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ORIGINAL RESEARCH

Comparing energy efficiency and price policy from a sustainable development perspective: Using fossil fuel demand elasticities in Iran

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ABSTRACT

- ***The price elasticity of fossil fuel demand is lower than one and inelastic.***
- ***The price policy is ineffective in reducing fossil fuel consumption.***
- ***The technology elasticity of fossil fuel demand is higher than one and elastic.***
- ***Energy efficiency improvement is much more effective than price policy for reducing fossil fuel consumption.***

This study aims to compare the effects of price policy with energy efficiency improvement on energy consumption and sustainable development. To this end, our research estimates the demand elasticities of diesel, gasoline, fuel oil, LPG, and kerosene using Dynamic Log-Linear and AutoRegression Distributed Lag in Iran during 1976–2017. In 2018, Iran had the first rank in the world for the amount of subsidy on various kinds of fossil fuels. Based on the results, technology is up to 100 times more effective than price policy. Technology, by only 10% improvement in energy efficiency, saves about 400 billion liters of fossil fuels (or 15% of total), 3.6 billion US Dollars of the expenditure thereon (or 17% of total), 217 billion tons of CO_2 emissions (or 15% of total), and more than 338 million DALYs (or 4.5 million lives). It leads to upgrading social, environmental, health, and economic pillars of sustainable development, especially with gasoline consumption drop. Thus, policy-makers are suggested to promote energy-consuming technologies rather than increasing the fuel price.

Keywords economics · environment · environmental impact · fossil fuel · government policy and funding · sustainability

Discussions

- Energy efficiency plays a crucial role in sustainable development in Iran.
- By only 10% improvement in energy efficiency, technology reduces fossil fuel consumption, expenditure thereon, and CO2 emissions by more than 15%.
- By only 10% improvement in energy efficiency, technology saves more than 338 million DALYs (or 4.5 million lives).

Introduction

The recently rapid spread of fossil fuel demand has constituted monumental challenges for sustainable development pillars, including (1) social,[1] (2) environment,[1, 2] (3) health,[3, 4] and (4) economy.[3–5] These challenges are the result of consumers expenditures on fossil fuel consumption; political and economic costs for importing fossil fuels[6]; threats made against energy security; traffic congestion[7]; emissions and air pollution[8, 9]; and environmental health issues,[10] diseases and mortalities; discouragement of investment in energy-efficient products[11]; and driving out the renewable energies[12] which are expensive at the first stages of development.[13]

An alternative to decrease fossil fuel demand in Iran is the price policy.[14, 15] Iran has one of the highest fossil fuel subsidies in the world, and it emits more than what produces.[16] In the 2000s, the GDP of this country was around 0.5 percent of the current global GDP, whereas it had more than 1.6 percent share of the global CO_2, implying that this country is 3-times more pollutant than productive.[17] The pollutant nature of this economy is for the extremely low price of all the fossil fuel types as it has the highest amount of fossil fuel subsidies worldwide (see Fig. 1).

Another alternative for fossil fuel reduction is the improvement of technology. In Iran, energy efficiency is considerably low due to old technology used in energy-consuming sectors such as transportation.[11, 12] Taghvaee et al. claim that a Mafia in Iran has supported the domestic car industry with very old technology for more than several decades. This Mafia, with tremendous power to affect economic and policy-making institutions and decision-makers, tries to set tariff and non-tariff barriers to the import of new cars from abroad with advanced technology thanks to the pretext of supporting the domestic car industry.[18] In this way, the car industry is a monopoly in Iran, limiting technology advancement and energy efficiency improvement.[19] Low energy efficiency increases energy consumption and greenhouse gas emissions, threatening energy security and polluting the environment.[20] High energy consumption is socially and politically risky since it increases the dependency on imported energy as a strategic good. Also, it is economically harmful since it increases the expenditure on energy consumption. In addition to social and economic threats, it heightens environmental pollution, which is dangerous for the environment and health.[21] Thus, increasing energy efficiency is a potential to save the social, environment, economy, and health in Iran, which are the dimensions of sustainable development.[22, 23]

Regarding the analysis mentioned in the above two paragraphs, the policy-makers are dubious about which approach is more effective: price policy or energy efficiency improvement. This study tries to fill this gap. Answering this question helps

