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Phasing-out natural gas subsidies based on dynamic recursive CGE approach: the case study of basic metal manufacturing in Iran

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Abstract

Energy subsidies have significant economic implications. On the one hand, they have protected consumers, but on the other hand, they have increased the budget deficit and public spending recently. Moreover, they have reduced private investment, especially in the energy sector, another dangerous consequence of energy subsidies. It is one of the key and controversial debates in the energy sector of the Iranian economy. The present paper is aimed at promoting thinking and research on how to eliminate energy subsidies. One idea is that energy subsidies should be reduced all at once, while others suggest a gradual elimination of energy subsidies. This paper simulates the elimination of energy subsidies in the base metals industry as one of the most energy-intensive industries in Iran. A dynamic recursive computable general equilibrium model is estimated to evaluate the economic impacts of removing gas subsidies in basic metal manufacture in Iran. according to the results, gas consumption will decrease, and electricity and petroleum products will increase in both scenarios (gradual increase in gas prices after 5 years as Scenario 1 and an increase in gas prices at once as Scenario 2). However, during the period, Scenario 2 reduces the supply of basic metals more than Scenario 1.

Highlights

- Energy subsidies cause deviations in relative prices from their equilibrium values, leading to inefficient allocation of resources
- It is suggested to gradually increase the price of natural gas over time instead of a sharp increase in one period.
- A gradual increase in the price of energy carriers will reduce energy consumption, while industry production will decline at a slower pace and industry will suffer less

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1. Introduction

However, the energy supply and demand in Iran, as well as its energy intensity index, indicate that the country's energy carriers are not being used efficiently. With regard to the price of energy carriers within the country, the government's subsidy, the limitation of fossil resources, the rapid growth of annual consumption, the technical and economic inefficiency of energy consumption, and the possibility of exporting oil products in case of savings, all pose problems. Furthermore, the irrational and inefficient fuel consumption and environmental concerns force the optimizing energy consumption in the country. As long as energy subsidies are significantly allocated, it is not possible to increase energy efficiency.

Energy subsidies cause deviations in relative prices from their equilibrium values, leading to inefficient allocation of resources. Disruptions in prices hinder development in a country's energy sector, as they reduce sufficient incentives for domestic and foreign investors to invest in up-to-date technologies and increase energy efficiency. Consuming more than the optimal level due to the low price of energy will increase imports or decrease exports. Energy subsidies will prevent energy costs from being included in the price of goods, leading to elevated use of energy and pollutant emissions. In a dynamic perspective, commodity prices will create transparency and certainty in the market, attracting investors to this market, and implicitly, in the medium term, these dynamic effects will be more important. Therefore, one of the critical policies to reduce energy consumption is to reduce subsidies and increase prices.

In 2020, Iran's energy consumption per capita was 1.7 times of the global average, and natural gas consumption was 6.1 times of the world. In recent years, energy efficiency has deteriorated. As shown in Fig. 1, energy efficiency declined since 2017. Energy consumption has continued to increase even during economic recessions. Although population growth has contributed to growth in energy consumption, the distortion of energy prices plays a more significant role in explaining why energy consumption is rising.

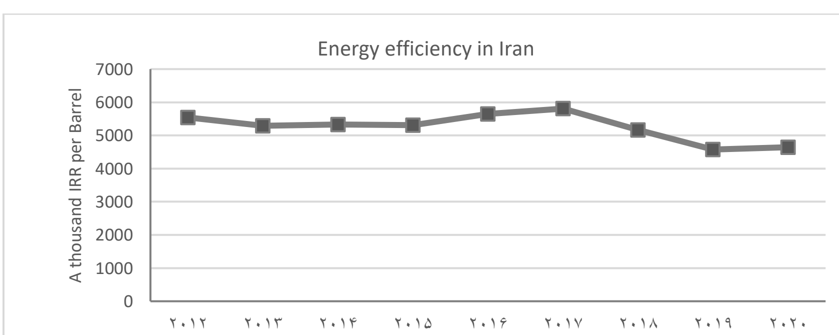

Fig. 1. Energy efficiency in Iran

Source: *Energy Balance sheet, Ministry of Energy*

Since 2000, Iranian economy has been independent to natural gas, particularly in manufacturing sector, where it can be observed that the share of gas has increased from 42% to 78% between 2000 and 2020.

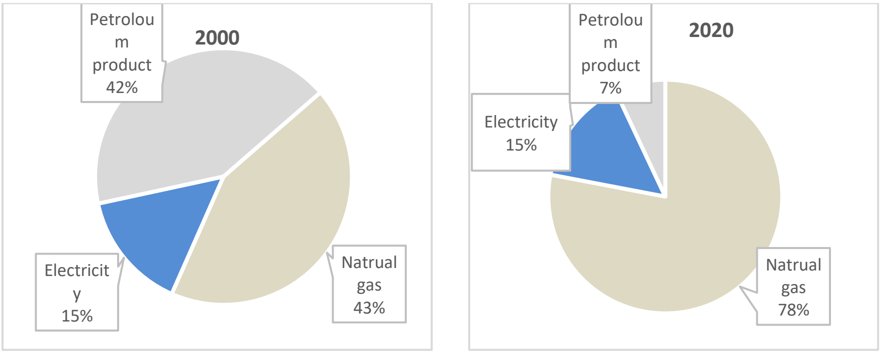

Fig. 2. The share of energy carriers in manufacturing sectors over time

Sources:*Energy Balance sheet, Ministry of Energy*

Basic metal industry accounts for 20% of the value added of Iran's manufacturing output, being as the second important industry after chemical materials and products. Table 1energy intensity in the industrial sector.Error! Reference source not found.

According to ،Tabe1Error! Reference source not found., the manufacture of basic metals has been the third highest energy intensity among industries. Hence, changes in energy prices affect the amount of production. Based on the statistical center of Iran, the contribution of natural gas among energy carriers in basic metal manufactures is 72%, and the consumption of electricity and petroleum products are 27% and 1%, respectively.

