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The Effects of cutting Energy consumption subsidies on Industrial Air Pollution in Iran

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Abstract

Air pollution is an example of a negative externality; it imposes harmful effects and costs on people other than polluters. In controlling air pollution, efficiency argument implies that, there is a role for the government to play. Studies show that taxation of fuels can be a powerful indirect instrument for controlling air pollution because of the association between fuels use and emissions. In Iran, fuel's consumption is highly subsidized and energy prices have for several years been below opportunity costs as measured by border prices. The present study examined the impact of fuel price increases—removing energy subsidies—on the emissions of air pollutants in the industry sector. We analyze interfuel substitution in this sector—within a translog cost model—and combine the results with emission factors to assess the potential for emission reductions via demand changes. The empirical results indicate that: (1) substitution possibilities were found for most combinations of fuel types in industry sector; (2) for SOx, NOx, SPM and HC, emission elasticities with respect to the price of heavy petroleum products are -0.289, -0.220, -0.255 and -0.072, respectively. Also, a 10 percent price increase for light petroleum products would reduce total emissions of CO and HC by 3.36% and 0.47% respectively.

Keywords: Air pollution; Negative Externality, Energy, Translog Cost System, Price Distortions

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1. Introduction and Background

Economists see pollution as the consequence of an absence of prices for certain scare environmental resources (such as clean air and water), and they prescribe the introduction of surrogate prices in the form of unit taxes or "emission fees" to provide the needed signals to economize on the use of these resources [8]. The efficiency argument for public intervention to mitigate pollution problems is well established in the theoretical literature (see, e.g., [36,3,13,16]). Pollution is an example of a negative external effect; it imposes harmful effects and costs on people other than polluters [10]. For correcting the externality, incentive systems have been promoted by economists for decades as a cost-effective alternative to technological restrictions and other forms of inflexible command-and-control environmental regulations [16].

Conventional approaches to regulating the environment are often referred to as "command-and-control" regulations, since they allow relatively little flexibility in the means of achieving goals. Regardless of the cost, such regulations tend to force firms to take on similar shares of the pollution control burden [32]. Command-and-control regulations do this by setting uniform standards for firms, the most prevalent of which are technology standards and emission standards. Technology standards specify the method, and sometimes the actual equipment, that firms must use to comply with a particular regulation. Emission standards are never-exceed levels applied directly to the quantities of emissions coming from pollution sources [13]. Under command-and-control instruments, the regulator more or less dictates that whole classes of firms choose certain technologies.[1] So they don't leave firms free to choose abatement technologies that minimize costs given their individual circumstances [5].

Policies that create financial incentives for abatement by putting an explicit or implicit price on emissions but which do not dictate abatement decision are referred to as "economic incentive" policies [5]. The three chief

1. Though emissions standards do not explicitly dictate firms technology decisions, in practice they usually create strong incentives for firms to choose only officially sanctioned technologies. Therefore, they can be regarded as "technology forcing". In the United States, emissions standards on point sources administered under both the Clean Air Act (e.g., Lowest Achievable Emissions Rates) and the Clean Water Act (e.g., effluent guidelines) are developed with reference to the abatement capabilities of specific technologies. Hence, firms that want to minimize their risks of being found in violation of such standards will want to adopt the technologies underlying the standards. The risk of paying a high penalty for using alternative approaches turns a *de jure* emission standard into a *de facto* technology standard [5].

examples of economic incentive policies are emission fees, product charges and marketable permits.

Theoretically, the best way to clear the environment is to make polluters face the marginal social costs of their actions, as initiated by Pigou [26]. A policy which could implement such a principle is to set an emission tax (known as Pigouian tax) equal to the marginal social damages caused by the emissions.[1] If things were really this straightforward pollution problems could have been resolved long ago with the use of economic incentives. But, measuring the monetary damages associated with emissions is a difficult task, as is estimating the pollution control costs of the emission sources. In addition, any charge system requires accurate information on the item to be taxed. If emissions are to be taxed, they must be measurable at reasonable cost. This rules out most nonpoint-source emissions because they are spread thinly over a wide area in a way that makes them impossible to measure. It would normally be impossible to tax the pollutants in agricultural runoff because the diffuse nature of the "emissions" makes them impossible to measure [13].