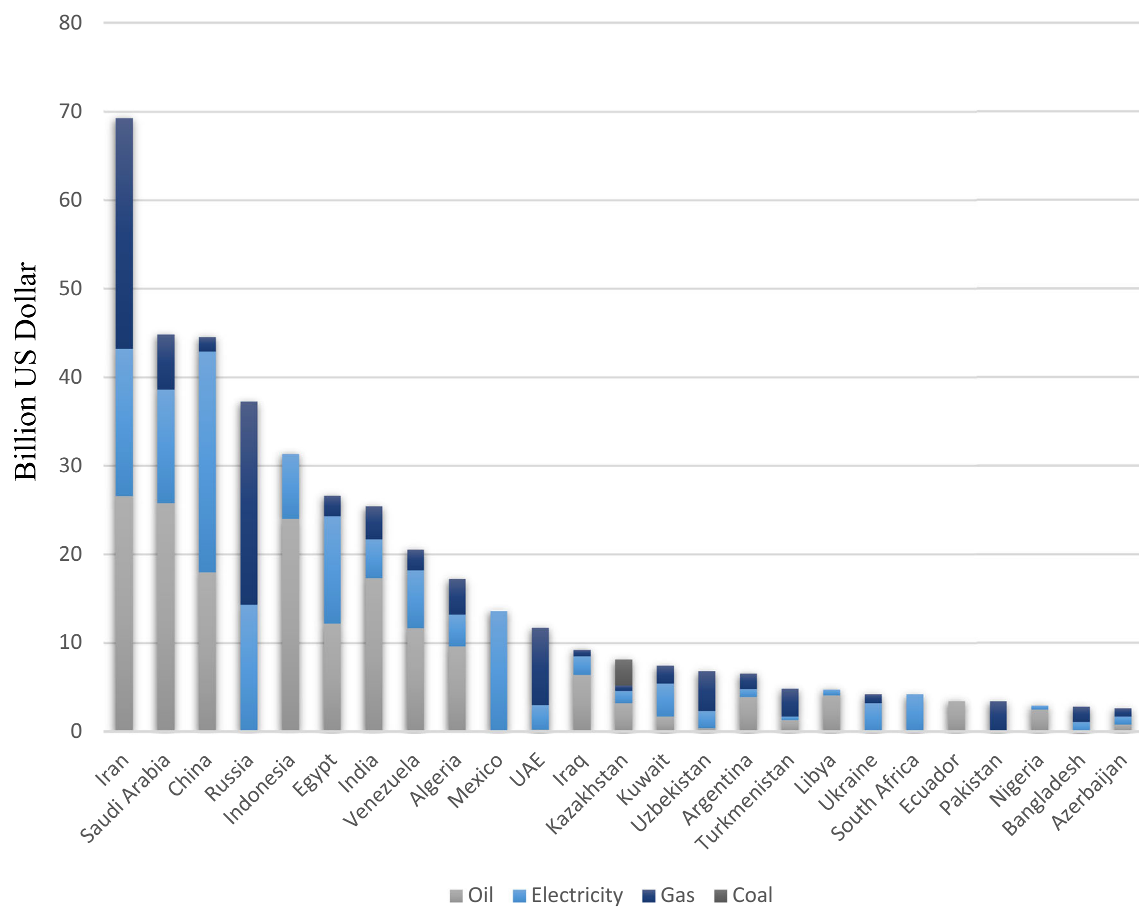

Figure 1. Subsidies of fossil fuels by countries in billion US Dollars in 2018. *Source* IEA 2018.[49]

policy-makers how to prioritize energy policies. In addition, this research completes the first question by a follow-up question "how much is that policy more effective than the other?". This question is also beneficial for strategists since it shows how much the prioritized policy is preferable.

This research aims to compare the price policy with energy efficiency improvement to find the most effective one to reduce fossil fuel consumption. The basis of this comparison is the estimated demand elasticities of diesel, gasoline, fuel oil, Liquefied Petroleum Gas (LPG), and kerosene. These elasticities pave the way to estimate a couple of hypothetical trends: price policy and energy efficiency improvement. The hypothetical trends show how each approach affects various dimensions of sustainable development, including economy, environment, and social. The study's novelty is the estimation of energy policy effects on sustainable development by demand elasticities of energy.

Literature review

Sustainable development

The most considerable viewpoints of sustainable development are weak, strong, heath-centered, and integrated sustainability.[24] Integrated sustainability considers four pillars for sustainability, including social, environment, economy, and spillover effects,[25] while health-centered sustainability has three pillars of environment, economy, and health which is the most influential pillar.[26, 27] Also, the weak sustainability covers three pillars of social, environment, and economy with equal values, and strong sustainability acknowledges the environment as the most critical pillar and the social as the 2nd most crucial pillar of sustainability.[28] Despite different sustainability perspectives,[29, 30] they unanimously agree on environment, economy, and social (health) as the main pillars of sustainability. Thus, our research reflects these four dimensions of sustainable development in investigating the fossil fuel demand strategies.[13]

Fossil fuel demand

The price policy is the subject of numerous researches,[3, 18–20, 31] while there is a lack in the studies about non-price policies, such as technology improvement for reduction of fuel consumption; changes in currency rate to combat fuel smuggling; and the comparison of these policies effects with the price policy ones.[6] This comparison can provide the strategists with the most effective policies, which may vary in different countries.

In addition to the lack of non-price policy studies, Moshiri believes that there is a limited number of studies on developing countries like Iran,[6] while it is numerous about the developed economies like the USA,[32] G20,[33] OECD and European countries.[34] Due to the different characteristics of developed and developing countries, the decision-makers should formulate different policies in various countries. For this reason, researchers should add case studies in this field to find the most effective strategy that fits the idiosyncratic and individual characters of the countries, especially the developing and oil-exporting countries with high fossil fuel consumption, like Iran.

Therefore, Iran is an excellent candidate to study and compare various policies for reducing the fossil fuel demand, due to the lack of research both about non-price policies like technology improvement and about developing countries, especially the oil-exporting ones with high fossil fuel consumption.[6]

Methodology

This research tries to estimate the price, income, and technology elasticities of fossil fuels' demands in Iran, using Dynamic Log-Linear and AutoRegression Distributed Lag (ARDL) models for diesel, gasoline, fuel oil, kerosene, and LPG.

Model specification

Following previous studies,[19, 24, 25, 28–30, 35–37] our research uses econometric model 1 to estimate the demand elasticities of various fossil fuels in Iran, including diesel, gasoline, fuel oil, kerosene, and LPG.

$$LnQ_t = C + \beta_1 LnP_t + \beta_2 LnY_t + \beta_3 LnEE_t + \beta_4 LnR + \beta_5 Ds + \varepsilon_t \quad (1)$$

where Q is the fossil fuel demanded quantity, C is intercept, P is the fossil fuel price, Y is income, EE is energy efficiency, R is currency rate, Ds is dummy variable for the years when the subsidy reform plan is implemented in Iran since 2010 which is equal to 1 and for other years is 0, ε is residual series, and β s are the elasticities since all the variables are in natural logarithm.[38]

For estimating regression 1, this research employs ARDL since it estimates the coefficients and statistics irrespective of whether the integration degrees of the variables are I(0) or I(1).[39] This capability offers a reliable and valid, relieving the risk of spurious regression estimations. Before running the models, the variables are put into different preliminary tests, including various unit root test, to check if the integration degree of variables ranges between I(0) and I(1). These preliminary tests and their results are explained in detail in the Appendix file of the associate Mendeley Dataset.[40] In addition, this appendix represents the methodology of the robustness tests for investigating the reliability of the models' results which is available at the following link.

