process "*a*" ($QINT_{ac}$); consumption by the household "*h*" (QCD_{ch}); and by the other components of the final demand "*f*" (QQf_{cf}). Parameter π_c^p is the estimate of emission per unit of input "*c*". β_a^p is the emission of pollutant "*p*" per unit of output in the production process "*a*". The selected pollutants also are CO_2, CH_4, N_2O, CO, NO_x and SO_2. The first three pollutants are aggregated into CO_2 equivalent using the corresponding transformation coefficients reported by the UNDP (2010).

Data

Seven main data sources were used including: (1) Iran SAM table for 1999 (Central Bank of Iran, 1999); (2) household expenditure survey (HES) for 2008 (Iranian Statistical Center, 2008); (3) policy data, including subsidies to energy products from energy balance sheets for 2008 (Iran's Energy Balance, 2008); (4) agricultural sectors' cost and production data for 2008 (Iranian Ministry of Agriculture, 2008); (5) GTAP 6 database to decompose labor account; (6) estimates of Iranian elasticities from Jensen and Tarr (2003); and (7) emission of the selected pollutants from the report of Iran's second national communication to UNFCCC for 2010 (UNDP, 2010).

The modified applied SAM table provides data on the costs of intermediate inputs and value added in 26 sectors and distinguishes household, government, investment and export demand and import supply by sectors. The database of the Iranian SAM of 1999 was modified using the above-mentioned sources of (2)–(6) and aggregated most of the industrial and services sectors, while agricultural sectors were decomposed into more sectors.

The agricultural sectors and commodities were initially disaggregated using shares of total costs and revenue. Industrial sectors other than agriculture industries presented in the original SAM of 1999 were aggregated into one sector namely, manufacturing. Also, services industries excluding transportation were aggregated into services.

Household accounts were also decomposed into 10 urban and 10 rural income deciles using HES data. We use share data from the HES to decompose the data on rural and urban household demand.

Another modification is the decomposition of labor account into skilled and unskilled labor, which is based on share values obtained from GTAP 6. Incorporating subsidies including energy and food subsidies as well as non-tariff trade barriers is another modification in our SAM. Non-tariff barriers are a special case of trade distortion. We do not focus on the trade distortions; however it is crucial to incorporate such distortion to get a model more compatible with the Iranian economy. Firstly, Tariff equivalent of non-tariffs was estimated using the Iranian import data of 2009 (Iranian Custom Administration, 2009). It was then incorporated like the tariffs account in the SAM.

Also, the emission data of the production process was disaggregated to make the pollutant emission compatible with the model sectors. This is disaggregated based on the data available in the report of Iran's second national communication to UNFCCC for 2010 (UNDP, 2010).

Simulation results

The model was run for removal of the energy subsidy under two scenarios of revenue redistribution, i.e. Complete Payment (CP) and Half Payment (HP) scenarios. In both scenarios, the part of revenue that accounts for the households is redistributed among all households in equal absolute amount. Production subsidy is also distributed among the sectors based on their energy cost share. It is worth to note that energy subsidy is removed for both producers who use energy as input in production process and consumers who use it for final consumption.

In this section, the macroeconomic and sectoral impacts of the scenarios are discussed (Table 3), followed by changes in welfare and pollutant emissions.

Macroeconomic and sectoral impacts

The macroeconomic and sectoral impacts of the scenarios are presented in Table 3. We focus briefly on energy and energy intensive sectors including manufacturing, transportation and services. In both of the scenarios, removing the energy subsidies expands the output in agricultural and agricultural-industries sectors, while the output of the other sectors decreases. Less than 2% of the production costs of agriculture sectors are assigned to energy, leaving an insignificant role for energy inputs. On the other hand, more than 80% of production value is allocated to value-added factors. Drawing these factors away from the sectors in which output decreases with the removal of energy subsidy as well as a decrease in their relative prices makes it suitable for agriculture sectors (except for aquaculture) to expand their output compared to the initial equilibrium.[9]

The rising energy prices, after removing subsidies, result in the rising prices paid by the consumers, lowering demand for energy products and their relative prices. On the other hand, direct payment to all households increases their incomes, especially those of the poor, causing demand for energy products to go up. As shown in Table 3, CP policy increases the private consumption by households including energy products consumption relative to their initial level. In the CP option, producers pay higher prices for the energy products compared to the

[7] –CO_2, CH_4 and N_2O are important in climate change and acidification (Kerkhof et al., 2009).
[8] Only energy products as intermediate input entail pollutant emission.

