Economic Analysis and Policy 81 (2024) 1535–1557

Contents lists available at ScienceDirect

Economic Analysis and Policy

journal homepage: www.elsevier.com/locate/eap

Modelling Economic Policy Issues

Analysis of energy policy reform in Iran: Energy and emission intensity changes

Hasan Raei [a], Abbas Maleki [b], Zakariya Farajzadeh [c,*]

[a] Master of Energy Systems Engineering, Sharif University of Technology, Department of Energy Engineering, Sharif University of Technology, Azadi Ave., Tehran, Iran

[b] Professor of Energy Policy, Sharif University of Technology, Department of Energy Engineering, Sharif University of Technology, Azadi Ave., Tehran, Iran

[c] Associate Professor of Agricultural Economics, Department of Agricultural Economics, College of Agriculture, Shiraz University, Shiraz, Iran

ARTICLE INFO

Keywords:
Energy subsidy
Energy intensity
Emission intensity
Dynamic CGE

ABSTRACT

The Subsidized energy system of Iran, with its high financial burden, failed to achieve its intended economic goals, resulting in increased energy consumption and pollutant emissions. Energy product subsidies in Iran are among the highest in the world and have important implications for developing countries. This study examines the impact of subsidy removal policy on energy and emission intensities using a Dynamic Computable General Equilibrium model. The findings reveal that after subsidy removal, total output experiences an annual growth of around 1.5%, with output composition changes mainly favoring agriculture and services that are less energy dependent. However, prices soar by at least 10% owing to the higher costs of energy products. The decreasing trend in energy intensity after subsidy reform is accompanied by a decrease in emission intensity. Higher prices of energy after subsidy removal and the corresponding improvement in the efficiency of energy consumption lead to lower emission intensity.

1. Introduction

Energy plays a central role in the production process and contributes to the living standards. In recent decades, these contributions have persuaded governments to proceed with their growth and development goals via subsidized energy products. Energy product subsidies[1] are inseparable from public policies (El-Katiri and Fattouh, 2017). Governments in developing countries prefer subsidized energy products to other social and economic support programs (Iwaro and Mwasha, 2010). Sponsoring energy products is mainly intended to expand low-income groups' access to modern energy utilization (Liu and Li, 2011), protect domestic industries against international competition, expand employment, foster economic growth, stabilize prices, and increase social equity (Lin and Jiang, 2011). Improving social welfare and patronage of domestic people are other possible reasons for energy subsidies.

* Corresponding author.
E-mail addresses: hasan.raei@alum.sharif.edu (H. Raei), maleki@sharif.edu (A. Maleki), zakariafarajzadeh@gmail.com (Z. Farajzadeh).

[1] Although subsidy is controversial to define and measure (El-Katiri and Fattouh, 2017), energy subsidy can be defined as the gap between consumer or producer price and market price (de Moor and Calami, 1997).

https://doi.org/10.1016/j.eap.2024.02.023
Received 2 August 2023; Received in revised form 12 February 2024; Accepted 18 February 2024
Available online 19 February 2024

These subsidies are considered a social safety net; however, they are costly and inefficient (El-Katiri and Fattouh, 2017).[2] In addition, they significantly distort economic incentives and lead economic activities in a distorted path. From the distributional perspective, while energy producers, producers of energy-consuming facilities, and high-income households, especially urban ones, benefit from subsidized energy systems, the intended groups are not expected to receive as much support as planned. There is evidence that low-income groups have been halted in an undesirable situation because they are not capable of accessing energy-using facilities (Goli, 2011). Contrary to the goals mentioned for subsidizing energy products, even energy-rich countries are expected to face severe challenges, including CO_2 and other greenhouse gases (GHGs) emissions, as subsidizing energy will result in inefficient and wasteful energy use (Lin and Jiang, 2011), causing higher pollution emissions. From the emission and environmental points of view, energy subsidies are destructive because they impose a heavy burden on the government's expenditures, accompanied by higher emissions. Financing these subsidies is different in countries depending on energy sector ownership, the government's financial situation, and being the importer or exporter of energy products (Fattouh and El-Katiri, 2012).

The polluting potential of energy products and their pressure on the government budget, especially in recent years, has cast some doubts on energy subsidies and the intensive use of energy (Mahdavi, 2014; Sarrakh et al., 2020), persuading policymakers in different counties to reform energy prices and targeting lower energy subsidies (Mahdavi, 2014).

Regarding the extent of the energy subsidies discussed in the following section, the reform in the price of energy products will affect output, energy use, and pollutants emissions significantly, requiring a comprehensive examination. Thus, in the current study, a multi-sector dynamic Computable General Equilibrium (CGE) model based on Social Accounting Matrix (SAM) data is developed to examine the effects of energy subsidy removal on energy and emission intensity, as well as output changes in economic sectors. It is worth noting that subsidy reform generates revenue, and two policy options for revenue redistribution are examined. As presented in the following sections, significant changes are expected in the economic and environmental variables, indicating the necessity of applying a comprehensive simulation model and understanding by policymakers.

The remainder of this paper is organized as follows. Section 2 discusses the Iranian background and relevant literature. The model features, along with the decomposition analysis framework are briefly presented in Section 3. The data were then described. Section 4 presents and discusses the simulation results of the model, and conclusions are presented in Section 5.

2. Iranian background and literature review

2.1. Iranian background

The Iranian government started reforming energy subsidies in December 2010, dramatically increasing the prices of gasoline (300 percent), natural gas (50 percent), and gas oil (900 percent). Restricting international sanctions and high inflation after the reform led to a suspension of further steps in subsidy reform (El-Katiri and Fattouh, 2017). The steep fall in the Iranian currency, as depicted in Fig. 3-Appendix, resulted in a reduction in the real prices of energy and a growing gap between the domestic and global prices of energy products. Indeed, the price reform eroded.[3] This issue is illustrated in Figs. 2-and 3-Appendix, where the domestic energy price in terms of real values shows a decreasing trend, indicating an increasing gap between domestic and global prices. In fact, the prices paid by domestic consumers account for less than 30 percent of the world's energy price at its highest levels.[4] In addition, as shown in Fig. 4-Appendix, higher values correspond to lower oil prices, indicating that the higher shares of prices paid by domestic consumers mainly originated from lower world oil prices. In general, energy subsidies have been increasing since the price reform was condemned to failure.

Currently, energy products in Iran are heavily subsidized. For instance, the energy subsidy in Iran exceeds that of China by USD 4.2 billion, while in terms of GDP, there is a significant difference between Iran and China. The GDP of China amounted to USD 27.3 Trillion in 2021, while the corresponding figure for Iran was approximately USD 1.45 Trillion (IEA, 2022; World Bank, 2021). As Fig. 1-Appendix illustrates, Iran, with USD 29.7 billion, ranked first position in the energy subsidy in 2020, accounting for 4.7% of Iranian GDP, followed by China, with a subsidy value of USD 25.5 billion and accounting for only 0.2% of China's GDP, (IEA, 2020; World Bank, 2021). Electricity, natural gas, and oil products accounted for 42.1, 41.1, and 16.8 percent of total energy subsidies, respectively. The economic growth of Iran was less than 3.8% during 1961–2021, while the corresponding figure for China was approximately 8%. Iranian economic growth has slightly exceeded global growth (World Bank, 2021). Thus, a subsidized energy system intended to achieve higher economic growth has not yet reached its aim. The main goals of the Iranian government to subsidize energy products are to encourage economic growth, employment, price stabilization, and social equity. However, there is no compelling evidence indicating the achievement of these goals (Bastanzad and Nili, 2005).

[2] Government subsidies encourage investment in industries. For instance, Yang et al. (2019) show that energy subsidy promotes investment in renewable energy. Output expansion will raise the tax revenue sources for the government. Thus, it will persuade the governments to enact energy subsidy programs.

[3] As declared by Guillaume et al. (2011), domestic inflation or exchange depreciation can erode small domestic price increases.

[4] In Fig. 4-Appendix, the price ratio has been calculated based on two values for the exchange rate. Officially, the subsidies of energy products are reported while the exchange rate reported in the government budgetary system is applied. We used the market exchange rate as another alternative for the exchange rate. The price ratio named *adjusted* includes the market exchange rate in the calculation process.

Regarding large oil and gas reservoirs,[5] energy products are supplied at much lower prices than global prices, resulting in the intensive and wasteful use of energy (Movahhedi, 2021). The price of energy products is determined by the government and is significantly lower than the global market price. The current situation in the energy system has caused budgetary problems, and the government has been convinced to reform prices. In addition, Iran has experienced high general or total inflation,[6] measured in terms of consumer price index (CPI) changes. As presented in Fig. 2-Appendix, the price paid by consumers has not increased proportionally, resulting in an increasing gap between domestic and global energy prices (Eskandary et al., 2016). As shown in Fig. 3-Appendix, the real price of energy products has decreased over the last decade, resulting in an increasing amount of energy subsidies. This widening gap with increasing population has caused an increase in the use of energy products (Khiabani and Hasani, 2010). This system has led to the expansion of energy-intensive sectors such as manufacturing.

In addition to the financial burden of energy subsidies, price distortions have resulted in high greenhouse gases emissions (Asiaei et al., 2012). CO_2 emissions grew annually by more than 4% during 1990–2019, increasing from less than 200 to more than 630 million tons. The corresponding global growth rate is less than 1.8% (World Bank, 2019). The economic growth figures for Iran and the world for the same period were 2.93 and 2.99 percent, respectively. A comparison of the figures for economic growth and CO_2 emissions indicated an increasing trend in CO_2 emission intensity in Iran. Energy subsidies account for a significant part of the growing emission intensity because they play a dominant role in CO_2 emissions. Worldwide emission intensity has been decreasing over that period, depicting a contradictory trend of emission intensity for Iran compared to that of the global economy.

Although financial and environmental concerns make it reasonable to suggest price reform and contract energy subsidies, they also contract the output and profitability of the industries. For the Iranian economy, Jensen and Tarr (2003) showed that a reduction in energy subsidies would reduce output in most of energy and manufacturing sectors. These effects result in lower welfare. In the short run, the limited possibility of technology change restricts the appropriate reaction of firms in response to increased energy prices, resulting in lower output and profitability. Redistribution of subsidy revenue can be considered a solution (Mahdavi, 2014). The redistribution of subsidy revenues dampens the contradictory output effects of subsidy reforms in Iran. Two subsidy revenue redistribution scenarios are likely to be implemented based on the Iranian subsidy targeting program[7] (STP). Under the most likely scenario, 50% of the subsidy revenue is assumed to be received by the household, whereas 30% is transferred to producers as production subsidy. Another possibility is to redistribute the entire subsidy revenue to households (Farajzadeh and Bakhshoodeh, 2015).

Energy price reform is inevitable; however, it has significant welfare and environmental effects that deserve further investigation. The welfare effects among income groups are expected to be substantial. The current literature on energy subsidy reform has mainly examined output and welfare effects (Jensen and Tarr, 2003; Manzoor et al., 2010), while energy and emission effects have not been considered profoundly and over time. Additionally, over the last decade, the exchange rate has experienced compelling changes, reinforcing the price gap between domestic and global prices of energy products. In particular, the emissions from energy consumption were investigated and compared with the output level, forming the emission intensity, defined as the pollution emitted per unit of output.

According to the Paris Agreement, Iran intends to mitigate GHG emissions by 4% by 2030, compared to its level in 2010. However, this could potentially reduce emissions by 12% (UNFCCC, 2014). Although 65% of global CO_2 emissions are caused by energy production and consumption (Marrero, 2010), the corresponding figure for Iran is greater than 81% (UNDP, 2017). Contrary to the decreasing trend in energy intensity worldwide, it has been increasing over the last few decades in Iran. Iran is the 8th largest emitter of CO_2 in the world while it is ranked 18 in terms of GNI[8] (PPP[9]), indicating a higher emission intensity compared to the world. The CO_2 emission intensity is 0.56 Kg, which is twice the global average (World Bank, 2018).

In summary, as mentioned above, the energy and emission intensity of Iran remains among the most unacceptable globally. The high consumption of heavily subsidized energy products accounts for this consumption pattern. The significant reserves of energy resources have endowed Iran with a cheap energy supply, and over the last decade, the real price of energy products has been decreasing. While energy subsidies were intended to provide, among others, higher economic growth, contrary to a high financial burden, they failed to approach the goal. In addition, the subsidized energy supply system resulted in higher emission intensity. From financial, economic or resource allocation, and environmental points of view, price reform is reasonable and persuasive. However, regarding the extent of energy use in the Iranian economy and the possible impacts of the proposed scenarios on the output composition and environmental variables, a comprehensive and economy-wide examination is needed.

[5] Based on British Petroleum (2021), Iran, with 32.1 trillion cubic meters of gas, has the second largest reservoirs in the world. The corresponding rank for oil is fourth, with 157.8 billion barrels.

[6] As presented in Fig. 2-Appendix, after the oil crisis of 1973, only four years are observed with an inflation rate of less than 10 percent, while many years have experienced inflation rates of greater than 20 percent. The inflation rates of Iran are much higher than global figures (World Bank, 2021). From 1960-2021, Iran experienced 15.7 percent inflation annually, on average.