https://www.dx.doi.org/10.17632/w2y9dccpvx.4

Projection

Regarding the estimated elasticities of energy efficiency and price, this research investigates the effects of fossil fuel demand reduction on sustainable development, which is the novelty of this study. This methodology goes beyond the only estimation of demand elasticities; and it estimates the effects on sustainability. To have a comparison between price policy and energy efficiency improvement, this methodology considers the following couple of assumptions:

10% increase in the price of the fossil fuel as a price policy

In this assumption, the price of the fossil fuel i increases 10% one time at the beginning of the period by decreasing the subsidies. This price increase prevails not only in the short-run but also in the long-run, sufficiently long for the quantity demanded to be in equilibrium. Following Mundaca's research in 2017 and Sterner's study in 2017,[6, 32] the new equilibrium projects a *hypothetical demand* quantity, HQi, for the fossil fuel i:

$$HQi_t = Qi_t\left(\frac{Pi_t + 0.1Pi_t}{Pi_t}\right)^{\text{Price elasticity}} \quad (2)$$

10% improvement in the energy efficiency of the fossil fuel as a technological policy

This assumption improves the energy efficiency (10%) one time at the beginning of the period by, for example importing new energy-saving technologies, funding Research and Development centers, and adopting higher energy-saving standards for energy-consuming products. This improvement in energy efficiency prevails for a sufficiently long period, denoted as follows[6, 32]:

$$HQi_t = Qi_t\left(\frac{EEi_t + 0.1EEi_t}{EEi_t}\right)^{\text{Energy efficiency elasticity}} \quad (3)$$

The hypothetical demand quantities affect the social pillar of sustainable development by increasing the energy security level, as well as the economic pillar via the expenditure reduction due to changes in both the consumption and the price of the fossil fuels as in the following equation.

$$\Delta EX_t = \left(Qi_t - HQi_t\right) \cdot \Delta P_t, \quad (4)$$

where ΔEX is the difference of expenditure on the actual and hypothetical fossil fuel consumption; and P is the fossil fuel price in the US Dollar, which can change in case of price policy.

These policies affect the environmental pillar of sustainable development via reducing greenhouse gas emissions[41] as in the following equations.[6, 32]

$$\text{HGHG}_t = \text{GHG}_t\left(\frac{Pi_t + 0.1Pi_t}{Pi_t}\right)^{\text{Price elasticity}} \quad (5)$$

$$\text{HGHG}_t = \text{GHG}_t\left(\frac{EEi_t + 0.1EEi_t}{EEi_t}\right)^{\text{Energy efficiency elasticity}} \quad (6)$$

where HGHG and GHG are the hypothetical and actual greenhouse gas emissions (including CO_2, CO, CH_4, NOx, N_2O, SO_2, and SPM).

The changes in the environmental quality affect the health status. To estimate the effect, this study employs the *health damage factors*, suggested by Hales et al. in 2014.[42] They estimated the Relative Risks (RR) of CO_2 emissions for human health to calculate the *health damage factors*, measured in DALY/kg CO_2.[1] It converts the CO_2 emissions into the health status as a conversion factor. Based on the findings of Tang et al. in 2019,[43] they are 1.3×10^{-6}, 1.5×10^{-6}, and 2.0×10^{-6} for the three Shared Socioeconomic Pathway (SSP) scenarios (i.e., SSP1, SSP2, and SSP3, respectively) in the World Health Organization (WHO) report, updated in 2014.[42]

$$\text{DALY}_{\text{SSP}_x} = \text{HDF}_{\text{SSP}_x} \times \text{CO}_2 x = 1, 2, 3, \text{ and } \overline{x} \quad (7)$$

$$\text{HDF}_{\text{SSP}_1} = 1.3\times10^{-6}; \text{HDF}_{\text{SSP}_1} = 1.5\times10^{-6}; \text{HDF}_{\text{SSP}_1} = 2.0\times10^{-6}; \text{and HDF}_{\text{SSP}_{\overline{x}}} = 1.6\times10^{-6}$$

where DALY is the Disability-Adjusted Life Years.[2] "Each DALY can be thought of as one lost year of healthy life",[44] i.e., one person's life is equal to 76 DALYs in Iran since its life expectancy is about 76 in 2018.[45] HDF is the health damage factor, and $SSP_{\overline{x}}$ is the average value of SSP1, SSP2, and SSP3 conversion factors. They represent the changes in DALY, resulted from the changes in the CO_2 emissions of the hypothetical fossil fuel consumptions.

The hypothetical demand quantities estimate the changes in the social, economic, environmental, and health effects of the energy efficiency and price policy. It helps us compare the energy efficiency improvement with the price policy. It completes our first question, "which policy is more effective in fossil fuel reduction?" by a follow-up question, "how much is that policy more effective than the other?".

Data

To study the energy policies and to estimate the demand elasticities of various fossil fuels in Iran, this study has annual time series within 1976–2017 from three distinctive databases. It derives the price of various fossil fuel kinds including diesel, gasoline, fuel oil, kerosene, and LPG, from the National Iranian Oil Refining and Distribution Company,[46] measured in Rials of Iran, divided by Consumer Price Index (CPI), constant price 2011, to capture inflation. With the same aim, Gross National Product (GDP) is divided by the CPI to make the current market value of the GDP to the constant value of 2011, measured in

1 This research considers CO_2 as a proxy for greenhouse gas emissions to estimate the health effects since it has the greatest share in the greenhouse gas emissions and air pollution.

2 *"Disability adjusted life years (DALY) is a health gap measure developed by the World Health Organization. DALYs represent the sum of years of life lost due to premature mortality (YLL) in the population and the years lost due to disability (YLD) for incident cases of health condition. One DALY stands for one lost year of healthy life and the burden of disease measured by the gap between the current health status and the ideal status of a life free of disease and disability."* (DALY. In: Kirch W., 2008).

Table 1. Estimated price, income, and energy efficiency elasticities of fossil fuels in summary.

Demand elasticities	Price	Energy efficiency	Income
Diesel	– 0.0347	– 1.0658	– 1.0174
Gasoline	– 0.2900	– 2.1797	– 2.9016
Fuel oil	– 0.1317	– 2.3680	– 2.5870
Kerosene	– 0.0233	– 0.9047	– 0.9189
LPG	– 0.2037	– 0.9514	– 1.3983

Source researchers' finding.