[9] Initial equilibrium refers to the situation of variables before implementing the energy subsidies removal.

Table 3
Sectoral and macroeconomic impacts of energy subsidies elimination (%).

Sectors	CP scenario			HP scenario		
	Output	Prices	Net export	Output	Prices	Net export
Wheat	20.7	20.4	−110.7	14.3	5	−32.6
Rice	55.1	−3	−41.3	17.3	−1	−13.7
Sugar beet	50.8	7	–	19.8	1	–
Cotton	46.3	−0.6	49.1	16.6	−2	11.5
Maize	14	−1.9	−7.6	9	−2.7	−0.4
Barley	10.4	9	−43.1	7	1.2	−10.8
Livestock	12.4	5.9	−7.4	7.1	−0.3	−12.1
Forestry	9.1	−3.5	78	6	−2.6	32
Aquaculture	−11.1	35.5	−54.5	−22.7	15.4	−59.6
Other agriculture	13.6	−4.3	30.5	13.6	−4	24.9
Mining	−24	15.1	−60.9	−6	1.3	−25.7
Food, beverage and tobacco	44.8	6.6	−288.4	17.5	−0.7	−39
Textile, leather and clothing	34.7	−3.3	49.6	10.2	−4.3	21.1
Wood and paper	10.1	4.1	−26.9	8.7	−0.4	−8.5
Crude oil and gas	−7	−10.9	16.4	−13.7	−7.9	1.2
Gasoline	−15.7	−9.1	36.8	−9.3	−6.9	26.9
Kerosene	−36.4	−10.6	−11.32	−42.2	−7.8	−26.7
Gasoil	−7.4	−9.8	24.5	−2.8	−7.4	20
Fuel oil	162.1	−32.3	229.3	74.5	−20.5	105.2
Liquid gas	−47	−22	−33.6	−78.3	−15.6	−74.6
Other oil products	−32.2	31.6	−450	−10.7	–	−166
Natural gas	−3.6	−7	–	−6.8	−6	–
Electricity	−1.8	10	−26	−1.5	1.6	−19.7
Manufacturing	−0.9	3.1	−16.6	1.9	−1.3	0.7
Transportation	−16.9	44.9	−727.5	−5.3	15.5	−340.1
Services	−6.1	−0.1	7	4.3	−0.4	−7.7

Macroeconomic variables	CP scenario	HP scenario
GDP	−20.71	−15.23
CPI	13.31	10.42
Government expenditure	−27.94	−19.91
Final consumption	28.20	4.50
Investment	−8.96	−8.91
Exports	23.29	4.31
Imports	33.91	6.71
Net export	1.37	0.01
Factor prices		
Unskilled labor	−16.87	−9.33
Skilled labor	−22.23	−9.61
Capital	−18.55	−14.55
Factor employment		
Unskilled labor	−2.58	−1.81
Skilled labor	−2.76	−1.82
Capital	−2.64	−1.92

initial equilibrium while they get no subsidy from energy subsidy revenues, resulting in a large decline in intermediate demand for energy products. Contrary to the increasing private demand for energy products by households, the total demand for energy products is expected to decrease due to the large decline of intermediate demand. Intermediate demand for energy products is much higher than their private final demand. Decreased demand results in lower prices received by energy producers relative to the initial equilibrium, while the price paid by energy consumers increases relatively. Production of energy products, compared to their initial level decreases as result of a decrease in producer price, however, fuel oil[10] output tends to increase significantly under CP option. Two sources may be mentioned for these changes. First, contrary to the other energy products, a greater part of fuel oil production value accounts for value added factors that experience a significant price decrease. So, resource reallocation that allows for lower production costs may be responsible for a part of significant output expansion compared to the initial level. Second, export expansion is expected to induce an increase in output. Especially, the substitution of fuel oil by gas in power generation creates a surplus of fuel oil that can be exported. Fuel oil exports from this source were around 80 mboe in 2001 (World Bank, 2004).

Under CP scenario, removing energy subsidies leads to an increase in production cost of manufacturing and transportation as energy-intensive sectors, causing a decrease in their outputs by 0.9% and 16.9%, respectively, compared to their initial levels. According to the same analysis procedure, increasing production costs of services also decreases its output by 6.1%.