[7] The Iranian government started to reform energy subsidies in 2010, in which the energy products prices were supposed to increase to 90 percent of their international prices. However, due to international sanctions and the steep fall in the Iranian currency value, further steps were suspended (El-Katiri and Fattouh, 2017).

[8] Gross National Income

[9] Purchasing Power Parity

2.2. Literature review

Many studies have focused on the output and welfare effects of the Iranian energy subsidy reforms (Khiabani, 2008; Manzoor et al., 2010; Shahmoradi et al., 2011). They suggest a reduction in welfare and output, especially in energy-intensive sectors, although a contraction in energy use has also been noted. However, the welfare and output effects depend on whether subsidy revenues are redistributed. For instance, Farajzadeh and Bakhshoodeh (2015), using a static CGE model, show that redistributing half of the subsidy revenue back to households induces a welfare loss among urban high-income deciles, while low-income groups enjoy higher consumption. They also report a significant reduction in output in the short run. In Egypt, a 4% reduction in GDP and substantial welfare losses have been reported (Abouleinein, 2009). In addition, adverse effects of energy subsidy removal, while the corresponding revenues are not redistributed, have been reported in China (Lin and Jiang, 2011; Lin and Ouyang, 2014). Similar results for output and welfare changes have been suggested for Malaysia (Solaymani et al., 2014). The output effects of energy subsidy reforms have been the focus of many studies. This effect is more significant in countries where energy is heavily subsidized. For example, in Iran (Eslami Andargoli et al., 2012) and Kuwait (Gelan, 2018), the output effects of removing only electricity subsidy are expected to be serious. In Iran, output effects without the redistribution of subsidy revenues are unacceptable. Therefore, it seems that energy subsidy removal, at least in the short run, should be accompanied by revenue redistribution, especially in Iran where energy products are heavily subsidized. Price reform brings about allocation efficiency, but it would not be accessible in the short run, requiring revenue support (Shahmoradi et al., 2011; Hoseininasab and Hazeri Niri, 2012). In the long-term, some benefits are expected. For example, in Malaysia, replacing fossil fuels with less polluting energy products, lowering the financial burden, and reducing energy use has been suggested (Yusoff and Bekhet, 2016; Li et al., 2017). Similar benefits from price reform are expected in Iran (Manzoor and Haghighi, 2010). Reduction in energy consumption in the short run and improvement in the consumption composition of energy products are expected benefits of the energy subsidy reform in China (Liu and Li, 2011). It is worth noting that revenue redistribution cannot be the ultimate goal of subsidy removal or price reform of energy products. A significant body of literature recommends energy subsidy removal with revenue redistribution as a short-run measure of dampening adverse effects (Shahmoradi et al., 2011; Hoseininasab and Hazeri Niri, 2012); however, AlShehabi (2013) declares that subsidy revenue redistribution will negatively affect the labor market and recommends investment of subsidy revenues. Specifically, investment in renewable energy production has been highlighted in the literature (Husaini et al., 2023).

As far as the adverse effects of the energy price reform are considered, the welfare effects of households should be investigated profoundly, since the consumption of Iranian households is not considerable, and Iran encounters an increasing poverty rate. It increased from 22 percent in 2011 to 32 percent in 2019 (Ministry of Social Welfare, 2021). It is worth noting that this poverty rate is expected to increase after 2019 because of high inflation and insignificant economic growth. In particular, the welfare effects on rural households were more substantial. Accordingly, the redistribution of subsidy revenue back to households is as essential as price reform. More vulnerable rural income groups have also been reported in Malaysia as well (Solaymani et al., 2014). Furthermore, for Malaysia, energy coupons for targeted groups, especially agricultural producers, are recommended, while coupons are recommended to be limited to particular thresholds to guarantee that consumers do not overconsume (Husaini et al., 2023).

Despite the welfare losses occurring in the short run after the energy price reform, pollution emissions are expected to contract after the reform as suggested for CO_2 in China (Lin and Ouyang, 2014), Malaysia (Li et al., 2017), Kuwait (Gelan, 2018) and Iran (Farajzadeh and Bakhshoodeh, 2015). The primary cause of the decrease in pollutant emissions was the reduction in energy use after the price reform. While the impact of energy price reforms on pollution emissions and energy use has been the focus of the literature, especially in recent decades, their changes compared to the output level, which measures emission intensity and energy intensity, respectively, have not been considered appropriately. To the best of our knowledge, Lin and Jiang (2011) is one of the limited empirical works examining the impact of subsidy reform accompanied by revenue redistribution on CO_2 emissions intensity, showing the non-increasing effect of subsidy reform in China. However, emission tax has been suggested as a measure to reduce the emissions. For example, Cabalu et al. (2015) showed that a carbon tax of USD 5 per ton leads to a 9.8% reduction in emissions in the Philippines.

To the best of our knowledge, increasing emission intensity and driving forces have not been adequately considered. In addition, CO_2 as the primary source of global warming (Böhringer and Löschel, 2006), has been the major case of interest; however, other pollutants are also important.[10] Evidence has shown that energy intensity is a determinant of greenhouse gas (GHG) emissions and carbon intensity (Steckel et al., 2011; Cheng et al., 2014). Also, for China's transportation emissions intensity, energy intensity is the primary determinant of decreasing carbon emissions (Yu et al., 2021). Accordingly, there is a need to focus on energy intensity to lower it. For example, energy intensity in Canada decreased by 23% between 1995 and 2010 (Torrie et al., 2016). Energy intensity in China, the largest energy consumer (Yang et al., 2016), has decreased since 1978 (Fisher-Vanden et al., 2004). A decreasing trend was reported for energy intensity in the UK and the USA, while the total energy consumption increased (Csereklyei and Stern, 2015; Rühl et al., 2012). A similar result was obtained for OECD countries (Liddle, 2012). Contrary to the decreasing trend in global energy intensity, Iran experienced an increasing tendency of energy intensity from 1973 to 2013 (Farajzadeh and Nematollahi, 2018). Energy use efficiency has been suggested as a driving force for decreasing energy-related CO_2 emission intensity in Australia (Shahiduzzaman et al., 2015) and China's transportation sector (Yu et al., 2021).

[10] Methane (CH_4), Nitrous Oxide (N_2O), Sulfur Dioxide (SO_2), Nitrogen Oxides (NO_x), and Carbon Monoxide (CO) are also important to examine since Iran stands for rank fourth in the production and consumption of oil and gas in the world (Farajzadeh, 2018). Based on the average values of damage costs estimated for pollutants (World Bank, 2004), around 43.7% of damages are related to NO_x, SO_2, and CO, and the remaining part is assigned to CO_2 (Farajzadeh and Nematollahi, 2023).

The output level is another factor that influences emission intensity. Specifically, there is significant evidence from China (Pan et al., 2019; Dong et al., 2018; Han et al., 2019). Rodríguez and Pena-Boquete (2017) suggest that the source of output expansion is important. If output expansion results from growth in labor productivity, a lower emission intensity is expected. The output-emission relationship, mainly in the context of the Environmental Kuznets Curve[11] (EKC), has been the focus of empirical works. For instance, Martınez-Zarzoso and Bengochea-Morancho (2004) showed, for CO_2, the existence of an environmental Kuznets curve in 22 OECD countries. Salari et al. (2021) found an inverted U-shaped relationship between CO_2 emissions and GDP in the US. An inverted U-shaped relationship has also been pointed out for the EU-27 (Mohammed et al., 2023) and the sub-Saharan African region (Aminu et al., 2023). In the EU-27, a 1% increase in GDP is expected to increase carbon emissions by 0.7%. Fan et al. (2006) reported that economic growth is the primary driver of CO_2 emissions in countries with different income levels. Jiang et al. (2022) showed an increase in emission intensity situation in China's economy since they reported a 4.81% decrease in China's GDP due to the COVID-19 pandemic, which was accompanied by a 4.58% decrease in CO_2 emissions.

A review of the literature shows that there is significant literature concerning energy subsidy in Iran; while they examine mainly the total energy demand and, in some cases, the total emissions of CO_2, they did not look at the relationships between energy subsidy reform and energy, and emission intensity. The current study takes further steps and examines the effect of energy subsidy reform on energy and emission intensity in terms of different energy products and selected pollutants. The current study is timely in that it uses more recent data on energy subsidies. In addition, it contributes to the literature in several respects. First, it applies a dynamic approach and depicts the time path of the Iranian economy after reforming energy prices by applying a multi-sector and economy-wide complex dynamic CGE model in which energy subsidies are determined endogenously for aftershock periods. In other words, in addition to the macroeconomic variables, the growth path for energy products consumption and pollutants emissions is also presented. In addition, a modified Social Accounting Matrix (SAM) is applied in the simulation process of the model. Second, the effect of policy reform on energy and emission intensity is examined, accounting for both environmental and economic impacts. The intensity variables are more articulated, as they combine environmental and economic variables. These variables allow us to examine the trade-off between the economic and environmental variables. Third, the emission intensity is decomposed into its driving components. This allows us to examine the emission intensity changes in terms of its sources, including energy consumption efficiency, energy structure or the composition of the energy products, and energy intensity. Fourth, it applies a modified SAM corrected for distortions, such as subsidies and trade barriers. This matrix is a policy analysis-oriented data-base that is a robust instrument for examining distorted environments. Energy subsidies and trade barriers are central distortions. Fifth, energy products were considered individually, including gasoline, kerosene, gas oil, fuel oil, liquid gas, natural gas, and electricity. This implies that, for energy products as intermediate inputs, the degree of substitution for each other matters. Finally, the evaluation of pollutants emissions was extended beyond CO_2 and a broad category of pollutants, and three sources of pollution emissions were examined. Pollutants emissions, in terms of their origin, are production-based, energy product use, and final non-energy consumption. This feature also distinguishes the current study from related literature. Further, in terms of energy and emission intensity, the Iranian case is interesting because the general trend of global energy and emission intensity in the current literature is decreasing, whereas Iran has experienced an increasing trend for these variables.

3. The model and data

To achieve the study objectives, we developed a recursive dynamic Computable General Equilibrium[12] (CGE) model for the Iranian economy. The small open economy model designed for energy policy analysis is based on the static models of Jensen and Tarr (2003), and Farajzadeh and Bakhshoodeh (2015), and the dynamic model of Farajzadeh (2018). The model includes detailed production sectors and consumer income groups that use Social Accounting Matrix (SAM) data. The developed model and applied SAM contain features that are consistent with the structure of the Iranian economy. These features are consumption subsidies, including energy subsidies and trade distortions incorporated into the SAM and the model framework. The model also includes pollutants emissions from energy use, production processes, and final non-energy consumption by households. Households were considered in urban and rural income deciles, and the utility function was assumed to be a Linear Expenditure System (LES).

Value-added factors include skilled and unskilled labor, and capital, which are assumed to be perfectly mobile among sectors, as applied by Gharibnavaz and Waschik (2015), for the Iranian economy. The value-added inputs are aggregated based on the constant elasticity of substitution (CES) function. Following the Armington assumption, goods used as intermediate inputs are a composite of imported and domestic goods aggregated based on the CES function. The total production technology is a function of the value-added and intermediate inputs aggregated using the fixed-coefficient (Leontief) production function. Individual firms behave competitively

[11] An EKC curve illustrates an inverted U-shaped relationship between emissions and economic growth. It is worth noting that EKC is a widely-used tool applied for other variables as well. For instance, Le et al. (2020) examined the relationship between export diversification and income inequality and found inverted U-shaped relationship.

[12] Computable general equilibrium models include three characteristics. These models are solved numerically (computable), their modeling extension is economy-wide (general), and they are based on the idea of equilibrium in which individual behavior is based on optimization (Burfisher, 2016). In the equilibrium situation, the endogenous variables adjust such that, subject to the constraints, producers maximize their profit and consumers maximize their welfare as well as in each market, supply equals demand. The solving technique is calibration, in which parameters are chosen such that the applied functional forms and data are consistent. In other words, the data produce a solution to the developed model (Markusen and Rutherford, 2004).

and select output levels based on the optimization principle in which the marginal cost equals the given market price. Government expenditures are financed by income sources, including tariff revenues, income taxes, exogenous lump-sum taxes, and rents on crude oil, and mining products. Expenditures also consist of public goods and services, subsidies for energy products, and food items, and transfers to households. The equilibrium module includes the agents' income balance and market clearing for factors, commodities, international trade, and saving-investment.

The selected energy products are gasoline, kerosene, gas oil, fuel oil, liquid gas, natural gas, and electricity. Contrary to global attempts, the energy and emission intensity of Iran has been increasing over the decades (Farajzadeh and Nematollahi, 2023). The energy sector accounts for 81% of the GHGs (UNDP, 2017). In other words, the pollutants emissions are closely related to energy consumption. In the case of other pollutants, such as CH_4, N_2O, CO, and NO_x, energy plays a significant role; however, the production process is also important (Ghaffarian and Farajzadeh, 2022). The selected pollutants were divided into three groups, including greenhouse gases[13] (CO_2, CH_4, and N_2O), acidifying substances[14] (SO_2 and NO_x), and health-damaging pollutants (CO[15]). The applied scenarios are two more likely options Complete Payment (CP), in which entire subsidy revenue is paid back to the households, and Half Payment (HP), the option that households and producers receive 50 and 30 percent of subsidy revenue, respectively.[16]

The recursive dynamic model was implemented over a 20-year horizon in the following years, in which the model was updated on a yearly basis. During each year, investment is implemented like that of a static model. Thus, the total amount of capital in each year is the sum of the total current capital stock and the investment from the previous period after discounting for capital depreciation. The dynamic features are labor and productivity growth, and capital stock accumulation, in which the total capital in each year is determined by the total capital stock adjusted for depreciation, along with the investment from the previous period. Thus, capital accumulation is endogenously determined (AlShehabi, 2013). For brevity, only the equations for the decomposition of the emission intensity, price gap, and emissions are presented.