Rials of Iran. The constant GDP is divided by population to create per capita GDP for considering the effect of the population.[13] It is the income proxy. The Iran Statistics Center is the source of GDP[47]; and the Central Bank of the Islamic Republic of Iran is the source of CPI, population, and consumption of the five fossil fuel types, measured in thousand barrels per day.[48] The consumption volumes are divided by population to offer the consumption per capita. It is the proxy of fossil fuel demand. Energy efficiency is the GDP divided by the summation of all the types of fossil fuel consumption (it is the inverse of fossil fuel energy intensity). In addition, the currency rate is from the Central Bank of the Islamic Republic of Iran,[48] which is the non-official currency rate in the Rials of Iran (the value of each US Dollar in Rials of Iran). It is the proxy of smuggling since the higher the currency rate is, the more motivation for smuggling is. Using these data, this research estimates the fossil fuel demand functions.

Result

Table 1 displays the estimated demand elasticities of various fossil fuels in Iran summarily. The results of these tests are in detail in Appendix,[40] in the following link. Based on these estimated elasticities, this research projects the hypothetical fossil fuel consumption in case of a 10% increase in the fossil fuel price and a 10% improvement in energy efficiency.

https://www.dx.doi.org/10.17632/w2y9dccpvx.4

Price policy or energy efficiency?

The projection of hypothetical trends shows that energy efficiency improvement is more beneficial for the sustainable development pillars, including social, economy, environment, and health than price policy.

Social

Figure 2 displays the hypothetical fossil fuel demand due to a 10% increase in its price and 10% improvement in energy efficiency, as well as the actual fossil fuel consumption and production. Energy is a necessary and strategic good because it is one of the most critical inputs at the macroeconomic level for national products.[38] Shortage of energy impedes economic growth as many geopolitical and strategic plans are rooted in the location of energy sources, emerging the critical concept of energy security as a social element. Countries with energy limitations have to import energy from other countries, increasing their economic and political dependence for this strategic good.[39] Based on Fig. 2, all kinds of fossil fuel energies in Iran are under the threat of dependency on the other countries since the consumption values are mostly more than the production ones, and the consumption values are increasing at a higher pace than the production one (the Appendix, Result section, and Social subsection have more explanations in detail for describing Fig. 2). Although the energy efficiency improvement is more effective than the price policy, it is insufficient to survive the security threat of energy import. Thus, energy efficiency is more effective than the price policy, but other policies should accompany it.

Table 2 shows the gaps between the hypothetical and actual consumptions of fossil fuels combustion. Among the fossil fuels, based on Table 2, the fuel oil shows the largest saving quantities, more than 111 billion liters, by adopting a technological policy in lieu of the price policy in the energy sector. Among the fossil fuel energies, gasoline is in second place with more than 96 billion liters of savings. It claims that the energy sector benefits mainly from adopting an energy efficiency policy on fuel oil and gasoline-consuming cars and utilities, saving about 20% and 18% of the actual fuel oil and gasoline consumption. In total, the fossil fuel consumption saving quantity is more than 366 billion liters, in case of adopting energy efficiency policy instead of price policy, which is more than 15% of total fossil fuel consumption in the period. It shows that energy efficiency is considerably more beneficial than the price policy in reducing fossil fuel consumption (about 366 billion liters) and increasing energy security as a social element.

Economy

Just like the social perspective, the energy efficiency policy has more benefits than the price policy from an economic viewpoint. Figure 3 displays the expenditure on fossil fuels in actual and hypothetical cases. The expenditure on all types of fossil fuels decreases, in case of improvement in energy efficiency, except for LPG, whose expenditure is negligible compared to those of the other fossil fuel types. However, the fossil fuel price policy not only cannot decrease the expenditures, but also it increases them. In the case of price policy, on the one hand, expensive fossil fuel decreases its demand and the expenditure thereon; on the other hand, it increases the price and the expenditure thereon. It shows that the price policy has (minor) advantages in reducing energy consumption and environmental pollution, while it causes some economic loss for the fossil fuel consumers, especially those with low-income levels. It is