Net exports of most of the sectors decrease compared to their initial levels, however, crude oil and gas and services that account for around two-thirds of the Iranian GDP benefit from the energy subsidy reform. This may be induced by falling domestic demand for their products.

Simulation results of cutting the energy subsidy under HP scenario are shown on the right hand side of Table 3. From the aspect of output changes direction, the results are similar to those of CP option with the exception of the manufacturing and services sector. From the aspect of relative price changes, the exceptions are livestock, food, wood and paper, and manufacturing sectors.

[10] Fuel oil is of heavier products of petroleum. Its density is over 900 kg/m^3. It covers all residual (heavy) fuel oils (including those obtained by blending). Kinematic viscosity is above 10 cSt at 80 °C. The flash point is always above 50 °C (OECD/IEA, 2005). Fuel oil is often used for power generation, however, metallurgical industries, refineries, cement works and electroplating industries also use fuel oil (World Bank, 2004).

Table 4
Welfare impacts of energy subsidies elimination in Iran (%).

	Income payment scenario	Income deciles	1	2	3	4	5	6	7	8	9	10	Overall
Urban	CP		113.9	70	52.6	42.8	33.4	28.5	20.3	12.4	5.52	−10.4	24.8
	HP		46.3	20.9	12.8	8.6	3.4	0.6	−3.4	−6.3	−8.2	−11.7	1.1
Rural	CP		259.6	156.5	120.7	102.9	84.2	70.2	55.2	44.5	28.8	6	61.1
	HP		126.3	74.7	56.6	48	38.3	31.7	24.4	18.8	10.7	−1.9	26.6

Energy products price level, with the exception of electricity, in the HP scenario is higher than in the CP option. Although final demand by households is expected to decrease due to cutting income transfer by one-half in HP scenario, considerable increase in intermediate consumption of energy products may cause such result. More than 70% of energy products intermediate consumption belongs to energy-intensive sectors (transportation, manufacturing and services). Expansion in the output of these sectors in HP scenario compared to CP is the main source of increased intermediate consumption and higher prices of energy products under HP scenario relative to CP option.

Net export of all sectors, except for manufacturing and services, changes in the same direction in both scenarios. However, the net export changes are larger in absolute value in CP scenario. In other words, energy subsidy elimination associated with HP policy results in lower trade compared to CP option. The possible reason for this difference is the energy products use. Under HP scenario as mentioned before, more energy products are expected to be used as intermediate input compared to CP one. As shown in Table 3, much more crude oil and gas are exported under CP scenario. In other words, higher energy product use under HP option compared to CP scenario results in lower export of crude oil and gas that is the leading sector in export.

As shown in the lower part of Table 3, removing energy subsidies has a significant impact on macroeconomic variables. Regarding the macroeconomic consequences of energy subsidy elimination, HP seems a more attractive option than CP, since changes in all variables, except for private consumption and trade, are more desirable under HP compared to CP scenario. While GDP falls by 20.7% compared to its initial level in CP scenario, the corresponding relative reduction is less than 16% in that of HP. Higher GDP under HP compared to CP option results from lower producer prices. These changes correspond to a 13.3% and 10.4% increase in CPI relative to its initial level, respectively. The relative increase of CPI seems considerable, especially at an inflation rate of 22% in 1990–2009 (UN data, 2008). Employment and factor prices also are relatively higher in HP scenario compared to CP scenario. However, private consumption is relatively much higher under CP. In spite of decreased government transfer to household in the HP option, its expenditure level is higher than that of CP scenario. HP is also preferred from the equity consideration point of view as it increases labor–capital price ratio more than the CP does, as a result of the fact that labor is owned by the poor rather than the rich households. However, in terms of employment changes there is a limited difference among primary factors.

Welfare impacts

The welfare impacts of eliminating energy subsidies measured in terms of EV are presented in Table 4. These impacts come from changes in the relative price of commodities and income earned by the households. As Table 3 indicates, elimination of the energy subsidies results in increased prices paid by consumers relative to the initial equilibrium while earning income from primary factors, especially capital return decreases. However, income transfer raises household income. In other words, income effect outweighs the consumption effect for most households, leading to higher welfare effects for most of the households. Especially, the poor receive a disproportionally large share of the transfers relative to their current incomes, leading to significant increase in their consumption. As Table 4 shows, removing energy subsidies under CP scenario increases the welfare of almost all income deciles except that of the urban's richest. The welfare gains for rural income groups are stronger since they have such low income that distribution of these revenues represents a significant share of their incomes. Urban and rural households' overall welfare gain from CP is 24.8% and 61.1%, respectively.