3.1. Decomposition analysis

Decomposition analysis is widely used to decompose energy and emission intensities into their driving forces using time series data. There are several techniques, formulations, and applications for decomposing energy and emission intensity. The Log Mean Divisia Index (LMDI) has been used more frequently because of its advantages of working with the remaining items and zero values (Ang, 2004, 2015). Following the LMDI method, the emission intensity of the selected pollutants was decomposed as follows (Zhang et al., 2019):

$$PI^k = \frac{P^k}{Y} = \sum_j \frac{P_j^k}{E_j} \times \frac{E_j}{E} \times \frac{E}{Y} \tag{1}$$

The variables are as follows:

P^k : Total amount of kth pollutant emissions

P_j^k : Amount of kth pollutant emitted by energy product j

E_j : Amount of jth energy product consumed

E : Total energy products used

Y: Total output

$\frac{P_j^k}{E_j}$: kth pollutant emission coefficient of energy product j

$\frac{E_j}{E}$: Share of the jth energy product in the total energy use

$\frac{E}{Y}$: Energy intensity

3.2. Price-gap approach

The price gap approach is used to quantify the subsidies paid to energy products as follows:

$$S_j = RF_j - DP_j \tag{2}$$

where S_j is the subsidy or price gap for energy product j, RF_j is the reference price or price without subsidy for energy product j, and DP_j is the price paid by domestic consumers for energy product j.

[13] Greenhouse gases include Carbon Dioxide (CO_2), Methane (CH_4), and Nitrous Oxide (N_2O). These pollutants are aggregated into CO_2-equivalent based on their global warming potential. The multiplication factors are 21 for CH_4 and 310 for N_2O (UNDP, 2010).

[14] These substances are Sulphur Dioxide (SO_2) and Nitrogen Oxide (NO_x).

[15] Carbon Monoxide (CO).

[16] The applied scenarios are based on the Subsidy Targeting Program (STP). This program was passed in February 2010 by the Iranian Guard Council, and it was performed in 2011. However, it should be noted that the program failed to be completely performed since it faced some problems (Farajzadeh and Baakhshoodeh, 2015). Thus, the STP is the most likely option to enact a subsidy reform program.

Table 1
Macroeconomic variables over the simulation period.

	Scenarios	CP			HP		
		1st year Changes	Period Average	Annual Changes	1st year Changes	Period Average	Annual Changes
Gross Domestic Product Changes (%)	GDP	−0.26	1.33	1.43	−0.18	1.40	1.50
Consumer Price Index Changes (%)	CPI	39.16	1.67	−0.31	12.42	0.58	−0.05
Output Changes (%)	Agriculture	96.73	6.56	1.82	44.94	5.21	3.12
	Mining	−22.89	−0.5	0.68	−14.73	−0.07	0.71
	Energy products	−19.19	−0.43	0.55	−15.81	−0.04	0.79
	Manufacturing	−10.79	0.73	1.33	−6.22	1.21	1.59
	Services	2.21	1.00	0.94	6.69	1.20	0.91
CO_2-equivalent Changes (%)	Energy consumption	−17.96	−0.06	0.88	−7.80	0.35	0.77
	Production process	3.69	1.67	1.57	9.98	2.19	1.78
	Household consumption	136.20	8.80	2.09	32.03	5.30	3.87

3.3. Emissions

The emission of each pollutant originates from three sources, including the production process, energy product consumption, and non-energy final consumption. The pollution emitted from each source is calculated using the exogenous coefficients. The total emissions for each pollutant are quantified as follows (Beghin et al., 2002):

$$P^k = \sum_i \alpha_i^k X_i + \sum_j \beta_j^k E_j + \sum_h \theta_h^k C_h \tag{3}$$

The first term quantifies the emission of pollutant k from the production process, where α_i^k is the amount of pollution emitted from each unit of output sector i and X_i is the total output of sector i. The second term calculates the emission of pollutant k from energy product j, where the parameter β_j^k represents the emission per unit of energy product j, and E_j is the amount of jth energy product consumed. The contribution of the non-energy final consumption to the emission of pollutant k is presented by the last term. θ_h^k represents the emission coefficient of pollutant k in household group h for each unit of consumption, and C_h is the total consumption of household group h.

3.4. Data

The primary data sets applied in the model are elasticities and the Iranian Social Accounting Matrix (SAM). SAM is the most basic data type for the CGE model, and the applied CGE model was calibrated based on SAM. We applied a modified SAM based on that used by Farajzadeh (2018) .[17] The modified SAM was updated using auxiliary data sources. Subsidies for energy products were obtained from the Energy Balance sheets for 2017 (Iran's Energy Balance, 2017). Pollutants emissions were obtained from Farajzadeh (2018). Another piece of data applied to build the modified SAM is the exchange rate to calculate subsidies based on the price gap approach (Central Bank of Iran, 2017). The aggregate version of the SAM includes 17 sectors and distinguishes between household, government, investment, export demand, and import supply by sector. The elasticity parameters in the constant elasticity of substitution (CES) and constant elasticity of transformation (CET) functions were obtained from Jensen and Tarr (2003), Farajzadeh et al. (2017), and Farajzadeh (2018). The share parameters are calculated based on the related data in the SAM table (e.g., tax and savings rates). The production sectors in the applied SAM are agriculture (four sectors), energy products (eight sectors), services (two sectors), mining, oil and gas, and manufacturing activities. For brevity, the results are reported for six sectors, as presented in Table 1.

4. Simulation results

The simulation tool was a dynamic Computable General Equilibrium (CGE) model. It was run to remove energy subsidies under two options of revenue redistribution: Complete Payment (CP) and Half Payment (HP). The CP option, due to higher revenue transfer, compared to the HP policy, is expected to encourage final demand more significantly, while the HP scenario will boost intermediate demand as half of the subsidy revenues are paid to producers. The results for both options were analyzed. The output is the primary variable in the energy and emission intensity analysis; thus, the output change is first discussed. Other variables related to energy and

[17] This SAM provides a detailed and more compatible representation of the Iranian economy's structure. The SAM data sources comprise the input-output tables of Iran from the Central Bank of Iran. Another essential statistical source includes the GTAP 9 database, which was applied to decompose the capital account, labor account, and agricultural and energy products activities accounts. Another significant modification is incorporating tariffs, and tariffs equivalent of non-tariff barriers.

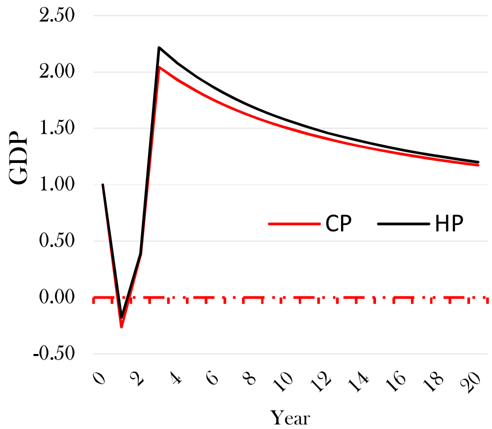

Fig. 1. GDP changes over the simulation period.

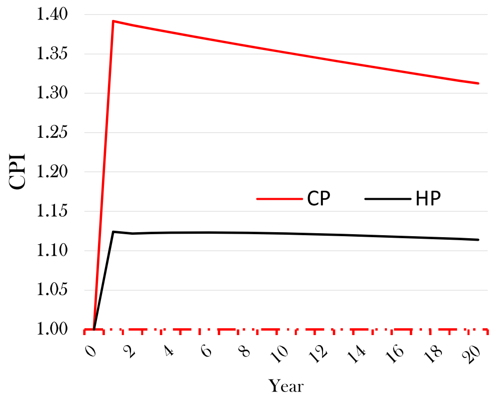

Fig. 2. CPI changes over the simulation period.

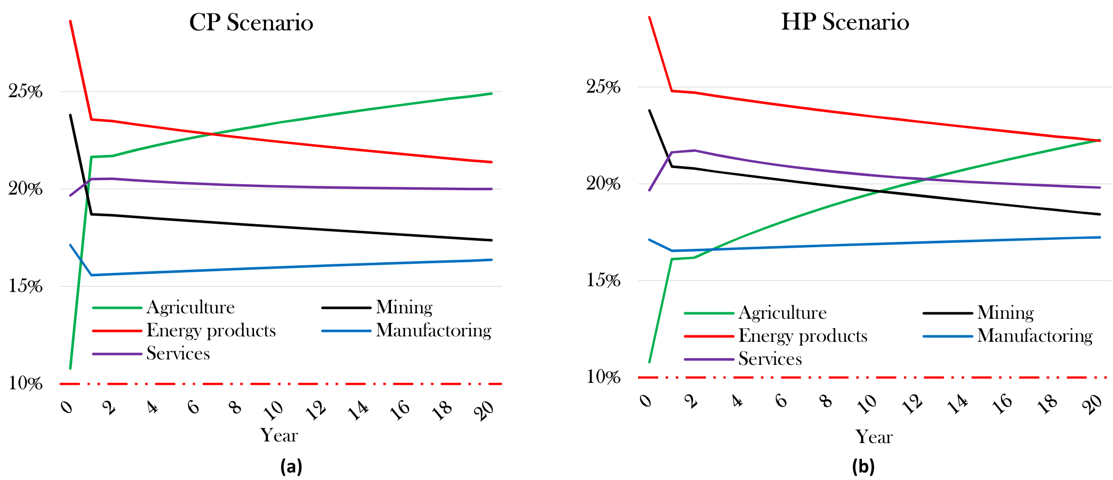

Fig. 3. (a): Changes in output composition under CP scenario (b): Changes in output composition under HP scenario.

emission intensity are energy consumption and pollutants emissions. Pollution intensity was also analyzed for emissions from both energy consumption and production processes. Accordingly, changes in output composition were examined at the level of the main sectors. These variables are discussed in the next section.

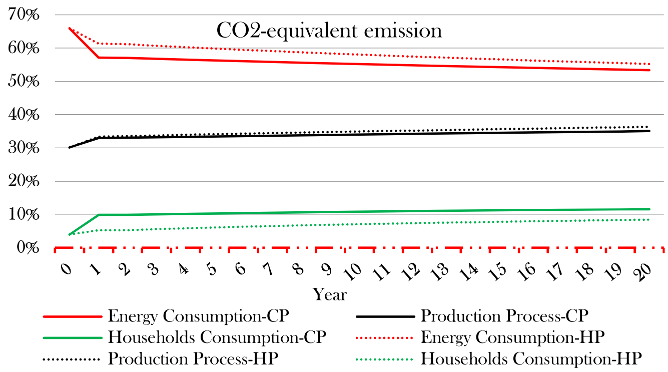

Fig. 4. CO2-equivalent emissions from different sources.

4.1. Macroeconomic variables

Fig. 1 shows the GDP changes under the CP and HP scenarios. The CPI trends are also shown in Fig. 2. GDP under both scenarios experiences a slight reduction after subsidy removal due to higher energy prices and an increase in production costs; however, redistributing the subsidy revenue back to households and final demand boosts the output after 2, 3 periods. From year 4, GDP tends to decrease, mainly due to a reduction in final demand, which in turn results from higher prices, as illustrated in Fig. 2. In other words, price shocks induce volatility in the GDP in the first few years. Dagoumas et al. (2020) also found that EU GDP suffers from oil price volatility in the long run. Households experience consumption prices higher than the corresponding increase in their nominal factor income, resulting in reduced purchasing power and final demand. In general, the higher final demand fueled by transferred revenue and slightly lowered output resulting from higher production costs leads to higher consumer prices and higher CPI under the CP scenario compared to the HP option. The output composition (Fig. 3) also shows that most of the output expansion takes place in services and agricultural commodities, which account for most of the final consumption by households. These sectors are relatively less dependent on energy inputs. In terms of output, there is a slight difference between the two options, while CPI changes show a significant gap. Inflation under the HP option remains 10–15% during the simulation period; for the CP scenario, it is above 30% which is mainly fueled by higher revenue transfer. This difference is expected to drive the output composition in the economy, and under the HP scenario, services commodities lose dominance in favor of industrial and manufacturing commodities. The CPI changes are higher than those reported by Farajzadeh and Bakhshoodeh (2015), because the subsidies in the current study are much higher than those in their study. Abouleinein et al. (2009) also report significant inflation due to Egypt's subsidy removal of petroleum products. The lower final demand by households under HP compared with CP is the main underlying reason for the change in output composition.