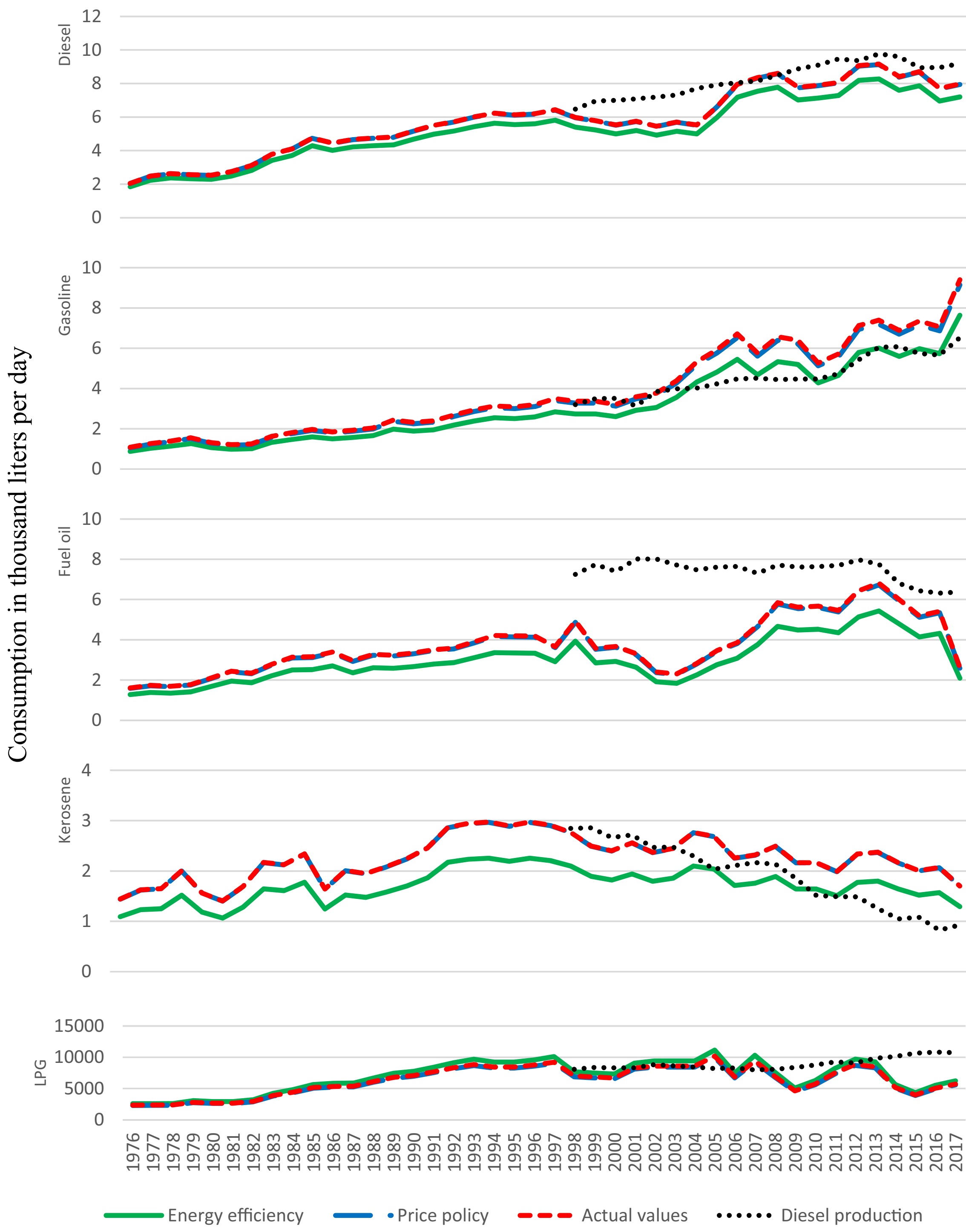

Figure 2. Actual and hypothetical consumption quantities of fossil fuels in Iran (thousand liters per day). *Source* Central Bank of the Islamic Republic of Iran 2020.[48]

another evidence for the higher benefits of energy efficiency improvement.

Table 2 shows the expenditures of actual and hypothetical fossil fuel consumption and their savings in the US Dollar during 1976–2017. The most incredible saving, with regard to Table 2, happens in the case of adopting energy efficiency policy in lieu of price policy for gasoline which is more than 3 billion US Dollars in constant price 2011. It is another evidence for the beneficial role of energy efficiency policy, specifically in gasoline consumption. Regarding all kinds of fossil fuels, the total saving from energy efficiency instead of price policy is 366 billion US Dollars in constant price 2011which is more than 14% of all the expenditures on fossil fuel. However, the total expenditure on fossil fuel increases in the case of price policy. It implies that price policy

Table 2. Actual and hypothetical fossil fuel consumption and their differences in Iran during 1976–2017 (in liter).

Consumption of fossil fuel	Diesel	Gasoline	Fuel oil	LPG	Kerosene	Total
Actual consumption	910,949,475,750	602,229,943,125	586,490,201,625	354,334,973,250	99,273,651,188	2,553,278,244,750
Energy efficiency hypothetical consumption	822,958,558,875	489,258,871,500	467,996,798,625	268,646,190,938	108,696,358,762	2,157,556,778,625
Price policy hypothetical consumption	907,941,702,375	585,812,273,250	579,174,382,125	353,548,965,000	97,364,873,813	2,523,842,196,750
Differences (saving quantities)						
Actual and energy efficiency consumption	87,990,916,688	112,971,071,700	118,493,402,813	85,688,782,313	– 9,422,707,560	395,721,466,125
Actual and price policy consumption	3,007,773,138	16,417,669,804	7,315,819,257	786,008,231	1,908,777,420	29,436,047,850
Energy efficiency and price policy values	84,983,143,538	96,553,401,900	111,177,583,575	84,902,774,100	– 11,331,484,980	366,285,418,275
Expenditure on fossil fuel						
Actual expenditure	4,446,966,401	11,739,779,696	1,637,289,707	516,113,996	3,125,967,960	21,466,117,760
Energy efficiency hypothetical expenditure	4,017,422,655	9,537,538,662	1,306,494,702	565,101,730	2,370,015,519	17,796,573,267
Price policy hypothetical expenditure	4,875,511,747	12,561,709,728	1,778,552,953	556,809,494	3,430,937,114	23,203,521,038
Differences (savings)						
Actual and energy efficiency expenditure	429,543,746	2,202,241,036	330,795,004	– 48,987,734	755,952,442	3,669,544,494

Table 2. (continued)

Consumption of fossil fuel	Diesel	Gasoline	Fuel oil	LPG	Kerosene	Total
Actual and price policy expenditure	– 428,545,345	– 821,930,033	– 141,263,246	– 40,695,498	– 304,969,154	– 1,737,403,277
Energy efficiency and price policy expenditure	858,089,092	3,024,171,069	472,058,251	– 8,292,236	1,060,921,596	5,406,947,771

is fiercely resisted by the people, especially the low-income ones, while the energy efficiency would be welcome, increasing not only the welfare level of the society but also the satisfaction level of people to the policy-makers.

Environment and health

Figure 4 shows that energy efficiency emits a lower amount of greenhouse gas emissions and the associated diseases and mortalities, compared with those of the price policy. It also shows that CO_2 has the largest share among the greenhouse gas emissions. Furthermore, the most considerable amount of emissions is attributed to diesel consumption, before gasoline and fuel oil. The other fuels and emissions have far much lower shares, as shown in the natural logarithm in Fig. 4 to provide a clear image for comparison. Despite the largest share of diesel combustion in emitting CO_2, NO_x, N_2O, and SPM, gasoline has the most amount of CO, CH_4, and SO_2. It affirms the second most significant role of gasoline after diesel in the emissions of greenhouse gases.