Table 1. Five industries with the highest energy intensity in Iran, 2020

Industry	Total amount of energy consumption: (million barrels equivalent to crude oil)	Output value (million Rial)	Energy intensity (barrel to one thousand rial)
Non-metallic mineral products	77.74	266.63	291.6
Chemicals and chemical products	92.82	915.94	101.3
Basic metal	56.10	663.84	84.5
Paper and paper products	3.56	70.91	50.2
Products of wood, cork	1.14	25.12	45.2
Manufacture of coke and refined petroleum products	41.23	1,067.31	38.6
Average of total industry	310.90	5,574.49	55.8

Sources: *Energy Balance sheet, Ministry of Energy, Statistical Center of Iran*

Steel is one of the energy-intensive industries in the world; i.e. steel production has a strong need for energy, including electricity and fossil fuels (coal and natural gas), and a major share of its cost is related to the price of energy since Iran has always export steel due to its easy access to cheap energy. Iran has so far provided cheap gas to industries including basic metal manufactures, creating a competitive advantage for them but there are some disadvantages for gas subsidy to this industry. On the one hand, the gas consumption of basic metal industry is inefficient, especially steel production units, leading to high air pollution. On the other hand, government funding is limited and costs must be saved.

Table 2. Basic metal energy expenditure (2011)

	Fossil fuel	Gas	Electricity
Basic metal energy expenditure (billion IRR)	2866	4180	9157
Share Basic metal energy expenditure of total output value (percentage)	0.61	089	1.95

Source: *SAM & Statistical Center of Iran, 2011*

Until 2010, the domestic prices of the five main products (except for gasoline, with a slight trend) have been accompanied by very small changes. However, in 2010, when the Energy Subsidy Reform was implemented, the prices of major petroleum products have increased significantly; while in recent years, due to rising exchange rates, the gap between domestic and global energy prices have been extended, causing an adverse effect on the Iranian economy. In this regard, in 2021, eleven years after subsidy reform because of high exchange rates, the gap between domestic and regional price of energy carriers is large and it is almost equal to the price gap before 2011. Thus, in the budget law of 2021, government has increased the price of gas for steel units. Table 3 shows the price of feed gas for steel units in 2021. In order to compete with global products, domestic steelmakers must reduce energy consumption globally, and improving the quality of raw materials used in steelmaking units is one of the effective factors in reducing energy consumption. One of the risks of removing subsidies is the increase in the import of foreign products. Regarding its tariffs, the decision-makers should solve this problem together with domestic steelmakers.

2. A Review of the Related Literature

What is common among all subsidies, including energy subsidies, is the government's intervention in the market of commodities. This intervention can be made in the form of a real energy price reduction for the consumer, whereas the price of energy careers are flat and the relative price of energy decreases due to high inflation rate. Supporting domestic industries and maintaining employment in those sectors is an idea of flattening energy price. The government supports manufacturing producers by maintaining a certain level of domestic energy prices besides maintaining employment in those sectors. Supporting low-income groups and social equality with the aim of energy availability is another reason why government tries to retain energy price fixed. By having a minimum level of energy for all income groups, especially the poor, governments guarantees low energy prices for consumers. This is usually done by controlling prices below the market price. Energy producing companies in countries paying such subsidies are usually state-owned. Many countries have previously paid or are currently paying such subsidies, including Colombia, Ghana, Malaysia, Indonesia, Zimbabwe, Azerbaijan, Nigeria, and Iran. The following can be countered harmful consequences of energy subsidies:

1- Negative side effects of energy subsidies on renewable energy and environment.

Subsidy causes excessive consumption of petroleum products, coal, and natural gas and reduces the incentive to invest in renewable and efficient energy, resulting in an increase in global warming and regional pollution. An increase in road traffic and in the rate of accidents and destruction of roads are other negative effects of paying fuel subsidies. Furthermore, electricity subsidy indirectly affects global warming and environmental pollution, the extent of which depending on the combination of energy sources for electricity production. Oil and gas subsidies also cause excessive use of irrigation pumps and cultivation of crops with high water consumption and depletion of underground water.

2- Increasing social inequality through receiving more benefits from subsidies by high-income households

Energy subsidies benefit households through lower prices for energy used for cooking, heating, and personal transportation, as well as lower prices for goods and services consuming energy as an input. Nevertheless, it is worth noting that the increase in energy prices may reduce the budget of poor households directly through the removal of subsidies or indirectly through the reduction of real income given the increase in the consumer price index.

3- Diversion of resources from spending in supporting the poor to energy subsidies

In many subsidy-paying countries, social justice can be improved by reallocating resources to programs targeted at health, education, and social protection. In the long term, creating a suitable social network along with removing subsidies and increasing spending to support the poor will result in the improvement of the low-income groups' situation.

Therefore, although energy subsidies are paid to enhance economic development, they have extensive negative consequences on the economy. Besides the aforementioned cases, the existence of energy subsidies causes consumers not to have the motivation to use energy carriers with higher efficiency due to low prices, that with the increase in energy efficiency, energy consumption does not decrease as much as the increase in energy efficiency. Therefore, it is expected to enhance the rebound effect and the main goal of increasing energy efficiency, which is to increase economic growth at the same time as reducing or stabilizing energy consumption is not achieved.