Reforming energy subsidies leads to significant changes in the output composition. The output composition is divided into agriculture, mining (including mining, and oil and gas), energy products, manufacturing, and services. Implicitly, Farajzadeh (2018) also suggests that higher prices of energy products will expand the output of agricultural and services activities because they are less exposed to higher production costs after subsidy removal. In both scenarios, the agricultural sectors benefit and experience output expansion. Energy products account for an insignificant cost share of agricultural output, resulting in a slight increase in production costs after the subsidy removal. Thus, agricultural output was not significantly affected by higher energy prices. Additionally, under both policy options, households receive a payment that motivates final demand, especially the demand for agricultural products. Under the CP option, the share of agricultural products increases from less than 10 percent to approximately 25 percent, and the corresponding value for the HP scenario is more than 22 percent. The annual output expansions of the agricultural sector after removing subsidies are 1.82 and 3.12 percent for the CP and HP scenarios (Table 1), respectively, which are the highest growth among the economic sectors. An interesting difference in agricultural output changes compared to other sectors is that it experiences expansion even in the first period or after subsidy reform, which occurs due to resources reallocation. Manufacturing also experiences growth in output share since it grows by 1.33 and 1.59 percent annually under CP and HP policy reforms, respectively (Table 1). For most years of the HP and the second half of the CP scenario, the manufacturing output share exceeds its current share. It is worth noting that in the first year after subsidy removal, manufacturing output drops significantly by approximately 11 percent (Table 1), owing to a production cost shock resulting from higher energy costs in the production process. Under the HP policy, the reduction in the first year is lower because this sector receives a significant production-compensating subsidy. Although energy plays an influential role in manufacturing production and higher energy prices contract output in these sectors, the increase in intermediate demand by sectors that enjoy output expansion and access to relatively inexpensive value-added inputs, which leave other sectors, creates an advantage for manufacturing activities. Regarding output share, the contribution of services output does not change significantly. The output of these sectors expands in the first year after the policy shock; however, the limited growth in output afterward, which is less than 1 percent (Table 1), outweighs the initial output increase, leading to an unchanged output share of approximately 20 percent. Increased final demand by households is spoiled by higher production costs, especially in energy-intensive sectors, such as transportation. In addition, the close interrelationship between transportation and other services activities does not allow for more output expansion in services.

The energy products and mining sectors experience a sharp drop in output (Table 1). In the first period, the output reduction for

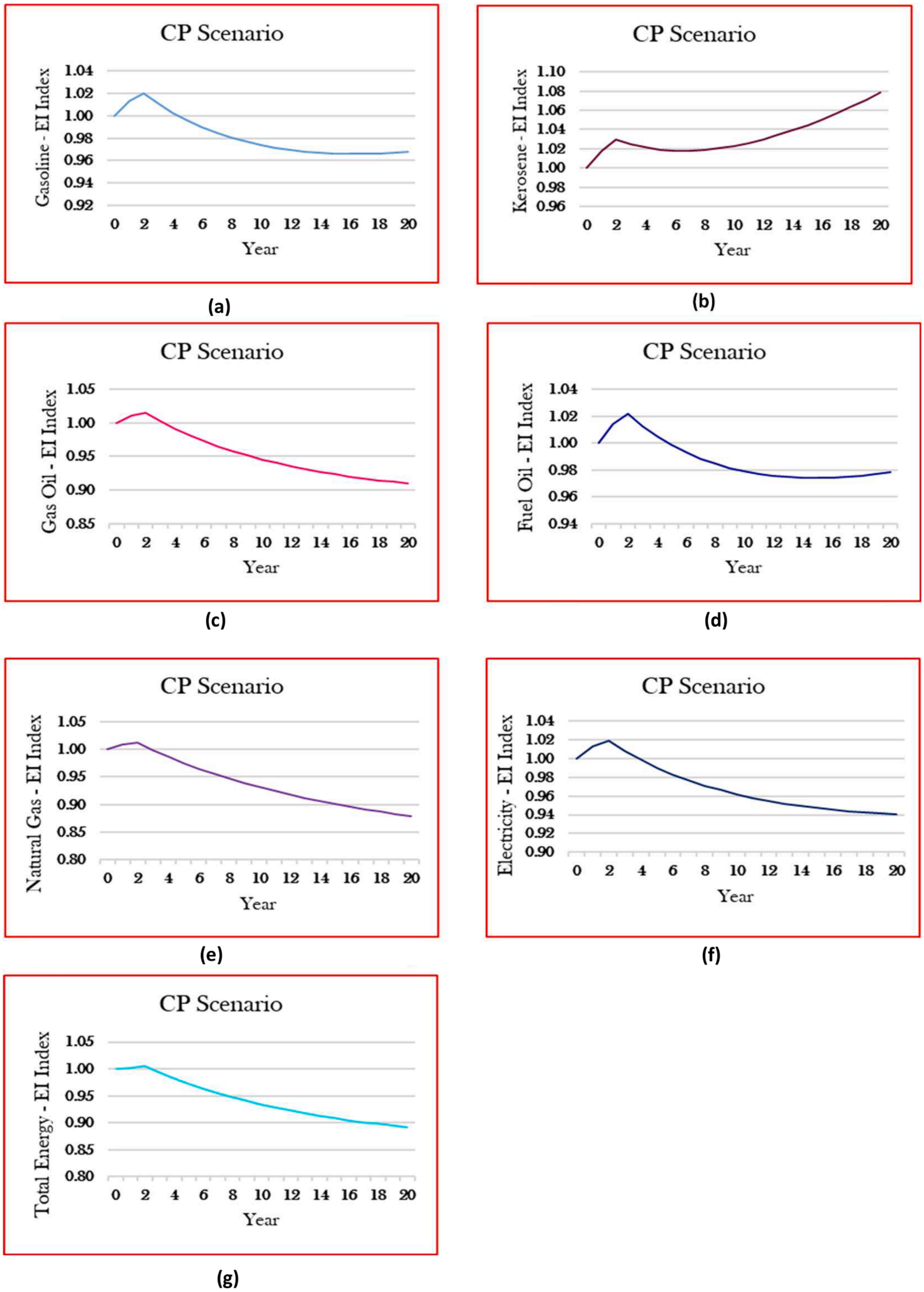

Fig. 5. (a): Gasoline energy intensity under CP (b): Kerosene energy intensity under CP (c): Gas oil energy intensity under CP (d): Fuel oil energy intensity under CP (e): Natural gas energy intensity under CP (g): Total energy intensity under CP

energy products is 19.2 and 15.8 percent under the CP and HP scenarios, respectively. These values for mining are 22.9 and 14.7. Although, after this sharp decrease, the mining sector experiences output expansion with an annual growth rates of around 0.7 percent, which is lower than that of the other sectors, and its output share drops continuously. The same changes hold for the energy products. It is worth noting that most of the mining output belongs to oil and gas, which are closely related to energy products, and their output changes are similar. In mining, which is an energy-intensive sector, removing the energy subsidy causes production costs to rise,

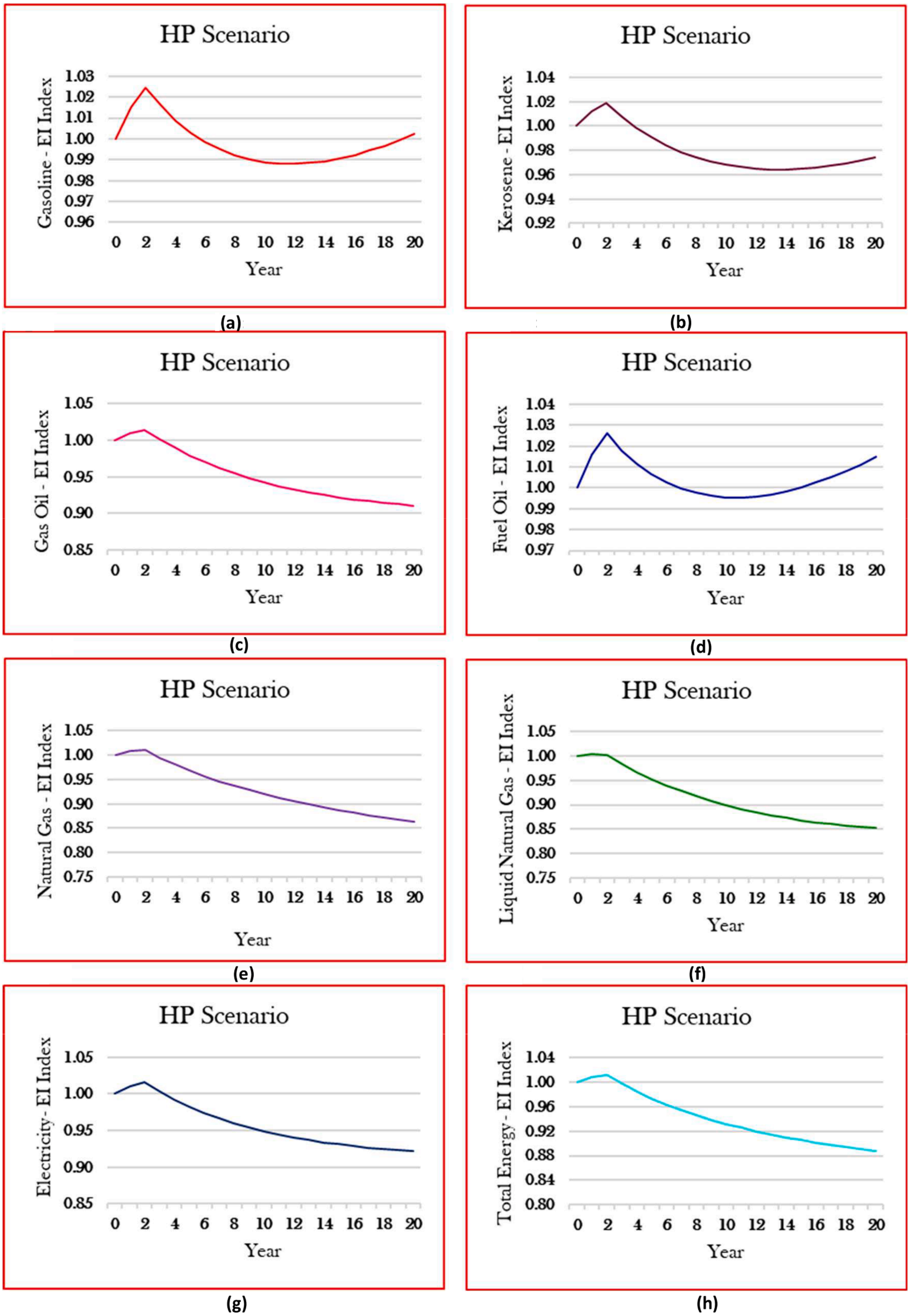

Fig. 6. (a): Gasoline energy intensity under HP (b): Kerosene energy intensity under HP (c): Gas oil energy intensity under HP (d): Fuel oil energy intensity under HP e): Natural gas energy intensity under HP (f): Liquid natural gas energy intensity (g): Electricity energy intensity under HP Fig. 6 (h): Total energy intensity under HP

Table 2
Descriptive statistics of energy intensity.

Scenarios	Statistics	Gasoline	Kerosene	Gas Oil	Fuel Oil	Liquid Gas	Natural Gas	Electricity	Total
CP	Max	1.021	1.079	1.015	1.022	1.000	1.012	1.018	1.006
	Min	0.966	1.000	0.910	0.974	0.000	0.879	0.941	0.892
	Average	0.982	1.034	0.954	0.987	–	0.939	0.970	0.941
	Last year value	0.968	1.079	0.910	0.978	0.000	0.879	0.941	0.892
HP	Max	1.025	1.019	1.015	1.026	1.004	1.011	1.016	1.013
	Min	0.988	0.964	0.911	0.995	0.852	0.863	0.923	0.888
	Average	0.998	0.980	0.952	1.005	0.914	0.929	0.958	0.941
	Last year value	1.002	0.974	0.911	1.015	0.852	0.863	0.923	0.888

thereby reducing output. As for energy products, higher prices after subsidy removal induce a reduction in demand for energy products, while production costs in energy-producing sectors also increase. In other words, a contraction in both demand and supply is the underlying reason.

Fig. 4 and the last three rows of Table 1 present the contribution of the three sources of CO_2-equivalent (weighted aggregation of CO_2, CH_4, and N_2O) emissions. While in the current situation, approximately two-thirds of CO_2-equivalent pollution is emitted from energy consumption, its contribution, after a significant drop in the first year, continues to decrease to approximately 53–55 percent due to a relative reduction in energy demand, as discussed above. However, in terms of total values, the emissions from the energy sources tend to increase over the simulation horizon by 0.88 and 0.77 percent annually under CP and HP, respectively (Table 1), because the total consumption of energy increases over the simulation horizon. However, for the CP option, it remains lower than the current level, even at the end of the study horizon. In other words, the primary effect of higher energy price shocks is the lower consumption of energy products, which in turn leads to lower emissions; however, in the following years, energy consumption tends to increase as the total output of the economy increases and demands more energy inputs.

Contrary to the energy consumption origin of CO_2-equivalent, the production process contributes to emissions, and its share increases from 30% to 35, 36%. The absolute changes in emissions from the production process increases by 1.57 and 1.78 under CP and HP, respectively (Table 1). The underlying reason is that paying back part of the revenue to output production leads to an expansion in output, especially in pollution-intensive sectors such as manufacturing, where its share tends to increase over the study horizon (Fig. 3).