According to Fig. 4 (and compared with the price policy), in the energy efficiency case, all the fossil fuels, except LPG, emit a lower volume of each greenhouse gas. CO_2 has the greatest amount of emissions in energy efficiency and price policy cases. The other greenhouse gas emissions are significantly lower than the CO_2 emissions of fossil fuel burning. Among the fuels, the largest amount of emissions is from diesel and gasoline, implying their strategic importance in emissions reduction.[47] Thus, in the CO_2 emissions reduction as the most critical greenhouse, the energy efficiency is the most effective, especially for diesel and gasoline with their highest role in pollution and health as the sustainable development pillars.

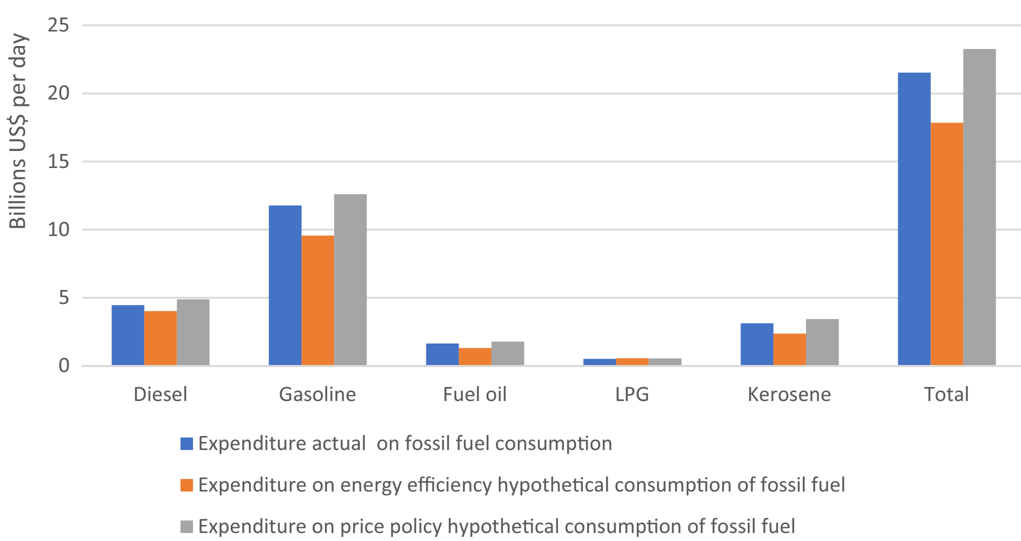

Figure 3. Actual and hypothetical consumers' expenditures on fossil fuel consumption in Iran throughout 2000–2017 (constant price 2011). *Source* researchers' findings.

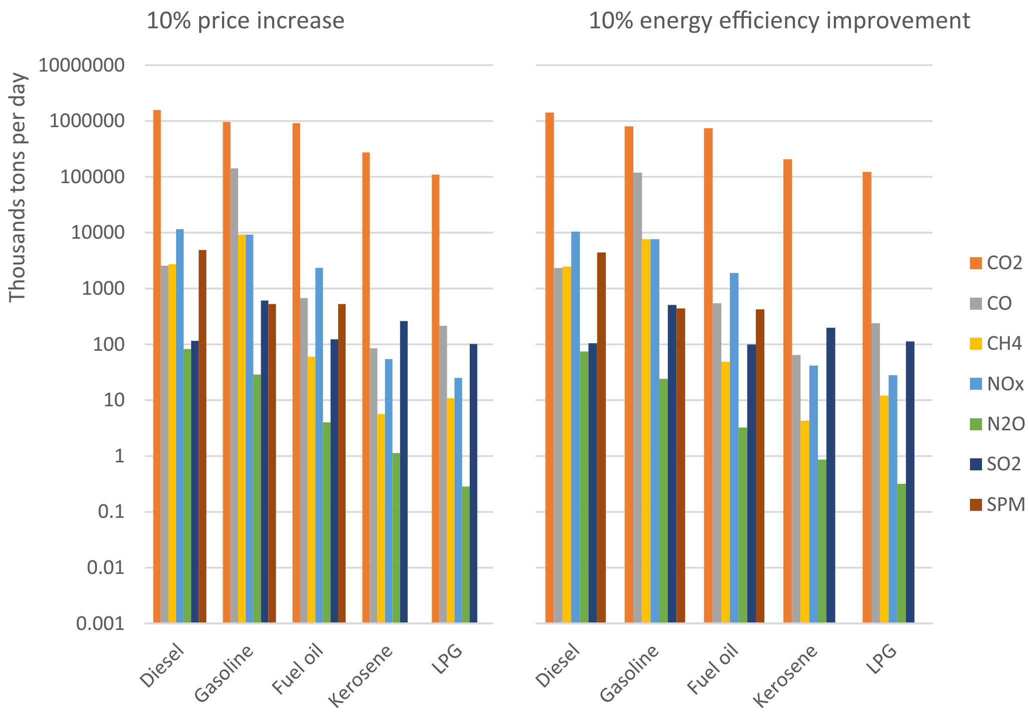

Figure 4. Logarithm of hypothetical greenhouse gas emissions in Iran during 2000–2017. Except for N_2O which is 2007 to 2017. *Source* Researchers' findings.

Figure 5 displays how much lower the hypothetical energy efficiency emits greenhouse gas than the price policy. The price policy case, regarding Fig. 5, emits about 200 billion tons of CO_2 more than what the energy efficiency case does in total. The most significant difference is in the CO_2 emissions of fuel oil, gasoline, and diesel with, respectively, more than 66, 59, and 54 billion tons, in the case of energy efficiency instead of price policy. It shows that fuel oil is an effective fossil fuel just like diesel and gasoline in CO_2 emissions reduction.