Basic metal production, especially steel, is affected by a number of factors including wage, capital rent, prices, exchange rate and particularly gas price. Gas price is a key variable in the steel making,. affecting the level of imports, exports, output, prices, etc. It has reached the point where steel companies and policy maker are being compelled to ask difficult but necessary question about how much the industry may be influenced to increase energy price for making steel products. Additionally, it is important to know how Iran's economy will be influenced by reducing the subsidy of gas price in basic metal and steel industry. On the one hand, gas price subsidy makes the country more competitive in foreign markets, thus increasing the exports. Besides, it can help achieving various social or technological goals (Koplow, 2004) .On the other hand, the subsidy of gas cannot be paid due to budget deficit, low energy efficiency, and destroying environment (Akasaka (2007)). Given the importance of energy subsidy, various studies have examined the economic impact of energy price reform. Among these studies include Arze del Granado, Coady & Gillingham (2012), Vagliasindi (2012), Burniaux, Martin & Oliveira-Martins (1992) and Coady, Parry & Shang (2020). Similar studies have been carried out on energy subsidy reform in Iran. Solaymani (2021) declared that only in the first two years of implementing the policy of energy subsidy reform in Iran, energy consumption and greenhouse gas emissions would decrease, and after that, due to the incomplete implementation of the policy, energy consumption would rebound. ShahakiTash & Norouzi (2014) have analyzed parametric energy structure and estimated the demand function of natural gas during 2003-2010. This paper assessed the factors affecting the short-run and long-run intensity of natural gas in Iran's energy-intensive industries. The energy-intensive industries consume on average 94.5% of total energy and over 97.5% of natural gas of entire industry. Based on a dynamic general equilibrium model, Khiabani (2018) has studied the policy of eliminating energy subsidies and improving technology in Iran, concluding that the policy of eliminating energy subsidies requires some consideration, such as providing a suitable platform for new technology, the ability of manufacturing firms to replace the factors of production and take out old technology; otherwise, the economy set into stagflation. However, if energy subsidies are phased out, firms will be contributed to adapt to the new conditions and energy intensity will decrease over time.

3. Model Structure and Database

The general equilibrium method is one of the methods used to assess the impact of reducing energy subsidies on energy consumption and macroeconomic variables . In this method, macroeconomic relations like income distribution among different groups, trade balance, and multi-sectoral production structure are modeled. The model includes equations related to the behavior of economic agents, such as equations related to household behavior (utility maximization) and firm behavior (profit maximization), as well as other systemic constraints. Markets are balanced in both nominal and real terms, with no surplus of supply and demand. Relative prices and quantities are all endogenous, and consumption depends on income, making consumption endogenous, too. The generality of the model stems from the fact that all economic sectors exist in the model, eliminating the need to assume “other fixed conditions” required in partial studies. The results of the model are usually obtained by comparing one equilibrium with another equilibrium resulting from changes in the model’s exogenous variables. The process works by considering a base year, then applying exogenous shocks to the model, leading to a new equilibrium, and comparing the results with the values of the base year.

The present paper creates a computable general equilibrium (CGE) model based on the latest Social Accounting Matrix (SAM) published in 2011. The final SAM is aggregated into 13 sectors: agriculture, electricity, gas distribution, other fossil fuels, food and beverage industries, textiles, chemical materials and products, other non-metallic mineral products, basic metals, vehicles and motor trailers, other industries, transportation, other services, two production factors (labor and capital), two income groups (urban and rural households), enterprises, government, saving-investment, and rest of the world.

The economic interactions among SAM accounts are formulated within a CGE framework, enabling the study of the impacts of a gas price increase on energy consumption in steel production. This CGE follows the standard CGE (Lofgren, 2000) modified to meet the requirements of Iran’s economy and the SAM 2011. The model’s mathematical formulation is presented in Appendix A. Here, the blocks of production and investment are presented.

3.1. Production block: The structure of the production layer is based on the structure depicted in Fig. 3, with energy-producing components separated from other non-energy components. Each sector can produce multiple products, and conversely, the production of each commodity by one sector may be used as an intermediate input by other sectors or as final consumption by households, government, etc. According to Fig. 3, production is characterized by a three-stage structure. Therefore, production is obtained through the combination of intermediate inputs and primary inputs. The primary inputs are divided into two subgroups: the first group includes labor and capital inputs, and the second group includes energy inputs. In this section, we will express these factors mathematically, following previous studies, by considering the factors L (labor input) and K (capital input) together and the factor E (energy input) separately.

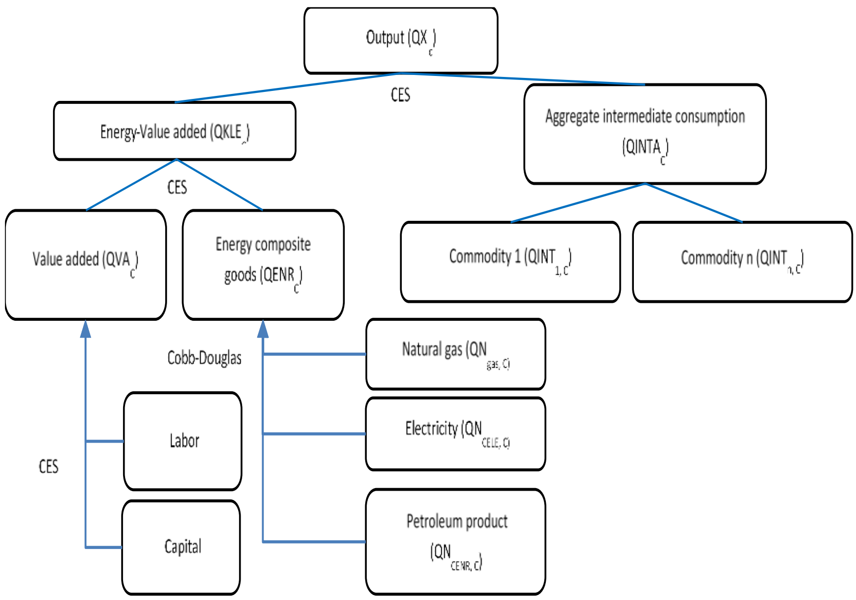

Fig. 3. Nested structure of production
Source: *Author assumption*

Total productive activities for the economy produce n goods, either consumed domestically or exported. On the other hand, the supply of domestic consumption is met by domestic production and imports. The production block considered in the model is known as a three-stage production structure, employing the Constant Elasticity of Substitution (CES) production function, assuming incomplete substitutability of production factors.

The elasticity coefficients of sectors are represented in Table 4.