Household consumption shows the most significant changes among the variables because, in the CP policy option, the entire subsidy revenues is redistributed back to households. In the HP scenario, they also receive half of the revenues. The emissions from households consumption under the CP scenario increase by 136 percent, showing a significant increase in consumption boosted by the transferred revenue, which leads to an increase in the emission contribution from less than 4 percent to approximately 10 percent. Subsequently, an annual increase of 2.1 percent leads to an emission share of 11.6 percent at the end of study horizon. This is caused by an explosion in final demand after paying back subsidy revenue to households. It is worth noting that the final demand or household consumption emissions result from the consumption of non-energy commodities. In addition, although under the HP scenario, the initial increase is much lower than the corresponding value of CP, it increases by 32% compared to the current values and then continues with a significant annual growth of 3.9 percent, resulting in an emission share of 8.5 percent at the end of the study horizon. Transferred revenue, which accounts for a significant part of households revenue, raises households consumption and brings about higher emissions.

4.2. Energy intensity

Figs. 5 and 6 show the energy intensity changes under the CP and HP scenarios, respectively. Descriptive statistics are presented in Table 2. In both scenarios, the energy intensity tends to increase for the first two or three periods after removing the subsidies. In other words, contrary to the output reduction, the energy intensity increases, indicating that the decrease in energy consumption has not been as high as the output contraction. This mainly stems from the fact that the final consumption of energy by households doesn't change significantly due to receiving subsidy revenue in the redistribution process, and the energy consumption, compared to output contraction, remains relatively high. Accordingly, the energy intensity under the CP option is higher than that under HP. Removing the energy products subsidy increases their prices. Thus, households are expected to finance their energy expenditures using the revenue received from the government. This leads to the inefficient use of energy products by households even after the reform, as Lin and Jiang (2011) expect for subsidized energy products. In other words, the reduced demand for energy products in the output production process is outweighed by the increasing demand of households, resulting in higher energy intensity.

Regarding the general trend of intensity changes, gas oil, natural gas, and electricity are similar because they illustrate a decreasing trend that lasts until the end of the simulation period. The primary reason for their emission intensity changes is their higher prices compared with other energy products after subsidy removal, leading to a fall in their consumption. In the CP scenario, the index values for the energy intensity of gas oil, natural gas, and electricity are approximately 9, 12, and 6% reductions compared to the current level, respectively. For natural gas, and electricity, under the HP option, the corresponding values are even higher. The more significant changes in natural gas intensity result from the fact that households consume around half of the natural gas and receive less compensating revenue under the HP option compared to the CP option, dampening their demand for natural gas. The energy intensity for gasoline and fuel oil tends to increase during the last quarter of the simulation period. Under the CP scenario, the energy intensity

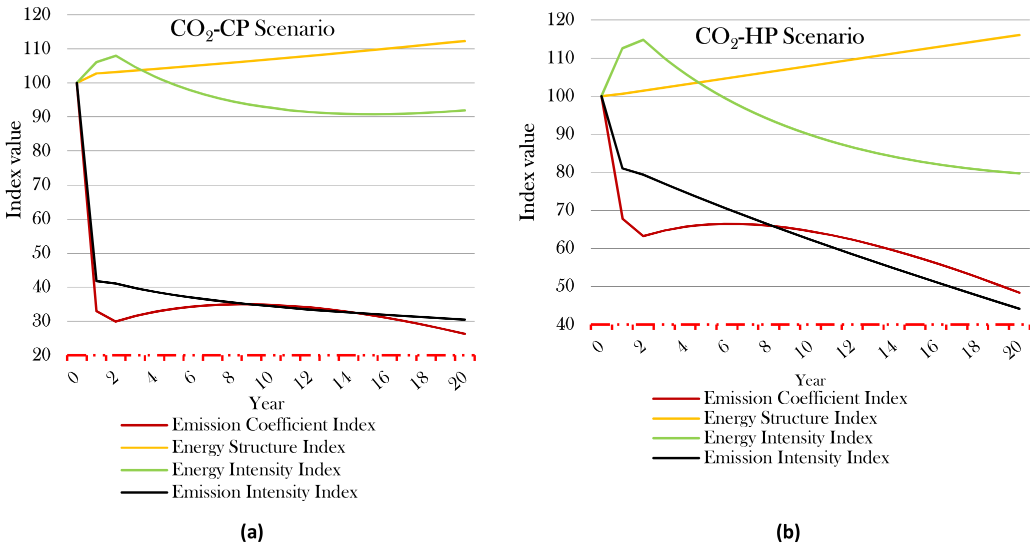

Fig. 7. (a): CO_2 emission intensity under CP scenario (b): CO_2 emission intensity under HP scenario.

remains only 2–3 percent lower than before subsidy removal, and in the HP option, it exceeds the initial values. Approximately three-fourths of gasoline and the entire fuel oil are consumed by the production process, and the output expansion under the HP option compared to the CP option is the main reason why energy intensity is higher in the HP scenario than in the CP scenario. Specifically, the output expansion of manufacturing after compensating for the higher production costs under the HP policy scenario, which leads to increasing demand for these energy products, is the primary source of increasing energy intensity under the HP scenario in the last quarter because the Iranian manufacturing sector is energy-intensive sector (Zarepour and Wagner, 2023). In addition, the lower prices of these energy products compared to their substitutes are expected to increase their intermediate use in the production process. Kerosene shows an even more distinct pattern as its intensity remains above the current level under CP.

Kerosene energy intensity, under the CP option, after rising by approximately 3 percent in the second year, decreases to approximately 1.8% above the initial value; however, it finally reaches an intensity of 8 percent higher than the initial level. Under the HP scenario, it remains lower than the current level and, in the middle of the simulation period, shows a decrease of approximately 3.5 percent. In the second half of the study period, it tends to rise; however, it remains approximately 2.5 percent lower than the initial level. This significant difference in kerosene intensity under the two policy options originates from the fact that more than 70 percent of kerosene is consumed by households that receive more considerable revenue in the CP scenario, keeping their final demand by households high, resulting in higher intensity. Furthermore, the underlying reason for the rising trend in kerosene energy intensity in the last quarter under the HP option is the replacement of natural gas consumption by households with kerosene, resulting in higher kerosene use. Primarily, this substitution results from the lower price of kerosene than that of natural gas. Thus, part of the higher consumption of kerosene at the households level originates from the substitution of other products by kerosene. The liquid gas production is shot down in the CP option. Under the HP scenario, it shows a decreasing trend in intensity after the second year. In general, it shows the highest reduction in energy intensity as the intensity value drops by approximately 15 percent in the last year of the simulation horizon. Liquid gas, after the subsidy reform, experiences the highest price; thus, it is replaced with other energy products because of its significant costs. The total energy intensity also shows a trend similar to that of natural gas, electricity, and gas oil because these items account for approximately 85 percent of the total energy use. The total energy intensity, under both scenarios, shows an approximately 11 percent reduction compared to the current level.

Table 2 presents the statistical facts of energy intensity for each energy product. Except for gasoline and fuel oil, the average intensity values are higher under the CP scenario, in which the final demand by households remains high because they receive significant revenue, causing higher energy consumption. These products are primarily used as intermediate inputs in the production process. According to the last year's values under the CP option, the energy composition changes in favor of kerosene, and to some extent, fuel oil, and gasoline enjoy higher contributions proportionately. As mentioned above, more than 70 percent of kerosene is used for the final consumption by households. In the HP scenario, gasoline, and fuel oil experience an increase in consumption because of manufacturing output expansion, which uses fuel oil intensively, and kerosene also benefits from income redistribution among households, proportionately leading to higher consumption. In both scenarios, natural gas and gas oil show the highest variations in the intensity criterion. This variation is owing to their significant role in energy consumption. Natural gas variation is mainly due to differences in revenue redistribution, which is halved in the HP scenario. It is worth noting that approximately half of the natural gas is consumed by households as final consumption. In addition, more than 90 percent of gas oil is consumed by the production process, which receives 30 percent of the subsidy revenue under the HP option.

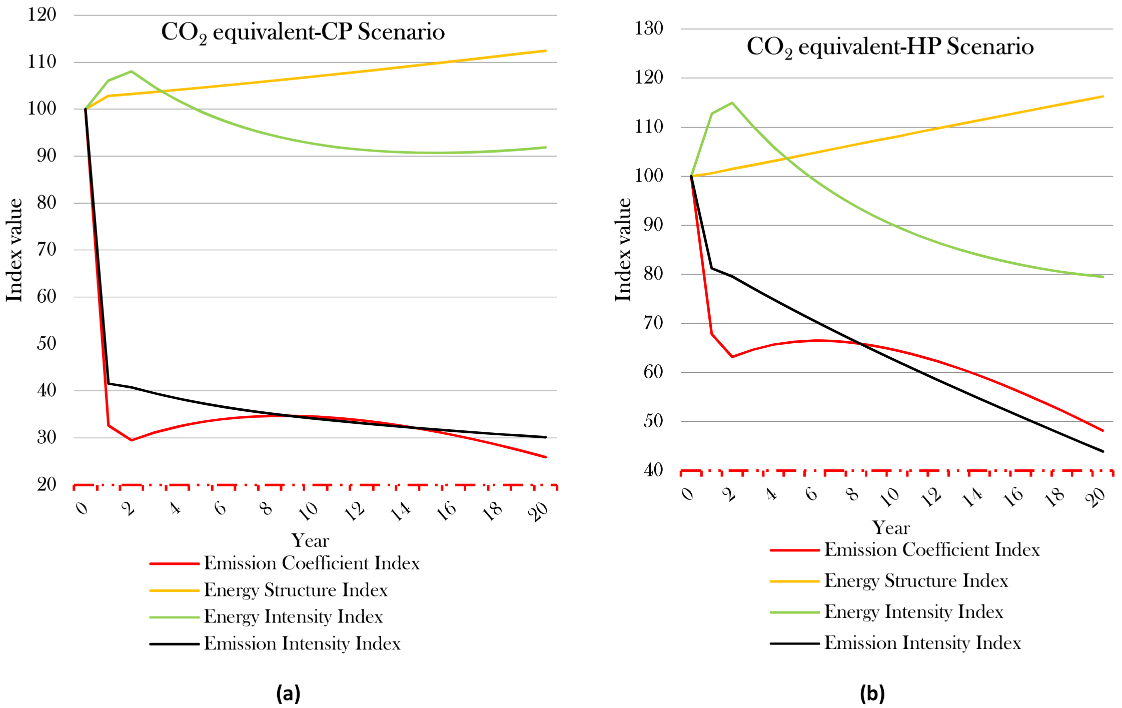

Fig. 8. (a): CO_2-equivalent emission intensity under CP scenario (b): CO_2-equivalent emission intensity under HP scenario.

4.3. Emission intensity

4.3.1. Energy consumption emission intensity

The emission intensity results are presented in Figs. 7 and 8 and Table 3. The trend of changes in emission intensity has been illustrated only for CO_2 and CO_2-equivalent emissions because, for other pollutants, the corresponding changes are insignificant. The changes after the removal of subsidies and the annual changes for all components and for all pollutants are presented in Table 3.

Fig. 7 shows the emission intensity of CO_2 from energy consumption while decomposing it into its components. As shown in Figs. 5 and 6, the energy intensity exhibits a decreasing trend and is expected to contribute to a lower emission intensity of CO_2. However, its contribution is not comparable to that of the emission coefficient, which accounts for most of the emission intensity reduction of CO_2. The emission coefficient is mainly attributed to growth in energy consumption efficiency. In other words, emission reduction is expected to be lowered by increasing energy use efficiency rather than by reducing the amount of energy consumption. Accordingly, Iran is a developing economy, and more output expansion is expected, resulting in higher energy consumption. Thus, the efficacy channel provides an opportunity for reducing emissions. The contribution of energy consumption efficiency to reducing emission intensity has been reported for energy-related CO_2 emissions intensity in Australia (Shahiduzzaman et al., 2015) and in the transportation sector of China (Yu et al., 2020). In contrary to the other components, the energy structure or composition of the energy products leads to higher emission intensities. Regarding that producers are looking for higher profits, this means that lower-cost energy products are those with higher emission capacity, such as fuel oil. However, its contribution to the study horizon remains as low as 116. Yu et al. (2020) found that in China's transportation utility, the energy structure contributes to restraining the growth of carbon emissions. As shown in Figs. 5 and 6, the energy composition changes in favor of gasoline, fuel oil, and kerosene. In addition, Table 3 and Figs. 7 and 8 illustrate that emission intensity experiences a significant drop in the first year or after the energy subsidy removal, primarily due to a fall in intermediate demand for energy products after the price shock. However, a substantial part of that under the HP scenario is wasted by the energy intensity component. This implies that, due to production cost shocks, producers replace high-cost energy products with those with lower costs but higher emission capacity. While the total emission intensity, in terms of the index value, decreases by approximately 19, the energy intensity increases by more than 12 in terms of the index value. In terms of CO_2 emission intensity, the CP scenario is preferred over HP. Regarding the higher output in the HP option compared to the CP option, this means that the production process in Iran is significantly energy-intensive with lower energy use efficiency. In particular, the Iranian manufacturing sector is considered energy-intensive (Zarepour and Wagner, 2023). Accordingly, the production technology of Iran is not considered technology-embodied (Gharibnavaz and Waschik, 2015). As presented in Table 3, the energy structure or combination of energy products does not play a pivotal role in the emission intensity changes. The annual contribution of the emission coefficient, which is considered equivalent to the energy use efficiency, to lowering the emission intensity under the HP scenario is more substantial than that under the CP scenario. Although this originates from the fact that a significant part of the emission intensity reduction under the CP scenario occurs immediately after the removal of subsidies, the annual contribution of 1.8% under the HP scenario is

Table 3
Changes of emission intensity components.