Welfare impacts of HP scenario are different from those of the CP option. As the results show, welfare gains for most of the rural income groups are around half of the gains obtained for CP option. Urban households' welfare changes strongly depending on revenue payment option, and while the vast majority of rich families in urban areas lose welfare under HP scenario, only the richest urban households face welfare reduction under CP program. Under HP scenario and compared to their initial levels, urban and rural income groups gain on average 1.1% and 26.6%, respectively. Khalili Araghi and Barkhordari (2012) also suggest a welfare gain for the Iranian households under scenario of 50% transfer of subsidy income transfer.

In general, the mentioned revenue distribution scenarios have two desired distributional impacts. First, they increase rural income groups' welfare more significantly than that of urban groups. Second, the low income groups experience a higher welfare increase compared to rich households. Even some of the richest household groups lose welfare relative to their initial levels.

Environmental impacts

Changes in emission of selected pollutants are shown in Table 5. Gasoline, gasoil, fuel oil and natural gas are the main pollutant producing products among the energy products.[11] Removing the energy subsidies reduces production and consumption levels of energy products except for fuel oil (Table 3); however, reductions for liquid gas and kerosene are higher than other energy products, followed by gasoline. About half of all natural gas is consumed by households; as a result, its consumption is not reduced significantly due to income transfer.

More considerable decrease in gasoline consumption compared to other energy products is the source of higher energy-based emission reduction of CO. Around 60% of CH_4 is released from gasoline consumption, so a significant energy-based emission reduction of 12.9% and 9.4% in CP and HP scenarios is observed, respectively. High involvement of gasoline and gasoil in energy-based emission of N_2O results in its significant emission reduction.

Among the other energy-based pollutants, CO_2 and NO_x are released mostly by natural gas. Insignificant reduction in natural gas consumption, relative to gasoline and gasoil, does not permit more reduction of CO_2 and NO_x emission. Under CP scenario, cutting energy subsidies would increase fuel oil consumption compared to the initial equilibrium. In spite of gasoil consumption reduction, however, removing energy subsidies causes SO_2 energy-based emissions to fall by only 2.6% due to increased fuel oil consumption.

The HP scenario indicates that removing the present energy subsidies and reallocating part of them to production will induce higher consumption of fuel oil, gasoline and gasoil compared to their consumption levels in CP scenario. However, natural gas consumption falls as households receive less income compared to CP option. Natural gas is

[11] These energy products account for more than 92% of energy-based emission of the selected pollutants (Iran's Energy Balance, 2009).

Table 5
Impact of energy subsidies elimination on pollutants emission in Iran (%).

Emission sources	Income payment scenario	CO_2	NH_4	N_2O	CO_2 equivalent	CO	NO_x	SO_2
CP	Energy consumption	−8.2	−12.9	−10.2	−8.2	−15.6	−7.6	−2.6
	Production process	4.1	17.3	17.2	10.4	9	−1.4	−7
	Non-energy final consumption	–	20.4	27.4	24	–	–	–
	Total	−5.8	17.5	18.5	−1.3	−14.5	−7.5	−2.8
HP	Energy consumption	−8.1	−9.4	−5.5	−8.1	−9.4	−4.9	1.9
	Production process	2.1	4.2	10.8	3.9	8.2	3.2	−13.7
	Non-energy final consumption	–	−0.6	4.2	1.9	–	–	–
	Total	−6.2	3.3	7.3	–4.1	–8.7	–4.8	1.4

considerable in emissions of CO_2 and NO_x, which show limited changes relative to CP scenario. Under CP option, emissions of CO_2 and NO_x reduce by 8.2% and 7.6%, respectively, while in HP scenario, the corresponding reductions are 8.1% and 4.9%, respectively. This happens because reduction in natural gas consumption under HP program relative to CP scenario is spoiled by the relative increase in consumption of gasoil and gasoline.