The changes in the environment, in turn, cause modifications in the health status, as in Table 3. It reveals the changes in DALY resulted from the price policy and energy efficiency. The energy efficiency, averagely, increases by more than 338 million DALYs. It is equal to about 4.5 million people's lives, considering 76 (years) life expectancy of Iran in 2018 according to the World Bank report.[17] It is about 350 thousand lives, in the case of price policy, since it saves about 27 million DALYs which is about 311 million DALYs more than that of the energy efficiency case. It implies that the 10% energy efficiency improvement saves more than 4 million more lives than a 10% increase in price does, indirectly, via the reduction in fossil fuel consumption.

Discussion

From a social perspective and compared with price policy, energy efficiency is a much more effective policy to reduce fossil fuel consumption, increasing energy security. According to Table 2, the energy efficiency hypothetical consumption of fossil fuel is about 400 billion liters, more than 15% of the actual one. This policy is essential specifically for gasoline and diesel. Needing to import gasoline and diesel threatens energy security since they are strategic goods. To increase energy security, one alternative solution is the import of energy-efficient cars, since car is not a necessary and strategic good, whereas it can decrease gasoline and diesel consumption up to 112 (18% of the total) and 87 (9% of the total) billion liters, in case of only 10% improvement in energy efficiency in Iran. If the Iranian government dispels the import of cars which is a normal good, soon they would have to import strategic and necessary goods (i.e., gasoline and diesel), threatening the energy security level as a social element.[3]

From an economic viewpoint, energy efficiency decreases the expenditure on fossil fuel demand-side, whereas the price policy increases it. Price policy decreases the welfare level and economic satisfaction among people. Table 3 shows that technology saves more than 3.6 billion US Dollars (in constant price 2011), 17% of the actual fossil fuel expenditure, with only 10% improvement in energy efficiency, specifically for gasoline with more than 2.2 billion US Dollar savings during the period. It is

[3] Many might claim that the improvement in energy efficiency is limited and it is impossible to increase it from a point onward. To respond this view-point, Iran energy efficiency is very lower than the global average value (see Figs. 5 and 6 in Jafari and Baratimalayeri.[19] There is a huge gap between energy efficiency in Iran and the global average value. It shows that there a considerable potential for improvement in energy efficiency in Iran as the priority should be on starting point of energy efficiency rather than its ending and limiting point.

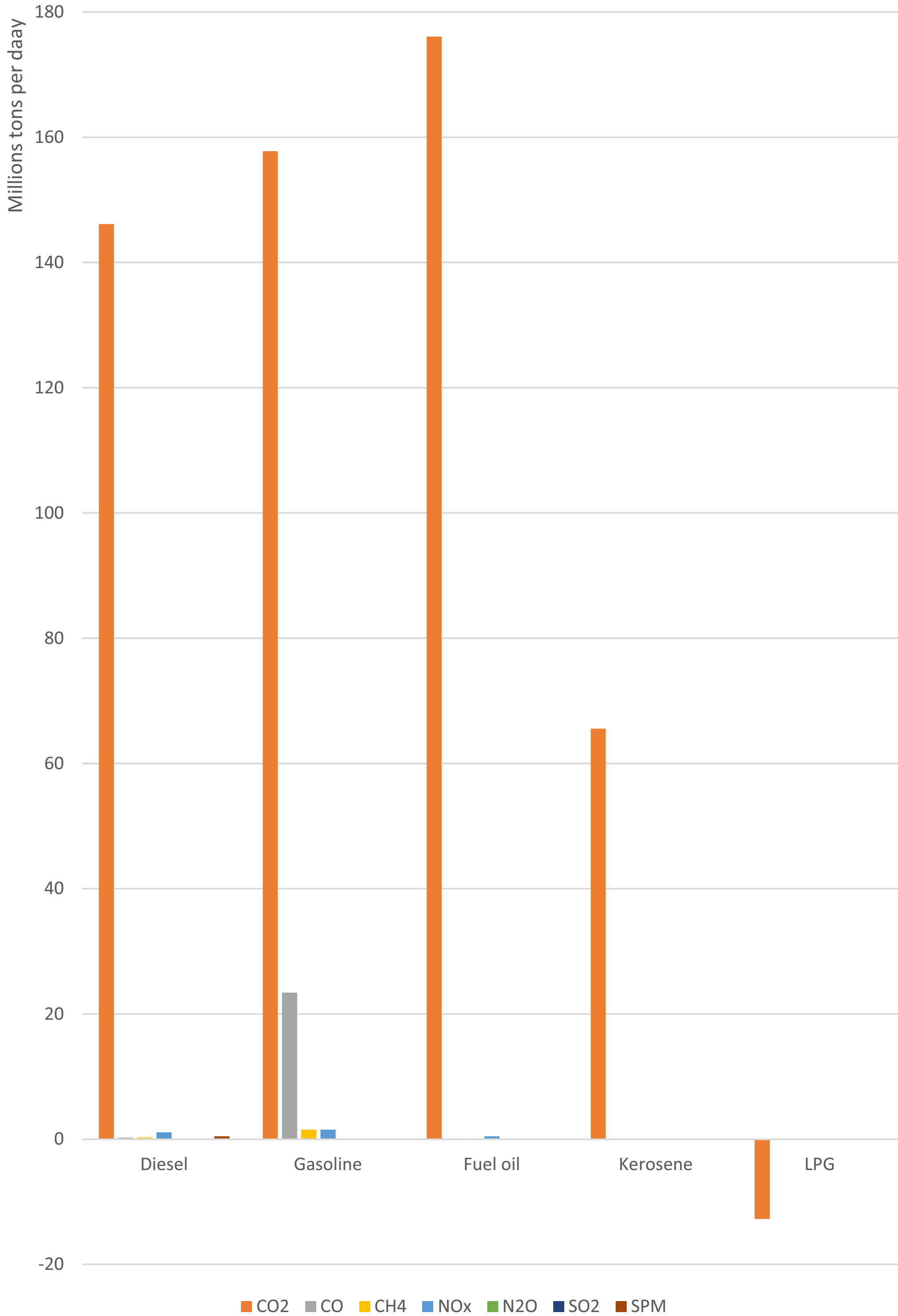

Figure 5. Difference of energy efficiency improvement and price policy (10%) in reduction of the greenhouse gas emissions. *Source* Researchers' findings.

another evidence for importing energy-efficient cars or attracting foreign direct investment in the car industry to assist the economic and social status of society.[4]

[4] The above findings assume that the rebound effect is zero.