	Scenarios	CP			HP		
Pollutants	Intensity components	1st year Changes (%)	Period Average Changes	Annual Changes (%)	1st year Changes (%)	Period Average Changes	Annual Changes (%)
CO_2	Emission coefficient index	−66.97	−3.68	−1.19	−32.17	−2.58	−1.77
	Energy structure index	2.77	0.61	0.47	0.60	0.80	0.76
	Energy intensity index	6.04	−0.40	−0.75	12.60	−1.01	−1.80
	Emission intensity index	−58.15	−3.47	–	−18.97	−2.80	–
CH_4	Emission coefficient index	−0.001	0.000	0.000	−0.001	0.000	0.000
	Energy structure index	0.000	0.000	0.000	0.000	0.000	0.000
	Energy intensity index	0.001	0.000	0.000	0.001	0.000	0.000
	Emission intensity index	−0.001	0.000	–	−0.001	0.000	–
N_2O	Emission coefficient index	−0.001	0.000	0.000	0.000	0.000	0.000
	Energy structure index	0.000	0.000	0.000	0.000	0.000	0.000
	Energy intensity index	0.000	0.000	0.000	0.000	0.000	0.000
	Emission intensity index	−0.001	0.000	–	0.000	0.000	–
CO_2 equivalent	Emission coefficient index	−67.34	−3.71	−1.21	−32.12	−2.59	−1.79
	Energy structure index	2.80	0.62	0.47	0.60	0.81	0.76
	Energy intensity index	6.10	−0.41	−0.76	12.72	−1.03	−1.82
	Emission intensity index	−58.44	−3.49	–	−18.79	−2.80	–
NO_x	Emission coefficient index	−0.189	−0.010	−0.001	−0.028	−0.006	−0.005
	Energy structure index	0.010	0.002	0.002	0.003	0.004	0.004
	Energy intensity index	0.022	−0.002	−0.003	0.046	−0.004	−0.006
	Emission intensity index	−0.157	−0.010	–	0.020	−0.007	–
CO	Emission coefficient index	0.340	−0.092	−0.019	1.891	3.839	−0.058
	Energy structure index	0.069	2.535	0.023	0.040	4.529	0.045
	Energy intensity index	0.186	−2.467	−0.036	0.263	−2.748	−0.043
	Emission intensity index	0.598	−0.024	–	2.194	5.620	–
SO_2	Emission coefficient index	0.067	0.004	0.001	0.496	0.012	−0.014
	Energy structure index	0.012	0.005	0.004	0.007	0.008	0.008
	Energy intensity index	0.021	−0.002	−0.003	0.049	−0.005	−0.008
	Emission intensity index	0.100	0.007	–	0.553	0.015	–

Table 4
Changes of emission intensity components.

Scenarios	CP			HP		
Pollutant	1st year Changes (%)	Period Average Changes	Annual Changes (%)	1st year Changes (%)	Period Average Changes	Annual Changes (%)
CO_2	−14.60	0.33	1.17	27.10	2.09	0.58
CH_4	0.79	0.05	0.01	0.81	0.04	0.00
N_2O	0.09	0.01	0.00	0.07	0.00	0.00
CO_2 -equivalent	14.95	1.69	0.80	29.42	1.42	−0.04
NO_x	−0.01	0.00	0.00	0.00	0.00	0.00
CO	0.43	0.02	−0.01	0.14	0.01	0.00
SO_2	0.00	0.00	0.00	0.00	0.00	0.00

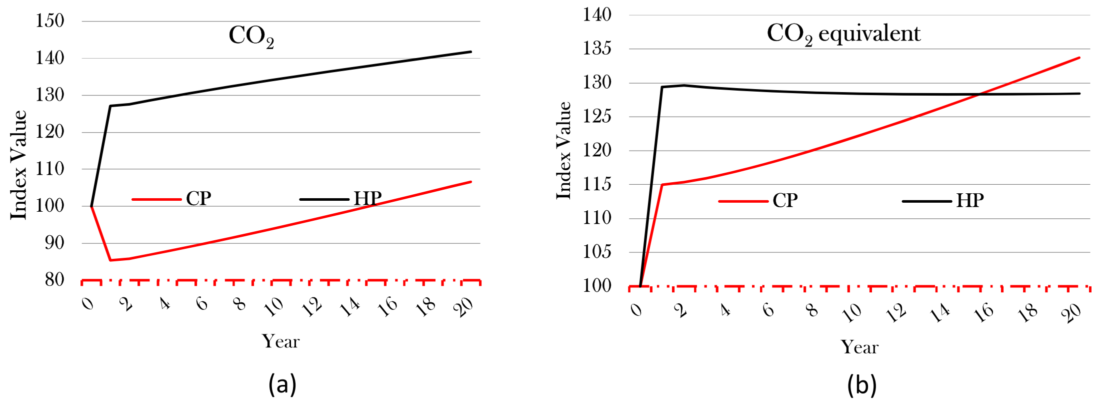

Fig. 9. (a): CO2 emission intensity in production process (b): CO2-equivalent emission intensity in production process.

interesting. This shows that the production process requires time to adjust the technology toward a more efficient and less polluting process. Regarding the insignificant changes in CH_4 and N_2O emission intensities, the changes in the emission intensity components for CO_2-equivalent are similar to those of CO_2. It is also worth noting that the production process accounts for most CH_4 and N_2O emissions, followed by energy consumption. As far as CH_4 and N_2O are concerned, lower consumption changes of the emitting energy products, including gasoline and gas oil, after subsidy reform result in an insignificant change in their emission intensity. In other words, relative changes in the composition of energy products favoring gasoline, and gas oil after subsidy reform, leads to insignificant changes in CH_4 and N_2O emissions. The changes in the emission intensity of other pollutants (NO_x, CO, and SO_2), which are mainly emitted from gasoline, gas oil, and fuel oil, are not significant because their consumption changes are not positively and closely related over the entire simulation horizon. The substantial reduction in CO_2 emission intensity is mainly due to the considerable decrease in natural gas consumption, which plays a significant role in CO_2 emissions. Natural gas also has a significant contribution to other pollutants; however, the changes in energy consumption in favor of gasoline and fuel oil outweigh the chance of achieving lower emission intensities for other pollutants.

Table 4 shows the emission intensity changes of the selected pollutants emitted from the production process. As presented, the emission intensities of CO_2 and CO_2-equivalent is significant, whereas for other pollutants, the presented statistics are slight and insignificant. Pollutants other than CO_2 are mainly emitted from the production processes of agricultural, manufacturing, and energy-producing activities. Although for most of these sectors, output is expanded after subsidy reform, the output composition within these sectors changes in favor of less-polluting activities. Thus, the emissions resulting from a higher output are counterbalanced by output composition changes. The trend of emissions intensity for CO_2 and the CO_2-equivalent is depicted in Fig. 9. As illustrated in Fig. 3, under the CP option, the output level of less CO_2-embodied sectors, that is, services and agricultural sectors, tends to increase, leading to a sharp reduction in CO_2 emission intensity. However, after subsidy removal and during the following years, the output composition changes in favor of CO_2 emitters, such as the manufacturing and forestry sectors. The CO_2 emission intensity under the CP scenario in the last quarter of the simulation horizon exceeds the current level. Under the HP scenario, the emission intensity of CO_2 increases by 27 percent (Table 4) and then continues to increase. After removing the subsidies, CO_2 emission intensity under the HP option grows by approximately 0.6 percent annually, indicating a more polluting output process. Thus, supporting the production process based on its energy costs will lead to an output composition with higher emission capacity in production processes, such as manufacturing activities. It is worth noting that the significant drop in CO_2 emission intensity under the CP scenario strongly decays after the first year of simulation because CO_2 emission intensity tends to increase by 1.17 percent annually, which is considerable. The changes in the output composition in favor of manufacturing and energy products is the underlying reason. As mentioned above, after removing the energy subsidies, higher prices dampen households' demand for commodities and change the composition of demand in favor of intermediate demand over final demand, leading to output expansion in the manufacturing sector, which entails higher emissions from the production process.

While CH_4 and N_2O do not experience a significant change in emission intensity, their contribution to CO_2-equivalent is meaningful, resulting in a sharp increase in the emissions under the CP, even in the first year or after the policy shock. More than 90 percent of N_2O is emitted from agricultural production processes. These sectors experience a substantial increase in output under CP because of the higher final demand by households. These changes lead to a significant increase in N_2O emissions. The same holds for CH_4 because approximately 40 percent of CH_4 emissions from the production process belong to agricultural production, and over the simulation horizon, approximately 40 percent of CO_2-equivalent emissions are related to CH_4. In the HP scenario, the lower output expansion of agricultural sectors and the output reduction of oil and gas, and natural gas sectors that account for one-third of CH_4 emissions are the main driving forces of the remaining CO_2-equivalent emissions intensity around an average. It even shows an insignificant reduction of 0.04 percent.

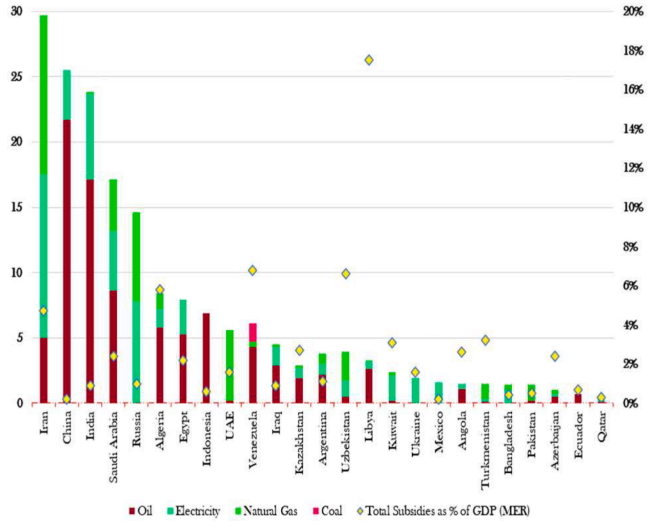

Fig. 1-Appendix. Energy subsidy in 2020 in billion USD (IEA, 2020).

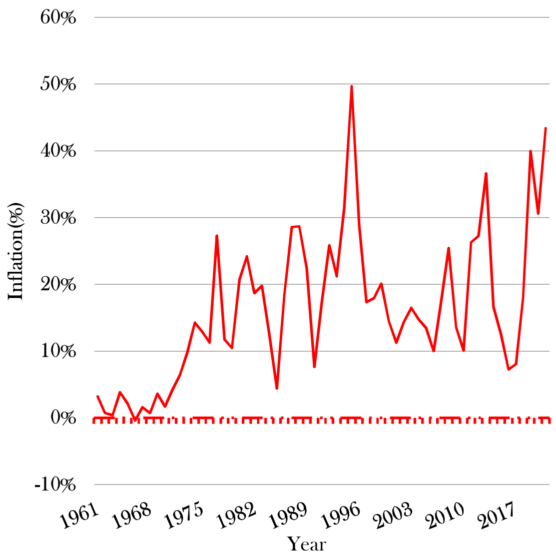

Fig. 2-Appendix. Iranian inflation over 1961–2021.

5. Conclusions and policy implication

The priority of subsidy reform in Iran is much higher than that in other economies. It sounds like a critical reform in terms of both the extent of expenditures, and energy use and emissions. The other supporting reasons can be social equity and the fact that it has failed to achieve intended goals such as economic growth, higher employment, price stabilization, and social equity (Bastanzad and Nili, 2005). In addition, over the last decade, an increasing poverty rate has been observed, indicating that the subsidy fragment for low-income groups has fallen. It is worth noting that over the previous decades, while subsidy expenditures have been increasing, the Iranian economy has not experienced significant growth, mainly because of restricting sanctions (Laudati and Pesaran, 2023). The current situation of the Iranian economy is characterized by heavy subsidies, high inflation, low economic growth, and a dramatic rate of currency depreciation. The Iranian experience of heavy subsidies provides important policy lessons for developing countries that subsidize energy products.