Given the information problems associated with the theoretically first-best schemes such as the emission taxes, the regulator's alternative form of price-based incentives is product charges. Product charges are fees or taxes levied on outputs or inputs that are potentially hazardous to humans or the environment when used in production, or when they or the containers that carry them become waste matter. These charges may also be levied on input characteristics, such as the persistence of a pollutant—an example being taxes on the sulphur content of coal as a means of reducing SO2 emissions from power stations. By increasing the cost of hazardous materials, product charges encourage producers and consumers to substitute more environmentally safe products or inputs [16].[2]

The major economic explanation for pollution is an absence of a sufficient set of private property rights in environmental resources, as Coase [7] argued nearly four decades ago. The main idea behind "marketable permits" is to allocate such rights, and make them tradable. This results in a market for the right to pollute developing and consequently a market price for this right

1. The Pigouian incentive can be either a tax on pollution or a subsidy for abatement. In the short term, the incentive effects can be the same. In the long term, when market entry and exit can be affected, a tax is normally preferable because it does not give firms incentives to enter a subsidized polluting industry ([10,8]).
2. One attraction of pollution taxes is that they can raise revenue while improving efficiency, by persuading firms and households to reduce negative externalities [10].

[16]. Under a marketable permit system, an allowable overall level of pollution is established and allocated among firms in the form of permits. Firms that keep their emission levels below their allotted level may sell their surplus permits to other firms or use them to offset excess emissions in other parts of their facilities [32].

In theory, if properly designed and implemented, economic incentive instruments allow any desired level of pollution cleanup to be realized at the lowest overall cost to society, by providing incentives for the greatest reductions in pollution by those firms that can achieve these reductions most cheaply. Rather than equalizing pollution levels among firms (as with uniform emission standards), market-based instruments equalize the incremental amount that firms spend to reduce pollution—their marginal abatement cost.[1] In contrast to command-and-control regulations, economic incentive instruments have the potential to provide powerful incentives for companies to adopt cheaper and better pollution-control technologies. This is because with market-based instruments, it always pays firms to clean up a bit more if a sufficiently low-cost method (technology or process) of doing so can be identified and adopted [32].

Environmental regulatory instruments also can be classified according to whether they require the regulator to monitor emissions. Policies that require the regulator to monitor emissions are called "direct" instruments and policies that do not are called "indirect" instruments. As shown in Table 1, Emission standards, emission fees, and marketable permits are examples of direct instruments while product charges and technology standards are examples of indirect instruments ([5,10,12]).[2]

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1. As long as there is no uncertainty about abatement costs, price-based incentives (such as taxes) and quantity-based incentives (such as marketable permits) have exactly the same effect. The same level of emissions and economic costs should result. A uniform emission tax will have the same incentive effects as emission permits, because the market will distribute them within the industry according to willingness to pay. Both minimize abatement costs overall, because high-cost abaters will either pay the tax or outbid low-cost abaters for permits [10]. Command-and-control approaches could—in theory—achieve this cost-effective solution, but this would require that different standards be set for each pollution source, and, consequently, that policy makers obtain detailed information about the compliance costs each firm faces. Such information is simply not available to government [32].

2. There is a large literature pertaining to the use of indirect instruments when a first-best Pigovian tax is not available. Examples are Sandmo [29], Balcer [2] and Wijkander [41]. For car emissions, fuel and automobile taxes are good candidates —

Table -1. A Classification of Policy Instruments to Reduce Pollution

	Direct Instruments	Indirect Instruments
Economic Incentives	• Emission fees • Marketable permits	• Product charges
Command and Control	• Emission standards	• Technology standards

To varying degrees, all of the types of environmental regulation addressed in Table 1 require a public-sector institution capable of establishing rules of conduct for polluters, monitoring performance with respect to these rules, and enforcing compliance. In many developing countries, a number of financial and institutional constraints undermine such capabilities. The literature has identified four key constraints (e.g., [10], [1], [21]). First, public sentiment generally favors economic development over environmental protection. In addition, private-sector environmental advocacy—historically a critical stimulus to effective environmental regulation—is generally less prevalent and less well-organized than in industrialized countries. As a result, it is often difficult to muster the political will to enforce environmental regulations. Second, environmental regulatory institutions, along with complementary judicial, legislative and data collection institutions, are generally much weaker than in industrialized countries. Third, fiscal and technical resources for environmental protection are generally in short supply. Finally, production is often dominated by hard-to-monitor small-scale firms [5].