Emissions of CH_4, N_2O and CO from energy consumption sources tend to decrease as energy subsidies are cut; however, due to relative increase in consumption of gasoline and gasoil, their corresponding levels in HP scenario are higher than those in CP. Increase in fuel oil consumption is also responsible for the increase in energy-based SO_2 emissions by 1.9%.

Cutting energy subsidies leads to increased emissions of most pollutants from the production process. More than 85% of CO_2 emissions caused by production come from sectors whose outputs tend to fall as energy subsidies are removed. However, cutting energy subsidies increases CO_2 production based emissions. Much of this emission increase stems from expansion in fuel oil production (Table 3).

Reduction in production process emission of CH_4, caused from falling output of energy sectors, is outweighed by increased production of livestock and food industries that account for about one-third of production-based emissions, resulting in CH_4 emission growth. Increased emission of N_2O is mainly due to output expansion of agriculture sectors.

More than 44% of production-based CO is emitted from manufacturing production; the rest is emitted by agriculture sectors. So, increased agriculture output is the main source of CO production-based emission growth of more than 8%.

NO_x emission from the production process is highly dependent on manufacturing and mining production, changing with their output correspondingly. In the same way, production-based emission of SO_2 decreases correspondingly with crude oil and gas output.

Despite the increase in the general level of prices (CPI) compared to their initial levels, households' final demand significantly increases in CP scenario (Table 3), leading to increased consumption-based emissions of CH_4 and N_2O by 20.4% and 27.4%, respectively. Although redistributing half of energy subsidy revenue to the households (HP option) increases consumption by 4.5% (Table 3), changes in consumption composition induce CH_4 emissions to not change significantly. N_2O emission also increases correspondingly in HP scenario; nevertheless, it is much lower than that of the CP option.

There are differences between CP and HP scenarios in terms of total emissions, including production-based, energy and final non-energy consumption emissions. Regarding the total emissions of CH_4, N_2O and CO_2 measured in terms of CO_2 equivalent, HP scenario seems preferable to the CP one. This preference, to a considerable extent, is due to relative reduction in CH_4 and N_2O emissions from final non-energy consumption under HP program. While CO_2 equivalent emission decreases by 1.3% in CP scenario, the corresponding reduction in HP option is 4.1%. Considering the emissions of other pollutants including CO, NO_x and SO_2, CP scenario may be preferred to that of HP, caused mostly from falling energy consumption. For quantitative comparison of the scenarios, we applied the World Bank (2004) estimates for damage costs of pollutants that contain three ranges of low, medium and high levels. We aggregate CH_4, N_2O and CO_2 into CO_2 equivalent. Based on the medium estimate,[12] the value of decrease in emission of pollutants will amount to 527.3 and 492.1 million USD in CP and HP scenarios, respectively. If we consider low estimates, the corresponding values would be 242.6 and 180.3 million USD. However, the priority of the scenarios changes in reverse order if we use the high estimates, as it corresponds to 16,850 and 29,585 million USD damage cost reduction in CP and HP options, respectively. Thus, from an environmental point of view, CP scenario is not necessarily preferred to HP.

From an emission reduction point of view, energy subsidy elimination success is limited to decrease in emissions from energy consumption, while emission of some pollutants from the production process and final consumption tend to increase.

Conclusion

The Iranian government has two options, i.e., CP and HP scenarios, to prevent negative impacts of the energy subsidy elimination. Irrespective of the policy options, removing energy subsidies is a considerable shock as it is expected to decrease the Iranian GDP relative to the initial equilibrium by at least 15% via resource reallocation and to contribute to the Iranian inflation by more than 10%.

Removing the energy subsidies, especially under CP scenario, is expected to change the output composition in favor of agriculture and agriculture-based industries as they are less dependent on energy.

In general, three implications may be derived from the findings contributing to show the applied scenario differences. First, all macroeconomic variables with the exception of final consumption and net export are expected to experience desirable changes as a result of removing energy subsidies basically under HP scenario compared to implementing it under CP option. Final consumption by households would increase by 28.2% under CP scenario, while rising by only 4.5% in HP option. As far as the welfare changes and especially the welfare gains of vulnerable groups are concerned, the first six urban income deciles and all of the rural groups, except the richest decile, still experience welfare gains under HP scenario. In other words, a great part of the differences in consumption under the two policy scenarios results from reduction in high income groups' consumption under HP option, leaving fewer concerns about lower consumption in HP.