Table 3. Elasticity coefficients of sectors

	Armington Elasticity	CET	Labor and Capital substitution	Value added and energy substitution
Agriculture	2	0.59	0.8	0.7
Electricity	0.7	0.59	0.8	0.7
Gas distribution	0.5	0.59	0.8	0.7
Other fossil fuel	0.6	0.59	0.8	0.7
Food and beverage industries	0.7	0.59	0.8	0.7
Textile	0.7	0.59	0.8	0.7
Chemical materials and	0.7	0.59	0.8	0.7

products				
Other non-metallic mineral products	0.7	0.59	0.8	0.7
Basic metals	0.7	0.59	0.8	0.7
Vehicles and motor trailers	0.7	0.59	0.8	0.7
Other industries	0.6	0.59	0.8	0.7
Transportation	0.4	0.59	0.8	0.7
Other services	0.9	0.59	0.8	0.7

Source: *Majdzade etal., 2016; Rafiei & Abbaspoor, 2021*

3.2 Investment block: Investment in new productive capacities is a way to enable economic growth. Designing investment behavior is a crucial part of pattern dynamics. To design an investment mechanism, it must be determined how much capital is allocated to each sector and subsector at each point in time. The amount of new investment in each sector is determined as a proportion of the community savings formed in each period. By considering the initial capital stock in the base year, the amount of capital stock in each period is obtained from Equation (1).

$$K_{t+1} = K_t(1-\delta) + I_t \tag{1}$$

According to Equation (1), the capital stock in the next period, K_{t+1}, is a function of the capital stock in the current period, K_t, after deducting depreciation at the rate of δ, and new investment, I_t, determined by the model. The amount of investment in each period is determined based on the amount of savings made. The amount of savings is a fixed ratio of disposable income, assumed to be equal to the final desire and the average desire to save, as determined by the information from the base year. The investment and accumulation of capital in period t in each sector depends on the expected rate of return on capital for period $t+1$, based on the actual rate of return on capital in period t. Therefore, model investment is recognized as a homogeneous hybrid commodity in the dynamic process of the economy, besides being a component of demand. This combined commodity is distributed among the economic sectors according to the real capital return rate of Section j in period t. The equilibrium expected rate of return on economic capital is determined by an inverse logistic function of relative growth in capital reserves. This approach to modeling dynamic investment behavior is based on the method used in the Monash University model designed by (Dixon & Rimmer, 2005). Equation (2) shows the expected equilibrium rate of return on investment for Section j in period t.

$$ROR_{j,t} = ROR0_{j,t} + \left({}^{1}/_{B_j}\right).\{\ln\left(KSKg_{j,t} - KSKg\, min_j\right) - \ln\left(KSKmax_j - KSKg_{j,t}\right) - ln \ln\left(KSK_{trend} - KSKg\, min_j\right) + ln\left(KSKmax_j - KSK_{trend}\right)\} \tag{2}$$

Where *ROR* is the equilibrium expected rate of return on capital, *KSKg* refers to the real capital growth rate, KSK_{min} stands for the minimum real capital growth rate, KSK_{max} shows the maximum real capital growth rate, KSK_{trend} indicates the historical capital growth rate, and β represents a positive parameter indicating the sensitivity of capital growth in Section *I*. In Equation (2), the maximum real growth rate of capital is assumed to be equivalent to the historical growth rate of capital plus 0.06, due to the avoidance of unrealistic estimates of growth rate. Fig. 4 illustrates how to determine the expected equilibrium rate of return on investment based on the above Equation. Accordingly, the expected rate of return on capital is determined based on the historical growth rate of capital, while its value is determined within the interval between the minimum and maximum real growth rate of capital.

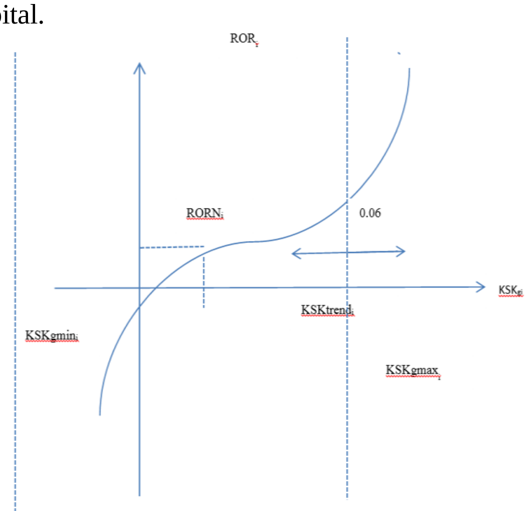

Fig. 3. Equilibrium's expected rate of return on capital in Section j
Source: *research finding*

Assuming that the investor does not expect a change in the price of the composite commodity to invest in the next period, the expected rate of return on investment is defined in terms of comparative expectations by Equation (3). In this regard, PCINDEXt represents the consumer price index in year t, deprj the depreciation rate in Section j, and the phrase (1 + RINTt) / (PCINDEXt) reflects the comparative expectations of the real interest rate. Additionally, obtained by solving the pattern in each period, the real interest rate in the year RINTt is equal to the rental rate of the capital. Finally, the capital stock in the next period (t + 1) is obtained from Equation (3).

$$ROR_{j,t} = -1 + \frac{[\frac{PK_t}{PK_{j,t}} + (1 - depr_j)]}{[\frac{1 + RINT_t}{PCINDEX_t}]} \tag{3}$$

$$KSK_{k,t+1} = \left(1 - depI_j\right)KSK_{j,t} + INV_{j,t} \tag{4}$$

The price shock is triggered by $te_{EN,C}$ in equation 5. $PN_{EN,C}$ is the price of each energy carrier in sector c and QN_C is the quantity of energy consumption in each sector too. PEN_C *and* QEN_C are the price and quantity of energy composite in secor c. in the baseline $te_{EN,C}$ is zero and for policy making of energy taxation it will increase. For example, in this article in one scenario it is increased by 650% for gas consumption(EN= gas) for baseline production (C= base metal).

$$PEN_C * QEN_C = \sum_{EN} PN_{EN,C} * QN_C * (1 + te_{EN,C}) \tag{5}$$

Depreciation rate of each sector is represented in Table According to the depreciation table, the subject of Article 151 of the Law on Direct Taxes is the life of transportation equipment, approximately 10 to 15 years, and for the use of machinery and equipment in the oil and gas extraction sector, it is approximately 10 years.