In 2010, the Iranian government attempted to commence subsidy reforms, starting with gasoline, natural gas, and gas oil (El-Katiri and Fattouh, 2017). However, regarding the price gap between market prices and prices paid by consumers, it has indeed taken steps back. Given the low consumption of households and widespread poverty, subsidy reform should be accompanied by revenue redistribution back to households. The amount of subsidy paid to energy products has increased compared to that examined in studies such as Farajzadeh and Bakhshoodeh (2015). This tremendous subsidy revenue can potentially create significant demand among

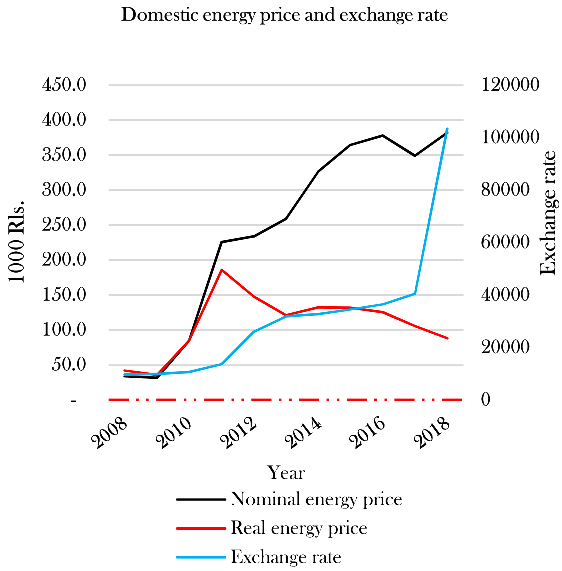

Fig. 3-Appendix. Nominal and real domestic price of energy and exchange rate.

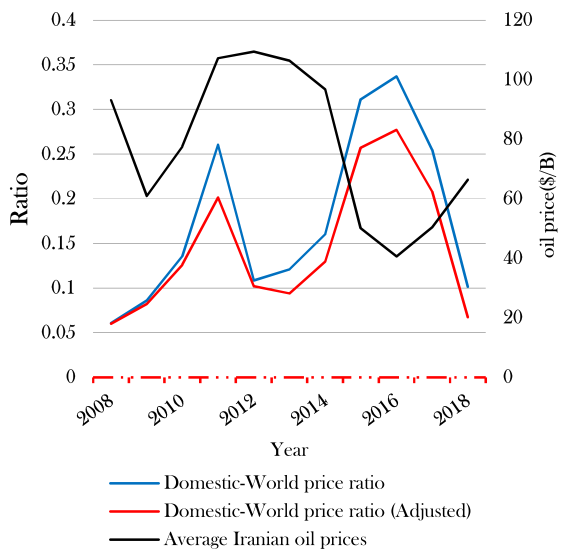

Fig. 4-Appendix. Energy prices and Iranian crude oil prices.

households and producers. Thus, the lower output changes after subsidy removal result from the fact that the subsidy revenue redistribution boosts demand and prevents adverse effects on output. Specifically, under the HP policy option, the manufacturing sector receives a significant part of subsidy revenue, resulting in output expansion. In other words, the returned revenue can compensate for the higher energy costs in the production process, especially in manufacturing activities that are more energy-intensive (Zarepour and Wagner, 2023). However, the ultimate goal is not to redistribute subsidy revenue. As AlShehabi (2013) declares, investment should be the last target for subsidy revenues. However, regarding the fragile condition of households, this should be suspended until a more desirable situation arises. Regarding high emission intensity, investing in renewable energy generation projects, as pointed out by Caetano et al. (2023), is recommended. Another possible policy option concerning renewable energy is to orient the subsidies for oil-based energy products toward renewable energy, as proposed for Ecuador (Pinzón, 2018). The findings of Salari et al. (2021) support the role of renewable energy in decreasing CO_2 emissions in the USA. Concerning investment in renewable energy after subsidy reform, private investment should also be considered, as the private sector is expected to perform better (Amin et al., 2021).

As far as the CP and HP scenarios are compared and the issue is to choose policy options, some points should be highlighted. First, CP and HP differ more in terms of the extent of inflation than the other variables. This is highly important because the current rates of inflation in Iran exceed 40 percent. Thus, imposing high inflation under CP increases inflation to unacceptable rates. This is important, especially among the high-income deciles that are expected to be adversely affected by subsidy reform, leading to resistance against the reform, especially since these groups have a strong influence on administrative and legislative bodies. Second, regarding climate change as a threat to the Iranian economy (Farajzadeh et al., 2022), and especially for sectors such as agriculture that depend more on weather variables, output expansion under CP toward agricultural sectors will be restricted. Third, the reform policies induce a reduction in energy intensity, which is higher in HP than in CP. The critical point is the reduction in natural gas intensity that is consumed in high amounts, especially at the household level. However, the energy intensity of kerosene tends to increase, especially in the CP. Regarding energy intensity, kerosene, gasoline, and fuel oil should be considered separately, and more attempts are required to reduce their energy intensity. Further steps, based on the pollution potential should be taken to reduce energy intensity. Emission tax is a possible policy action, especially when environmental damage results from the production process (Walter and Chang, 2020). Environmental regulation has also been suggested in the literature (Caetano et al., 2023). Fourth, in terms of CO_2 emission intensity, the CP policy option is preferred over HP; however, a decreasing trend in emissions intensity under HP is expected after the simulation period. While the output under HP is slightly higher than that under CP, the emissions intensity for HP remains higher, indicating an energy-intensive production process and an economy with a lower level of technology, as pointed out in the literature (Gharibnavaz and Waschik, 2015). This simply shows a trade-off between the economic and environmental goals, while under the subsidized regime, both aspects are in an inappropriate situation. Under both policy scenarios, output composition experiences significant adjustments, changing in favor of the agricultural and manufacturing sectors, while energy products and mining suffer from contractions in output share. In addition, a slight decreasing trend in the total output is observed owing to falling demand.

The energy intensity tends to decrease under both CP and HP, mainly because of the intensity reduction of natural gas, electricity, and gas oil. In other words, the composition of energy use will be more inclined toward other energy products, especially kerosene and gasoline. It seems that natural gas and kerosene are substitutes for the final consumption by households. A similar relationship is expected for gasoline and gas oil in the production process. This point is also confirmed by the slight but positive contribution of the energy structure index to the emission intensity. Based on energy intensity, gasoline, fuel oil, and kerosene benefit from subsidy reform. Based on emissions intensity from energy sources, gasoline, and fuel oil should be considered more profoundly and separately. The lower emissions of the selected pollutants originating from lower natural gas consumption are outweighed by the higher emissions of these energy products. This is also conceivable from the contribution of the energy structure to higher emission intensities, even for CO_2. The lesson is that elimination of subsidies removes the distortions and brings economic gains; however more steps are needed to dampen environmental externalities.

Based on the decomposition analysis, efficiency change remains the primary source of emission intensity reduction. However, there is a chance of reducing pollutants emissions by reducing the consumption of gasoline and fuel oil. The significant contribution of the efficiency parameter to dampening emission intensity indicates that there are compelling opportunities to access the world market to enjoy better technology. Thus, along with possible economic gains from integration with the global economy (Farajzadeh et al., 2017), environmental benefits are also expected.

Decomposing the pollutants emission changes, in terms of their origin, into three sources, including production-based, energy products use, and final non-energy consumption, provides a better view to examine the sources of emission changes because there is a widely held view that attempts should be focused on energy products. Accordingly, it was found that the production process plays a more critical role in pollutants emissions after the energy subsidy reform. In other words, the composition of both energy consumption and output should be considered. In the same vein, an interesting point is that energy products, in addition to their contribution through fuel consumption, play a significant role in emissions from the production process. In addition, the agricultural sectors significantly contribute to production emissions. In general, changes in output composition, especially in favor of the agriculture and manufacturing sectors, lead to a higher emission intensity of CO_2-equivalent under both policy options. Specifically, agricultural activities contribute to higher emissions from the production process. The contribution of the production process to pollutants emissions, especially after subsidy reform, reinforces the role of non-CO_2 pollutants against CO_2 which has not been considered significantly in empirical works. Thus, in addition to attempts to reduce emissions intensity from energy consumption, specific efforts are needed to find measures to reduce production process emissions intensity. In this regard, output expansion of less polluting activities, such as services or technological progress in polluting sectors, such as manufacturing, is recommended. Globally, it sounds like there have been attempts to reduce emissions and energy intensity, with a focus on output expansion. Reductions in the emission intensity of industrialized countries, such as the OECD economies (Liddle, 2012), the USA, and the UK (Csereklyei and Stern, 2015; Rühl et al., 2012), Canada (Torrie et al., 2016), and even China (Fisher-Vanden et al., 2004) prove these attempts. As far as measures to reduce production-based emissions are considered, it should be strongly advised that access to modern technologies is essential because the production process in Iran is not considered very technology-embodied (Gharibnavaz and Waschik, 2015). In this context, the critical restrictions are sanctions that make it more difficult to access modern production technology.

In general, reform policies are expected to bring more benefits in the long term than in the short term. Efficiency in resources reallocation, improvements in energy composition leading to lower energy consumption, and lower financial pressure are some of these benefits (Yusoff and Bekhet, 2016; Li et al., 2017; Manzoor et al., 2010; Liu and Li, 2011). However, most of the literature focuses on immediate effects. Accordingly, using dynamic models contributes to the investigation of a more extended time horizon and depicts the time path for the economy. The time path of the Iranian economy after subsidy reform is characterized by slight output growth and relatively high inflation, while a decreasing trend for energy and emission intensity is observed.

As for Iran, although subsidy reform contributes to lowering emissions and energy intensity, there are gaps compared to the global figures for energy and emissions intensity, and serious attempts, even after removing subsidies, are required. Regarding the increasing energy and emissions intensity, especially over the last decade, any postponement in the reform will cause more economic problems and make it more challenging to implement. Thus, it is recommended to provide an appropriate environment for reforming the subsidy system. In particular, the chronic inflation should be dampened.

The current study applied a dynamic CGE model, contributing to the related literature. However, regarding the extent of energy subsidies and the necessity of policy reform, some extensions can be recommended for future studies. More policy scenarios for subsidy revenues can be examined. Primarily, investment in renewable energy production, as pointed out in the literature (Husaini et al., 2023), is an appealing scenario. The combination of subsidy reform and some trade policies are other possible extensions. In addition, the development of technology changes that are closely related to energy and emissions is another group of scenarios that needs to be examined.

Acknowledgment

We would like to thank the Editor-in-Chief for allowing us to revise the manuscript. Also, we thank Co-Editor Prof. Sushanta Mallick and the three anonymous reviewers for their helpful and constructive comments, which have significantly improved the article.

Appendix

References

Abouleinein, S. (2009). The impact of phasing out subsidies of petroleum energy product in Egypt. Egyptian center for economic studies. Working Paper, 145.
AlShehabi, O.H., 2013. Modeling energy and labor linkages: a CGE approach with an application to Iran. Econ. Model. 35, 88–98.
Amin, S., Jamasb, T., Nepal, R., 2021. Regulatory reform and the relative efficacy of government versus private investment on energy consumption in South Asia. Econ. Anal. Policy 69, 421–433.
Aminu, N., Clifton, N., Mahe, S., 2023. From pollution to prosperity: investigating the environmental Kuznets curve and pollution-haven hypothesis in sub-Saharan Africa's industrial sector. J. Environ. Manage. 342, 118147.
Ang, B.W., 2004. Decomposition analysis for policymaking in energy: which is the preferred method? Energy Policy 32, 1131–1139.
Ang, B.W., 2015. LMDI decomposition approach: a guide for implementation. Energy Policy 86, 233–238.
Asiaei, M., Khiabani, N., Mousavi, B., 2012. The environmental effects of the emission of energy carriers' subsidies in Iranian manufacturing sector. Iran. Energy Econ. 1 (4), 1–24 [in Persian].
Bastanzad, H., Nili, F., 2005. Analysis of pricing policy of energy carriers in Iranian economy. J. Econ. Res. 68, 201–226 [in Persian].
Beghin, J., Dessus, S., Ronald-Holst, D., Van der Mensbrugghe, D., 2002. Empiricalmodeling of trade and environment, trade and environment in general equilibrium: evidence from developing economics. Kluwer Acad. Publ. 31–78.
Böhringer, C., Löschel, A., 2006. Promoting renewable energy in Europe: a hybrid computable general equilibrium approach. Energy J. 27, 135–150.
BP (British Petroleum) (2021). Statistical Review of World Energy. 70th edition.
Burfisher, M.E., 2016. Introduction to Computable General Equilibrium Models, 3rd Ed. CambridgeUniversity Press.
Cabalu, H., Koshy, P., Corong, E., Rodriguez, U.P.E., Endriga, B.A., 2015. Modelling the impact of energy policies on the Philippine economy: carbon tax, energy efficiency, and changes in the energy mix. Econ. Anal. Policy 48, 222–237.
Caetano, R.V., Marques, A.C., Afonso, T.L., Vieira, I., 2023. Could private investment in energy infrastructure soften the environmental impacts of foreign direct investment? An assessment of developing countries. Econ. Anal. Policy 80, 961–977.
Central Bank of Iran (2017). Economic Time Series Database. Available at: https://tsd.cbi.ir/Display/Content.aspx.
Cheng, Y., Wang, Z., Ye, X., Wei, Y.D., 2014. Spatiotemporal dynamics of carbon intensity from energy consumption in China. J. Geogr. Sci. 24, 631–650.
Csereklyei, Z., Stern, D.I., 2015. Global energy use: decoupling or convergence? Energy Econ. 51, 633–641.
Dagoumas, A.S., Polemis, M.L., Soursou, S.E., 2020. Revisiting the impact of energy prices on economic growth: lessons learned from the European Union. Econ. Anal. Policy 66, 85–95.
de Moor, A., Calamai, P., 1997. Subsidizing Unsustainable Development. Earth Council and the Institute for Research on Public Expenditure. Available at. www.cbd.int/doc/case-studies/inc/cs-inc-earthcouncil-unsustainable-en.pdf.
Dong, F., Yu, B., Hadachin, T., Dai, Y., Wang, Y., Zhang, S., Long, R., 2018. Drivers of carbon emission intensity change in China. Resour. Conserv. Recycl. 129, 187–201.
El-Katiri, L., Fattouh, B., 2017. A brief political economy of energy subsidies in the Middle East and North Africa. In: Combining Economic and Political Development, pp. 58–87. Brill Nijhoff.
Eskandary, M., Nasiri Aghdam, A., Mohammadi, H., Mirzaei, H., 2016. The effects of adjustment of energy carrier prices on Iran's economy. Econ. Growth Dev. Res. 7 (25), 51–64 [in Persian].
Eslami Andargoli, M., Sadeghi, H., Ghanbari, A., Mohammadi Khabazan, M., 2012. The welfare effects of cash transfers of electrical energy subsidies on Iran economy. Econ. Res. 12 (2), 39–60 [in Persian].
Fan, Y., Liu, L.C., Wu, G., Wei, Y.M., 2006. Analyzing impact factors of CO_2 emissions using the STIRPAT model. Environ. Impact Assess. Rev. 26 (4), 377–395.
Farajzadeh, Z., 2018. Emissions Tax in Iran: incorporating pollution disutility in a welfare analysis. J. Clean. Prod. 186, 618–631.
Farajzadeh, Z., Bakhshoodeh, M., 2015. Economic and environmental analyses of Iranian energy subsidy reform using Computable General Equilibrium (CGE) model. Energy Sustain. Dev. 27, 147–154.
Farajzadeh, Z., Nematollahi, M.A., 2018. Energy intensity and its components in Iran: determinants and trends. Energy Econ. 73, 161–177.
Farajzadeh, Z., Nematollahi, M.A., 2023. Components and predictability of pollutants emission intensity. Glob. J. Environ. Sci. Manag. 9 (2), 241–260.
Farajzadeh, Z., Ghorbanian, E., Tarazkar, M.H., 2022. The shocks of climate change on economic growth in developing economies: evidence from Iran. J. Clean. Prod. 372, 133687.
Farajzadeh, Z., Zhu, X., Bakhshoodeh, M., 2017. Trade reform in Iran for accession to the world trade organization: analysis of welfare and environmental impacts. Econ. Modell. 63, 75–85.
Fattouh, B., El-Katiri, L., 2012. Energy subsidies in the Arab World. Arab Human Development Report. UNDP.
Fisher-Vanden, K., Jefferson, G.H., Liu, H., Tao, Q., 2004. What is driving china's decline in energy intensity? Resour. Energy Econ. 26 (1), 77–97.
Gelan, A., 2018. Economic and environmental impacts of electricity subsidy reform in Kuwait: a general equilibrium analysis. Energy Policy 112, 381–398.
Ghaffarian, F., Farajzadeh, Z., 2022. Factors affecting emission intensity of pollutants emitted from agricultural production. J. Agric. Econ. Dev. 35 (4), 333–347.
Gharibnavaz, M.R., Waschik, R., 2015. Food and energy subsidy reforms in Iran: ageneral equilibrium analysis. J. Policy Model. 37, 726–774.
Goli, Z., 2011. Energy subsidies and reforms in selected countries. Econ. J. 11 (11), 43–60 [in Persian].