The second implication is the environmental aspects of the policy options. Based on the low and medium estimates of damage cost, CP is preferred to HP as it results in further decrease of emission damages, whereas the latter is preferred to the former option taking the high estimate damage cost into account. As far as the environmental context is concerned, under CP scenario a considerable decrease in energy-based emission of the pollutants is outweighed by higher emissions caused by non-energy final consumption, therefore significant attempts in reducing pollutants emitted from energy consumption may be spoiled easily by increasing final consumption. Generally speaking, in terms of

[12] Medium damage cost estimations for CO_2, NOx, CO and SO_2 are 10, 600, 188 and 1825 USD per ton, respectively.

environmental aspect, it is difficult to determine the better choice among the policy options.

Third, there is a political issue that may contribute to the preference for the HP option over CP. In general, subsidizing the energy is a distortion and it is suggested that the subsidies to some socially inevitable cases and, especially to anti-poverty programs be limited. Therefore, we should expect the Iranian government to finally plan to perform the subsidy program in limited form. Redistribution of the whole of the subsidy revenue back to households (CP option) makes them more dependent on the income transfer program, and more difficulties are expected in the future with regards to shrinking the income transfer or to targeting it toward vulnerable groups. Thus, by choosing the HP scenario policy makers may face fewer administrative problems.

Based on the above implications, energy subsidies should be removed where the HP scenario is chosen. However, as a result of the increasing prices and their association with the current high inflation in Iran, redistributing a part of the subsidies back to all households in general and to vulnerable groups specifically, is strongly recommended.

Several possible extensions of this study are proposed for future studies. First, potential efficiency gains resulting from higher energy prices were not covered and should be addressed. Second, an alternative option for subsidy revenues is to invest them. Third, we applied a static CGE model; a more comprehensive investigation may be achieved using a dynamic CGE model.

References

Alam MJ, Begum IA, Buysse J, Rahman S, Van Huylenbroeck G. Dynamic modeling of causal relationship between energy consumption, CO_2 emissions and economic growth in India. Renew Sustain Energy Rev 2011;15:3243–51.

Anderson K, McKibbin WJ. Reducing coal subsidies and trade barriers: their contribution to greenhouse gas abatement. , 7. University of Adelaide, Center for International Economic Studies (CIES); 1997 [http://www.cepr.org/pubs/dps/DP1698.aspS].

Aydin L, Acar M. Economic impact of oil price shocks on the Turkish economy in the coming decades: a dynamic CGE analysis. Energy Policy 2011;39:1722–31.

Basranzad H, Nili F. Analysis of pricing policy of energy carriers in Iranian economy. J Econ Res 2005;68:201–26. [in Persian].

Beghin J, Dessus S, Ronald-Holst D, Mensbrugghe VD. Empirical modeling of trade and environment. Trade and environment in general equilibrium: evidence from developing economics. Dordrecht: Kluwer Academic Publishers; 2002. p. 31–78.

Burniaux JM, Martin JP, Oliveira MJ. The effects of existing distortions in energy markets on the costs of policies to reduce CO_2 emissions: evidence from Green. OECD Econ Stud 1992:141–65.

Central Bank of Iran. Iranian Social Accounting Matrix of 1999. http://www.cbi.ir/simplelist/5728.aspx, 1999.

Central Bank of Iran. A yearly publication of the Central Bank of Iran; 2009.

de Melo J, Tarr D. A general equilibrium analysis of US foreign trade policy. Cambridge, MA: MIT Press; 1992. p. 41–63.

Dube I. Impact of energy subsidies on energy consumption and supply in Zimbabwe. Do the urban poor really benefit? Energy Policy 2003;31:1635–45.

Gangopadhyay S, Ramaswami B, Wadhwa W. Reducing subsidies on household fuels in India: how will it affect the poor? Energy Policy 2005;33(18):2326–36.

Sharif Hossain Md. Panel estimation for CO_2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy Policy 2011;39:6991–9.

IEA. World energy outlook insights, looking at energy subsidies: getting the prices right. Paris: OECD; 1999.

Iran's Energy Balance. Deputy of electricity and energy affairs. Tehran: Ministry of Energy; 2008 [http://pep.moe.org.ir].

Iran's Energy Balance. Deputy of electricity and energy affairs. Tehran: Ministry of Energy; 2009 [http://pep.moe.org.ir].