Table 5. Depreciation rate of sectors

Sector/sources	Salimian etal., 2016	Kiani & Naghibi, 2015	Depreciation ratio in this paper
Agriculture	5.8	5.8	5.76
Electricity	4	4.1	4.00
Gas distribution	10	4.1	7
Other fossil fuel	10	6.3	10*
Food and beverage industries	5	4.9	5
Textile	5	4.9	5
Chemical materials and products	5	4.9	5
Other non-metallic mineral products	5	4.9	5
Basic metals	5	4.9	5
Vehicles and motor trailers	5	4.9	5
Other industries	5	4.9	5
Transportation	10	4.9	6.66*
Other services	4	3.5	3.75

4. Empirical Results

The present paper is aimed at investigating the impact of a gas subsidy decrease (PNgas) on various economic variables, including energy consumption of basic metal manufacture (QN), consumer price index (CPI), quantity of goods imported by basic metal manufacturers (QM), quantity of basic metal exports, and quantity of aggregate marketed commodity output of basic metal (QXbasic metal), and total output of industries including basic metal (QXtotal). We illustrate the model with two simulations, with each Scenario allowing for comparison of results to the baseline. In S1, the price of gas for basic metal manufacture increases immediately in the first period by 650%, the amount of the increase in gas price for basic metal production in 2022. In S2, the gas price increases by 50% every period. The simulation results for S1 and S2 are presented in Table 6 and Table 7, respectively.

This model enables the understanding of the basic metal's response to gas price changes. Increasing gas prices lead to changes in the supply of products and gas consumption, similar to findings in many studies, like those by (Khiabani, 2018), (ShahakiTash & Norouzi, 2014), and (Solaymani, 2021). In real terms, gas consumption has decreased for all times. As shown in Fig. 5, gas consumption has rapidly increased compared to the baseline Scenario, along with an increase in emission reduction. Furthermore, gas consumption in both Scenarios exhibits a decreasing trend, but this decrease is more gradual in the Scenario with increasing gas prices compared to the baseline Scenario. Additionally, in S2, after the first period, the reduction in gas consumption stops and remains almost stable. The important point is that the percentage of gas reduction in S1 converges to the percentage of gas reduction in S2, and by the fifth year, both policies reduce gas consumption by the same amount.

On the other hand, the supply of basic metal products responds differently to these two Scenarios. In S2, the reduction in supply is much higher and faster than in S1 (Fig. 6). Although the policy of gradual reduction of gas prices leads to a similar reduction in energy consumption at the end of the five-year period, it causes a more severe decline in production compared to the policy of once reduction of prices. Consequently, a policy of gradual reduction of energy subsidies is proposed.

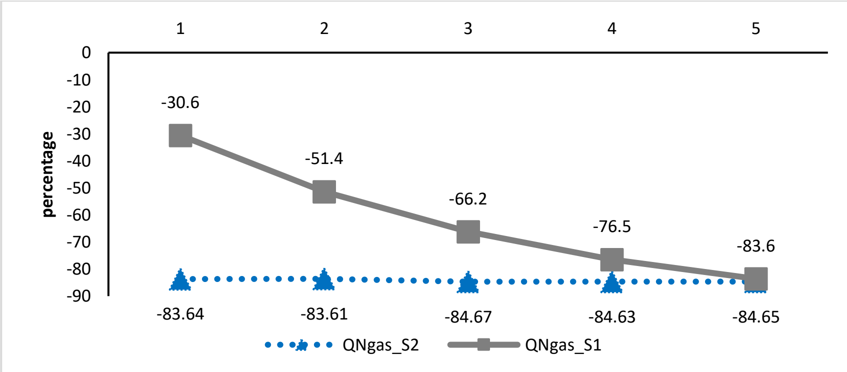

Fig. 4.Effects on gas consumption in Scenario 1 and Scenario 2
Source: *research finding*

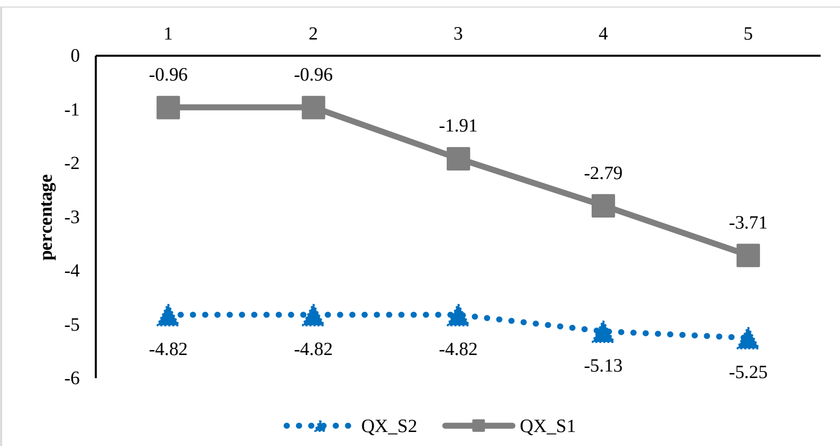

Fig. 5. Effects on basic metal supply in Scenario 1 and Scenario 2
Source: *research finding*

When the price of gas increases, its consumption will decrease in both scenarios as described above. The firms would use other energy carriers to compensate for gas energy content. In Table 4 and Table 5, it can be observed that the energy consumption of other energy carriers will increase in both Scenarios; however, the increase in energy usage percentage in S1 is more than 2% in the first period and will become less in the final year.