Guillaume, D., Zytek, R., and Farzin, M.R. (2011). Iran–The Chronicles of the Subsidy Reform. IMF Working Paper. Available at: https://www.imf.org/external/pubs/ft/wp/2011/wp11167.pdf.

Han, X., Cao, T., Sun, T., 2019. Analysis on the variation rule and influencing factors of energy consumption carbon emission intensity in china's urbanization construction. J. Clean. Prod. 238, 117958.

Hoseininasab, D.E., Hazeri Niri, H., 2012. Computable general equilibrium analysis of the effect of energy carrier's subsidies reform on inflation and GDP. Econ. Growth Dev. Res. 2 (7), 67–80 [in Persian].

Husaini, D.H., Lean, H.H., Puah, C.H., Affizzah, A.D., 2023. Energy subsidy reform and energy sustainability in Malaysia. Econ. Anal. Policy 77, 913–927.

IEA. (2020). Energy Subsidies: Tracking the Impact of Fossil-Fuel Subsidies. Available at: https://www.iea.org/topics/energy-subsidies.

IEA. (2022). Energy Subsidies: Tracking the Impact of Fossil-Fuel Subsidies. https://www.iea.org/topics/energy-subsidies.

Balance, I., 2017. Deputy of electricity and energy affairs. Minist. Energy. Available at. http://pep.moe.org.ir.

Iwaro, J., Mwasha, A., 2010. Towards energy sustainability in the world: the implications of energy subsidy for developing countries. Int. J. Energy Environ. 1 (4), 705–714.

Jensen, J., Tarr, D., 2003. Trade, exchange rate, and energy pricing reform in Iran: potentially large efficiency effects and gains to the poor. Rev. Dev. Econ. 7 (4), 543–562.

Jiang, S., Lin, X., Qi, L., Zhang, Y., Sharp, B., 2022. The macro-economic and CO_2 emissions impacts of COVID-19 and recovery policies in China. Econ. Anal. Policy 76, 981–996.

Khiabani, N., 2008. A computable general equilibrium (CGE) study of the impact of increase in the price of energy products on the Iranian economy. Energy Econ. Rev. 5 (16), 1–34 [in Persian].

Khiabani, N., Hasani, K., 2010. Technical and allocative inefficiencies and factor elasticities of substitution: an analysis of energy waste in Iran's manufacturing. Energy Econ. 32 (5), 1182–1190.

Laudati, D., Pesaran, M.H., 2023. Identifying the effects of sanctions on the Iranian economy using newspaper coverage. J. Appl. Econ. 38 (3), 271–294. https://doi.org/10.1002/jae.2947.

Le, T.H., Nguyen, C.P., Su, T.D., Tran-Nam, B., 2020. The Kuznets curve for export diversification and income inequality: evidence from a global sample. Econ. Anal. Policy 65, 21–39.

Li, Y., Shi, X., Su, B., 2017. Economic, social and environmental impacts of fuel subsidies: a revisit of Malaysia. Energy Policy 110, 51–61.

Liddle, B., 2012. Breaks and trends in OECD countries' Energy–GDP ratios. Energy Policy 45, 502–509.

Lin, B., Jiang, Z., 2011. Estimates of energy subsidies in China and impact of energy subsidy reform. Energy Econ. 33 (2), 273–283.

Lin, B., Ouyang, X., 2014. A revisit of fossil-fuel subsidies in China: challenges and opportunities for energy price reform. Energy Convers. Manage 82, 124–134.

Liu, W., Li, H., 2011. Improving energy consumption structure: a comprehensive assessment of fossil energy subsidies reform in China. Energy Policy 39 (7), 4134–4143.

Mahdavi, R., 2014. The investigation of impact of complement policy for energy price policy reform on transport sector in Iran by computable general equilibrium. Iran. Energy Econ. 3 (12), 145–178 [in Persian].

Manzoor, D., Haghighi, I., 2010. Impacts of energy price increase and cash subsidy payments on energy demand. Trade Stud. 17 (67), 101–124 [in Persian].

Manzoor, D., Shahmoradi, A., Haghighi, I., 2010. An assessment of the impact of reducing implicit and explicit energy subsidies in Iran: using a computable general equilibrium model based on a modified micro consistent matrix. Energy Econ. Rev. 7 (26), 21–54 [in Persian].

Markusen, J.R., Rutherford, T., 2004. MPSGE: A User's Guide. Department of Economics. University of Colorado, Boulder.

Marrero, G.A., 2010. Greenhouse gases emissions, growth and energy mix in Europe. Energy Econ. 32 (6), 1356–1363.

Martınez-Zarzoso, I., Bengochea-Morancho, A., 2004. Pooled mean group estimation of an environmental Kuznets curve for CO_2. Econ. Lett. 82 (1), 121–126.

Ministry of Social Welfare (2021). Investigation of poverty in 2020. https://poverty-research.ir/wp-content/uploads/2021/08/16.pdf.

Mohammed, S., Gill, A.R., Ghosal, K., Al-Dalahmeh, M., Alsafadi, K., Szilárd, S., Oláh, J., Alkerdi, A., Ocwa, A., Harsanyi, E., 2023. Assessment of the environmental kuznets curve within EU-27: steps toward environmental sustainability (1990–2019). Environ. Sci. Ecotechnol., 100312

Movahhedi, S., 2021. Qualitative Analysis of Comparison of Energy Carrier Subsidy Reform Policies in Selected countries: Suggestions for Iran. Master Thesis. Faculty of Energy Engineering. Sharif University of Technology [in Persian].

Pan, X., Kamal Uddin, Md., Saima, U., Jiao, Z., Han, C., 2019. How do industrialization and trade openness influence energy intensity? Evidence from a path model in case of Bangladesh. Energy Policy 133, 110916.

Pinzón, K., 2018. Dynamics between energy consumption and economic growth in Ecuador: a granger causality analysis. Econ. Anal. Policy 57, 88–101.

Rodríguez, M., Pena-Boquete, Y., 2017. Carbon intensity changes in the Asian dragons: lessons for climate policy design. Energy Econ. 66, 17–26.

Rühl, C., Appleby, P., Fennema, J., Naumov, A., Schaffer, M., 2012. Economic development and the demand for energy: a historical perspective on the next 20 years. Energy Policy 50, 109–116.

Salari, M., Javid, R.J., Noghanibehambari, H., 2021. The nexus between CO_2 emissions, energy consumption, and economic growth in the US. Econ. Anal. Policy 69, 182–194.

Sarrakh, R., Renukappa, S., Suresh, S., Mushatat, S., 2020. Impact of subsidy reform on the kingdom of Saudi Arabia's economy and carbon emissions. Energy Strategy Rev. 28, 1–10.

Shahiduzzaman, M., Layton, A., Alam, K., 2015. Decomposition of energy-related CO_2 emissions in Australia: challenges and policy implications. Econ. Anal. Policy 45, 100–111.

Shahmoradi, A., Haghighi, I., Zahedi, R., 2011. Impact analysis of energy price reform and cash subsidy payment in Iran: CGE approach. Econ. Res. Polic. 19 (57), 5–30 [in Persian].

Solaymani, S., Kari, F., Zakaria, R.H., 2014. Evaluating the role of subsidy reform in addressing poverty levels in Malaysia: a CGE poverty framework. J. Dev. Stud. 50 (4), 556–569.

Steckel, J.C., Jakob, M., Marschinski, R., Luderer, G., 2011. From carbonization to decarbonization? Past trends and future scenarios for China's CO_2 emissions. Energy Policy 39 (6), 3443–3455.

Torrie, R.D., Stone, C., Layzell, D.B., 2016. Understanding energy systems change in Canada: 1. Decomposition of total energy intensity. Energy Econ. 56, 101–106.

UNDP (United Nations Development Programme), 2010. Department of Environment. Iran Second National Communication to United Nations Framework Convention On Climate Change (UNFCCC). National Climate Change Office, Department of Environment, Tehran.

Third National Communication to United Nations Framework Convention On Climate Change, 2017. UNDP (United Nations Development Programme. https://unfccc.int/sites/default/files/resource/Third%20National%20communication%20IRAN.pdf.

UNFCCC (United Nations Framework Convention on Climate Change) (2015), 2014. UNFCCC Country Brief, Iran.

Walter, J.M., Chang, Y.M, 2020. Environmental policies and political feasibility: eco-labels versus emission taxes. Econ. Anal. Policy 66, 194–206.

World Bank. (2004). Islamic Republic of Iran energy-Environment Review Policy Note. Report No. 29062-IR. Washington D.C.

World Bank. (2018). https://data.worldbank.org/indicator/EN.ATM.CO2E.KT?locations=IR-1W.

World Bank. (2019). https://data.worldbank.org/indicator/EN.ATM.CO2E.KT?locations=IR-1W.

World Bank. (2021). https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.CD?locations=IR-CN.

Yang, G., Li, W., Wang, J., Zhang, D., 2016. A comparative study on the influential factors of China's provincial energy intensity. Energy Policy 88, 74–85.

Yang, X., He, L., Xia, Y., Chen, Y., 2019. Effect of government subsidies on renewable energy investments: the threshold effect. Energy Policy 132, 156–166.

Yu, Y., Li, S., Sun, H., Taghizadeh-Hesary, F., 2021. Energy carbon emission reduction of China's transportation sector: an input–output approach. Econ. Anal. Policy 69, 378–393.

Yusoff, N.Y.B.M., Bekhet, H.A., 2016. Impacts of energy subsidy reforms on the industrial energy structures in the Malaysian economy: a computable general equilibrium approach. Int. J. Energy Econ. Policy 6 (1), 88–97.

Zarepour, Z., Wagner, N., 2023. How manufacturing firms respond to energy subsidy reforms? An impact assessment of the Iranian Energy Subsidy Reform. Energy Econ., 106762

Zhang, C., Su, B., Zhou, K., Yang, S., 2019. Decomposition analysis of China's CO_2 emissions (2000–2016) and scenario analysis of its carbon intensity targets in 2020 and 2030. Sci. Total Environ. 668, 432–442.