The environmental angle is also consistent with the social and economic ones about the higher benefits of energy efficiency than those of price policy. Only a 10% improvement in energy efficiency can decrease more than 217 billion tons (15% of total) of the CO_2 emissions as the most dominant greenhouse gas, especially

Table 3. Health effects of energy efficiency and price policy in DALY.

	SSP1	SSP2	SSP3	Average
Difference of actual and Hypothetical fossil fuel consumption effects on health in DALY, due to 10% improvement in energy efficiency				
Diesel	71,802,319	82,848,830	110,465,106	88,372,085
Gasoline	87,592,054	101,067,755	134,757,006	107,805,605
Fuel oil	89,041,580	102,740,285	136,987,046	109,589,637
LPG	31,401,540	36,232,546	48,310,061	38,648,049
Kerosene	− 5,032,816	− 5,807,095	− 7,742,794	− 6,194,235
Total	274,804,677	317,082,320	422,776,426	338,221,141
Difference of actual and Hypothetical fossil fuel consumption effects on health in DALY, due to 10% increase in price				
Diesel	2,454,402	2,832,002	3,776,003	3,020,803
Gasoline	12,729,431	14,687,805	19,583,739	15,666,992
Fuel oil	5,497,455	6,343,217	8,457,623	6,766,098
LPG	288,041	332,355	443,140	354,512
Kerosene	1,019,508	1,176,355	1,568,474	1,254,779
Total	21,988,836	25,371,734	33,828,979	27,063,183
Difference of energy efficiency improvement and price policy in improvement of health in DALY				
Diesel	69,347,917	80,016,827	106,689,103	85,351,282
Gasoline	74,862,623	86,379,950	115,173,267	92,138,613
Fuel oil	83,544,125	96,397,068	128,529,424	102,823,539
LPG	31,113,499	35,900,191	47,866,921	38,293,537
Kerosene	− 6,052,324	− 6,983,451	− 9,311,267	− 7,449,014
Total	252,815,841	291,710,586	388,947,448	311,157,958

through a reduction in diesel, gasoline, and fuel oil consumption within the period. In addition, gasoline consumption reduction causes the other greenhouse gas emissions to fall. It provides a preponderance of evidence for adopting stronger environmental standards, attracting foreign direct investment, and removal of import barriers for energy-efficient products, especially cars.

In Iran, the monopoly atmosphere in the car industry remains no incentive for improving the technology in this industry, as they are highly energy-inefficient, consuming a great volume of fuels compared with the world technology. In addition to transportation which has the highest share of fossil fuel consumption in Iran, fossil fuel is the input for other economic activities such as petrochemical and power generation.[18] The car industry is only one example for the analysis of fossil fuel demand management. Thus, supporting domestic industry is a flimsy pretext to limit the importation and utilization of the world energy-efficient cars, since this support raises the great amount of additional costs to the society, including an increase in fuel consumption, threatening energy security, decrease in the quality of transportation, CO_2 emissions, environmental pollution, health issues, and traffic death.

The health dimension also confirms the other pillars of sustainable development for more payouts of energy efficiency, compared with the price policy. This difference is, regarding Table 3, more than 300 million DALYs. It means that the energy efficiency survives about 4 million more lives than the price policy does.

Therefore, technological improvement is more beneficial than price policy to achieve sustainable development. The strategists should prioritize technological improvement compared with the price policy. The policy-makers should formulate long-run and elaborate plans for increasing fuel efficiency, e.g., promoting energy efficiency utilities, decreasing tariff and non-tariff barriers for importing energy-efficient products, encouraging domestic industries to produce and use energy-efficient plants and utilities, inspiring foreign direct investment for increasing the energy efficiency, especially in car industry. Price policy works only when consumers have substitute energies, specifically the renewable ones. In this case, the energy demand elasticities are high, and the price policy is effective.

Conclusion

This study estimates the demand elasticities of fossil fuels in Iran to compare the effects of energy efficiency policy and price policy. The price policy has benefits for only three sustainable development pillars, including social, environment, and health, while the energy efficiency benefits economic pillar as well as the other three pillars. Energy efficiency saves 15% of the fossil fuel consumption by only 10% improvement in energy efficiency, which is 15% less than the price policy hypothetical consumption. It decreases the importation of energy and increases energy security, especially for gasoline. If the authorities avoid importing energy-efficient cars, which is a normal good, they must, in the near future, import gasoline, which is a strategic and necessary good, threatening energy security as a social element.

In addition to the social pillar, energy efficiency benefits the economic status of consumers through falling the expenditure on fossil fuels by about 14% by only 10% improvement in energy efficiency. At the same time, the price policy increases this expenditure, reducing the economic welfare of the people as well as their social status.

Just like the social and economic ones, the energy efficiency policy, compared with the price policy, has more positive effects on the environment. From the environmental perspective, only a 10% improvement in energy efficiency decreases more than 217 billion tons of CO_2 emissions as the most dominant greenhouse gas, especially via reducing the consumption of gasoline, diesel, and fuel oil. In addition, the gasoline consumption reduction is the most crucial cause to decrease the other greenhouse gases. This means that the energy efficiency can save about 4 million lives compared to the price policy, confirming the higher benefits of energy efficiency than the price policy.

Based on our findings, the strategists are advised to improve energy efficiency rather than increase the energy price. To this end, they should promote investment in energy-efficient technologies and adopt strong standards for energy efficiency. They also should decrease tariff and non-tariff barriers for importing energy-efficient technologies and encourage foreign direct investment in energy-saving utilities, especially car industries. A limitation of this study is the ignorance of the rebound effect. A future study can consider this effect in the analysis.

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Data availability

The datasets related to this study can be found at[40]: https://www.dx.doi.org/10.17632/w2y9dccpvx.4.

Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

Supplementary Information

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