Table 4. Simulation of increase gas price 650% at first period (Scenario 1)

Period	PN_{gas}	QN_{gas}	$QN_{other\ energy\ carrier}$	CPI	QM	QX	QX-TOTAL
1	650	-83.64	22.68	2.17	1.28	-4.82	-11.05
2	650	-83.61	22.96	2.86	1.42	-4.82	1.77
3	650	-84.67	14.95	5.36	-2.38	-4.82	1.35

4	650	-84.63	15.30	4.21	-2.68	-5.13	2.52
5	650	-84.65	15.13	4.12	-2.54	-5.25	3.73

Source: *research finding*

Table 5.Simulation of gas price increase of 50% every period (Scenario 2)

Period	PN_{gas}	QN_{gas}	QN_{other} energy carrier	CPI	QM	QX	QX-TOTAL
1	50.0	-30.6	4.08	0.43	0.15	-0.96	-10.74
2	125.0	-51.4	9.29	2.65	0.81	-0.96	2.80
3	237.5	-66.2	14.21	0.79	0.97	-1.91	4.02
4	406.3	-76.5	19.12	1.73	1.30	-2.79	5.42
5	659.4	-83.6	24.37	0.86	1.59	-3.71	6.74

Source: *research finding*

By increasing gas prices in both Scenarios, the total supply of production sectors, i.e. QX-TOTAL, decreases by about 10% as a whole of industrial products. In both Scenarios, the production growth will be positive in the second period. However, in S1, production growth at all stages is higher than in that in S2. The inflation rate, shown by CPI in Table 6 increases; however, in S1, it will rise more compared to the other Scenario. In the CGE model, all calculations and simulations are based on real terms. If the total output of the economy, QX-TOTAL, decreases significantly in the first year, it negatively affect prices, leading to an increase in CPI. The results show a direct relationship between total output and inflation, with S1experiencing a greater increase in inflation compared to S2, where total output increases less.

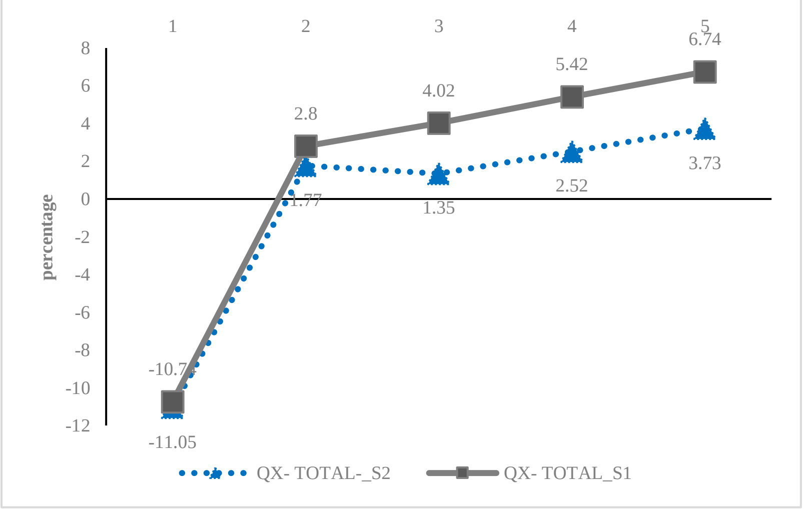

Fig. 6. Effects of total industries supply in Scenario 1 and Scenario 2
Source*: research finding*

5. Sensitivity Analysis

To gain further insight into the model, sensitivity analyses are conducted. The central parameter values in all simulations are retained fixed, as shown in Table 8 and Table 9) and only the elasticity of value added and energy substitution, which is crucial, is modified. Therefore, a sensitivity analysis is performed to assess the model's robustness. Two simulations are considered: 1) 50% above the baseline value of the elasticity, and 2) 50% below the baseline value of the elasticity. The results are presented in real terms in Table 8 and Table 9. Thus, the quantity of aggregate marketed commodity output in each sector does not significantly change with the increase or decrease in elasticity, indicating the robustness of CGE model and confirming our qualitative insights by the sensitivity tests.

Table 8. Sensitivity test for value added and energy substitution on quantity of aggregate marketed commodity output (QX) in period 1 in Scenario 1

	Low elasticity	Baseline	High elasticity
Agriculture	879.593	878.092	877.921
Electricity	123.899	123.842	123.79
Gas distribution	80.905	82.991	78.619
Other fossil fuel	1248.37	1248.307	1250.737
Food and beverage industries	485.943	485.95	485.974
Textile	80.85	80.85	80.819
Chemical materials and products	401.348	401.691	402.094
Other non-metallic mineral products	155.044	155.065	154.974
Basic metals	324.176	318.355	314.321
Vehicles and motor trailers	365.327	365.145	364.54
Other industries	562.376	562.088	564.036
Transportation	489.016	488.995	488.544
Other services	4383.468	4382.074	4379.262

***Source**: research finding*

Table 9. Sensitivity test for value added and energy substitution on quantity of aggregate marketed commodity output (QX) in period 1 in Scenario 2

	Low elasticity	Baseline	High elasticity
Agriculture	877.792	877.973	877.606
Electricity	123.794	123.791	123.789
Gas distribution	80.639	81.291	81.674
Other fossil fuel	1248.995	1249.243	1249.582
Food and beverage industries	485.952	485.944	485.951
Textile	80.849	80.87	80.86
Chemical materials and products	401.933	401.995	402.039
Other non-metallic mineral products	155.16	155.138	155.093
Basic metals	332.617	331.259	330.217
Vehicles and motor trailers	364.967	364.883	364.752
Other industries	562.505	562.409	562.316
Transportation	489.244	489.166	489.04

Other services	4382.917	4382.074	4381.262

Source*: research finding*

5. Conclusion and Implications

Energy subsidies have far-reaching economic implications. Although being intended to protect consumers, they worsen the government's fiscal balance, increase public spending, and reduce private investment, especially in the energy sector. In addition, subsidies prevent the optimal allocation of resources through encouraging over-consumption of energy, artificially encouraging energy-intensive industries, reducing the incentive to invest in renewable energy, and accelerating the depletion of resources. In 2010, the government implemented energy subsidy reforms and the price of energy carriers increased significantly, but due to depreciation of exchange rate and high inflation level, the effectiveness of this plan decreased sharply. In this paper, it is suggested to gradually increase the price of natural gas over time instead of a sharp increase in one period. Among energy carriers, natural gas is the main focus of the present paper, since it includes about 80% of the energy consumption in industries. At the same time, the effect of increasing gas prices on the base metals industry is examined, one of the largest industries in terms of value added and export.