Iranian Custom Administration. Trade statistical yearbook. http://www.irica.gov.ir, 2009.

Iranian Ministry of Agriculture. Cost statistical yearbook. http://dbagri.maj.ir/cost/, 2008.

Iranian Statistical Center. Household expenditure survey; 2008 [Tehran].

Jensen J, Tarr D. Trade, exchange rate and energy pricing reform in Iran: potentially large efficiency effects and gains to the poor. World Bank policy research working paper 2768; 2002. [www.worldbank.org/research/trade/majoract.htm].

Jensen J, Tarr T. Trade, exchange rate, and energy pricing reform in Iran: potentially large efficiency effects and gains to the poor. Rev Dev Econ 2003;7(4):543–62.

Kebede B. Energy subsidies and costs in urban Ethiopia: the cases of kerosene and electricity. Renew Energy 2006;31:2140–51.

Kerkhof AC, Nonhebel S, Moll HC. Relating the environmental impact of consumption to household expenditures: an input–output analysis. Ecol Econ 2009;68:1160–70.

Khalili Araghi M, Barkhordari S. An evaluation of the welfare effects of reducing energy subsides in Iran. Energy Policy 2012;47:398–404.

Khiabani N. A CGE framework to evaluate increased prices of energy products in Iranian economy. J Energy Econ Stud 2008;16:1–34. [in Persian].

Lin B, Jiang Z. Estimates of energy subsidies in China and impact of energy subsidy reform. Energy Econ 2011;33:273–83.

Liu W, Li H. Improving energy consumption structure: a comprehensive assessment of fossil energy subsidies reform in China. Energy Policy 2011;39:4134–43.

Manzoor D, Aghababaei ME, Haghighi I. Analysis of rebound effect of improved efficiency in electricity consumption in Iran: A CGE model. J Energy Stud 2011;28:1–23. [in Persian].

Marrero GA. Greenhouse gases emissions, growth and the energy mix in Europe. Energy Econ 2010;32:1356–63.

McDonald S, Thierfelder K, Robinson S. Globe: a SAM based global CGE model using GTAP data. http://econpapers.repec.org/paper/usnusnawp/14.htm, 2007.

Menyah K, Wolde-Rufael Y. Energy consumption, pollutant emissions and economic growth in South Africa. Energy Econ 2010;32:1374–82.

OECD/IEA. Energy Statics Manual. France: IEA PUBLICATIONS, 9 rue de la Fédération, 75739 PARIS Cedex 15; 2005.

Pao HT, Tsai CM. Modeling and forecasting the CO_2 emissions, energy consumption, and economic growth in Brazil. Energy 2011;36:2450–8.

Pao HT, Yu HC, Yang YH. Modeling the CO_2 emissions, energy use, and economic growth in Russia. Energy 2011;36:5094–100.

Saboohi Y. An evaluation of the impact of reducing energy subsidies on living expenses of households. Energy Policy 2001;29:245–52.

Sancho F. Double dividend effectiveness of energy tax policies and the elasticity of substitution: a CGE appraisal. Energy Policy 2010;38:2927–33.

Soytas U, Sari R, Ewing BT. Energy consumption, income, and carbon emissions in the United States. Ecol Econ 2007;62:482–9.

Steenblik RP, Coroyannakis P. Reform of coal policies in Western and Central Europe: implications for the environment. Energy Policy 1995;23:537–53.

Tsani SZ. Energy consumption and economic growth: a causality analysis for Greece. Energy Econ 2010;32:582–90.

UN data. http://data.un.org, 2008.

UNDP (United Nations Development Program). Department of Environment. Iran second National Communication to United Nations Framework Convention on Climate Change (UNFCCC). Tehran: National Climate Change Office, Department of Environment; 2010.

UNEP and IEA. Reforming energy subsidy, an explanatory summary of the issues and challenges in removing or modifying subsidies on energy that undermine the pursuit of sustainable development. Paris: UNEP; 2002.

Wang SS, Zhou DQ, Zhou P, Wang QW. CO_2 emissions, energy consumption and economic growth in China: a panel data analysis. Energy Policy 2011;39:4870–5.

World Bank. Islamic Republic of Iran energy-environment review policy note. Report No. 29062-IR; 2004. [Washington D.C.].

Zhang XP, Cheng XM. Energy consumption, carbon emissions, and economic growth in China. Ecol Econ 2009;68:2706–12.