This study uses a dynamic recursive computable general equilibrium model to evaluate the economic impacts of gas subsidies removal in basic metal manufacture in Iran. Based on the results, the scenario of gradual increase in gas prices after 5 years (S1) and the scenario of increase in gas prices at once (S2) would lead to decreased gas consumption and increase electricity and petroleum products increase. However, the S2 reduces the supply of basic metals more than the S1. Moreover, the total supply of all sectors in S1 increase in all sections is higher than S2. In addition, the CPI increased after both Scenarios, but the households' real income is also decreased. By increasing in gas prices, the competitive advantage of the production of base metals will decrease, and consequently, the export of this product will decrease in both Scenarios, although the decrease in exports in S2 is more severe. Furthermore, the import of inputs of this industry will increase.

From a policy implication point of view, several recommendations can be posed from this research. A gradual increase in the price of energy carriers will reduce energy consumption, while industry production will decline at a slower pace and industry will suffer less. Economic decision-makers in Iran sometimes decide to suddenly increase the price of energy carriers, such as the experience of increasing the price of gasoline in 2019 and 2009, but if they increase the prices gradually with the increase in inflation, the amount of production will not decrease much. Moreover, energy consumption will be further reduced and policies will be closer to their goals, i.e. to increase efficiency.

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Conflicts of Interest

The authors declare no conflict of interest.

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Appendices

A.1. Model equations

A.1.1. Price block

$$PM_C = PWM_C\ EXR\ (1 + tm_c)$$

$$PE_C = PWE_C\ EXR\ (1 - te_c)$$

$$PDD_C = PDS_C$$

$$PQ_C\ QQ_C = (PDD_C\ QD_C + PM_C\ QM_C) \times (1 + \mathrm{tq}_c)$$

$$PX_C\ QX_C = PDS_C\ QD_C + PE_C\ QE_C$$

$$PINTA_C = \sum_C PQ_C\ ica_{C.C}$$

$$PX_C\ (1 - ta_c)\ QX_C = PVA_C\ QVA_C + PINTA_C\ QINTA_C$$

$$CPI = \sum_{CD} cwts_C\ PQ_C$$

$$PKLE_C\ QKLE_c = PVA_C\ QVA_C + PEN_C\ QEN_C$$

$$WF_f\ \overline{WFDIST_{f,c}} = PVA_c QVA_C (\sum_f \delta_c^{VA} \times QF_{F.C}{}^{-\rho_c^{VA}})^{-1}\ \delta_c^{VA}\ QF_{F.C}{}^{-\rho_c^{VA}-1}$$

A.1.2. Production block

$$QX_c = \frac{QINTA_C}{\mathrm{inta}_c}$$

$$QX_c = \frac{\mathrm{QKLE}_C}{\mathrm{iva}_c}$$

$$\frac{QKLE_C}{QINTA_C} = [\frac{deltaA_C}{1 - deltaA_C} * \frac{PINTA_C}{PKLE_C}]$$

$$PX_C * QX_C = PKLE_C * QKLE_C + PINTA_C * QINTA_C$$

$$\mathrm{Q}KLE_C = \mathrm{alphaKLE}_C * \left(deltaKLE_C * QVA_C{}^{-rhokle_C} + (1 - deltaKLE_C) * \mathrm{Q}EN_C\right)^{-1/rhokle_C}$$

$$\mathrm{Q}VA_C = \mathrm{Q}EN_C * [\frac{deltaKLE_C}{1 - deltaKLE_C} * \frac{PEN_C}{\mathrm{PVA}_C}]^{\frac{1}{1+rhokle_C}}$$

$$QN_{EN.C} = \frac{PEN_C * QEN_C * alpha_{EN,C}}{PN_{EN.C}}$$

$$QM_C = QD_C \left(\frac{PDD_C}{PM_C}\right) (\frac{1 - \delta_c^q}{\delta_c^q})^{1/(\rho_c^q+1)}$$

$$\mathrm{Q}VA_C = \mathrm{alpha}VA_C * \left(\sum_F deltaVA_C * QF_{F.C}{}^{rhova_C}\right)^{-1/rhova_C}$$

$$\mathrm{Q}EN_C = aen_C * \prod_{EN} QN_{EN.C}{}^{alpha_{EN,C}}$$

A.1.3. Income and expenditure block

$$\mathrm{YF_F} = \sum_{\mathrm{C}} \mathrm{WF_F}\ \mathrm{wfdist_{F.C}}\ \mathrm{QF_{F.C}}$$

$$YIF_{INSD.F} = shif_{INSD.F}\ YF_F$$

$$YI_{INSDNG} = \sum_{F} YIF_{INSDNG.F} + \sum_{INSDNG} TRII_{INSDNG.INSDNG} + trnsfr_{INSDNG.GOV} CPI + trnsfr_{INSDNG.ROW} EXR$$

$$EH_H = \left(1 - \sum_{INSDNG} shii_{INSDNG.H}\right)(1 - MPS_H)(1 - TINS_H) YI_H$$

$$TRII_{INSDNG.INSDNG} = shii_{INSDNG.INSDNG}(1 - MPS_{INSDNG})(1 - TINS_{INSDNG}) YI_{INSDNG}$$

$$PQ_C\ QH_{C.H} = PQ_C\ \gamma^m_{c,h} + \beta^m_{c,h}\ (EH_H - \sum_{C} PQ_C\ \gamma^m_{c,h})$$

$$QINV_C = IADJ\ .\ qbarinv_C$$

$$QG_C = GADJ\ .\ qbarg_C$$

$$YG = \sum_{F} YIF_{GOV.F} + \sum_{INSD} tins_{INSDNG} YI_{IMSDNG} + EXR\ trnsfr_{gov.ROW}$$

$$EG = \sum_{C} PQ_C QG_C + \sum_{INSD} trnsfr_{INSDNG.gov}$$

A.1.4. Equilibrium block

$$\sum_{C} QF_{F.C} = QFS_F$$

$$QQ_C = \sum_{H} QH_{H.C} + QINV_C + QG_C + \sum_{C} QINT_C$$

$$\sum_{C} pwm_c\ QM_C + \sum_{F} trnsfr_{ROW.F} + \sum_{INSD} trnsfr_{ROW,INSD} = \sum_{C} pwe_c\ QE_C + \sum_{F} trnsfr_{F,ROW} + \sum_{INSD} trnsfr_{INSD,ROW}$$

$$GSAV = YG - EG$$

$$TINS_{INSDNG} = tinsbar_{INSDNG}\ (1 + TINSDAJ \times tins01_{INSDNG}) + DTINS\ .\ tins01_{INDNG}$$

$$MPS_{INSDNG} = mpsbar_{INSDNG}\,(1 + MPSDAJ \times mps01_{INSDNG}) + DMPS\,.mps01_{INDNG}$$

$$\sum_{i \epsilon INSDNG} (MPS_i\,(1 - tins_i)\,YI_i + GSAV = \sum_{C} PQ_C\ QINV_C + FINV\,.EXR$$

$$TABS = \sum_{H}\sum_{C} PQ_C\,QH_{H.C} + \sum_{C} PQ_C\,QG_C\ + \sum_{C} PQ_C\,QINV_C$$

$$\mathrm{INVSHR}\,.TABS - FINV.EXR = \sum_{C} PQ_C\,QINV_C$$

$$\mathrm{GOVSHR}\,.TABS = \sum_{C} PQ_C\,.QG_C$$

A.2. indices

C	Commodity
F	Factor production
INSD	domestic institutions
INSDNG	domestic non-government institutions
H	households

A.3. Parameter

aen_C	Efficiency parameter in the firms energy production function
$alpha_{EN,C}$	Power of energy carrier in the Cobb-Douglas production function
$ica_{C.C}$	intermediate input c per unit of aggregate intermediate
inta_C	aggregate intermediate input coefficient
iva_C	aggregate value added coefficient
α_c^{VA}	shift parameter for CES value-added-energy production function
δ_c^{VA}	share parameter for CES value-added-energy production function
ρ_c^{VA}	CES value-added-energy production function exponent
α_c^q	shift parameter for Armington function
ρ_c^q	Armington function exponent
δ_c^q	share parameter for Armington function
α_c^t	shift parameter for CET function
ρ_c^t	CET function exponent
δ_c^t	share parameter for CET function

$\beta_{c,h}^{m}$	marg share of hhd cons on marketed commodity c
$cwts_{C}$	consumer price index weights
$\gamma_{c,h}^{m}$	per-cap subsist cons of market com c for hhd h
$qbarg_{C}$	exogenous (unscaled) government demand
$qbarinv_{C}$	exogenous (unscaled) investment demand
$shif_{INSD,F}$	share of dom. inst i in income of factor f
$shii_{INSDNG,INSDNG}$	share of inst i in post-tax post-sav income of inst ip
$tins_{i}$	0-1 par for potential flexing of dir tax rates
$trnsfr_{INS,INS}$	transfers fr inst. or factor ac to institution ins
$tinsbar_{INS}$	rate of (exog part of) direct tax on dom inst ins
A.4. Variable	
PVA_{C}	value added price
$QF_{F,C}$	quantity demanded of factor f from activity a
QFS_{F}	quantity of capital labor energy supply
QVA_{C}	quantity of aggregate value added
$\mathrm{WF_{F}}$	economy-wide wage (rent) for factor f
$\mathrm{wfdist_{F,C}}$	factor wage distortion variable
$QINTA_{C}$	quantity of aggregate intermediate input
$\mathrm{QINT_{C,cp}}$	quantity of intermediate demand for c from activity a
$PINTA_{C}$	price of intermediate aggregate
CPI	consumer price index (PQ-based)
DMPS	change in marginal propensity to save for selected inst
DTINS	change in domestic institution tax share
EG	total current government expenditure
EH_{H}	household consumption expenditure
EXR	exchange rate
FINV	foreign investment
GADJ	government demand scaling factor
GOVSHR	govt consumption share of absorption
GSAV	government savings
IADJ	investment scaling factor (for fixed capital formation)
INVSHR	investment share of absorption
MPS_{INSDNG}	marginal propensity to save for dom non-gov inst ins
MPSADJ	savings rate scaling factor
PDD_{C}	demand price for com c produced & sold domestically
PDS_{C}	supply price for com c produced & sold domestically
PE_{C}	price of exports

PM_C	price of imports
PQ_C	price of composite good c
PX_C	average output price
QD_C	quantity of domestic sales
QE_C	quantity of exports
QG_C	quantity of government consumption
$QH_{H.C}$	quantity consumed of marketed commodity c by household h
$QINV_C$	quantity of fixed investment demand
QM_C	quantity of imports
QQ_C	quantity of composite goods supply
QX_C	quantity of aggregate marketed commodity output
TABS	total absorption
$TINS_{INSD}$	rate of direct tax on domestic institutions ins
TINSADJ	direct tax scaling factor
$TRII_{INSDNG.INS}$	transfers to dom inst insdng from insdngp
WALRAS	Savings-Investment imbalance (should be zero)
WALRASSQR	Walras squared
$\mathrm{YF_F}$	factor income
YG	total current government income
$YIF_{INS.F}$	income of institution ins from factor f
YI_{INS}	income of (domestic non-governmental) institution ins