Given the constraints on environmental regulation discussed above, indirect instruments like product charges may stand a better chance of being effective in developing countries, since by definition they are less demanding of regulators than direct instruments. Product charges are relatively easy to administer for at least two reasons. First, quantities of goods are usually much easier to monitor than quantities of emissions. Second, product charges operate through government tax collection

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the technology is not yet available to measure and tax each car's total emissions. Fullerton and west [14] have derived a set of fuel and car optimal taxes, which are able to mimic, at least in theory, the unavailable tax on emissions. Also, see Eskeland [9], Eskeland and Devarajan [12] and Innes [18] on how standards should be accompanied by taxes on inputs and outputs.

institutions rather than environmental regulatory institutions, and in most developing countries, the former are more established and effective than the later [5].

Taxation of fuels—energy carriers—is such an indirect instrument that is potentially attractive for air pollution control, because energy consumption is a proxy for the utilization of polluting equipment. Thus, if individuals and firms are induced to economize on energy use or to switch to cleaner fuels, their emissions will fall [11].

Iranians not only do not pay taxes on energy carriers, but also energy consumption is heavily subsidized in Iran. Distorted price regime imposes a heavy weight on economic efficiency and government budgets. Over-consumption, due to excessively low prices, decreases the availability of fuels for export and increases import requirements. Funds supporting subsidies could be redirected to social benefits and income redistribution. So, eliminating energy subsidies should enhance overall economic performance, and its removal are likely to provide at least some environmental benefits. In Central and Eastern Europe, for example, removing long-standing fuel subsidies initiated during the Soviet period has probably done more to improve environmental quality than any explicit environmental policy (See, e.g., [28,22]).

The main objective of this study is to analyze the impact of fuel price increases—removing energy consumption subsidies—on the emissions of air pollutants. I follow the model provided by Eskeland et al. [11]. The model combines econometric estimates on how fuel demand responds to price changes with engineering estimates of the link between input use and emissions. I apply the model to industrial sector. In the next section, I briefly review energy statue and environmental situation in Iran. The third section then presents the theoretical structure of the model employed in this study. Section 4 discusses model estimation and data issues, while the empirical results are reported and analyzed in section 5. Finally, section 6 provides summery and some concluding remarks.

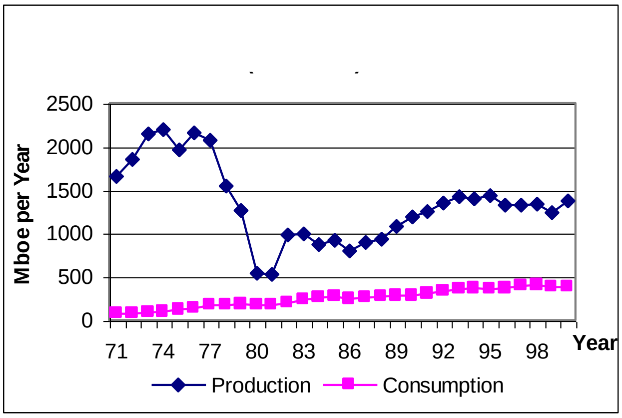
2. Energy and Environmental Situation in Iran

2.1 Energy Statue Overview [1]

Iran is OPEC's second largest oil producer. It also has the world's second largest natural gas reserves. As of late 2002, Iran held 90 billion barrels of proven oil reserves (roughly 9% of the world’s total) and 23 trillion cubic-meter of natural gas —surpassed only by those found in Russia [38].

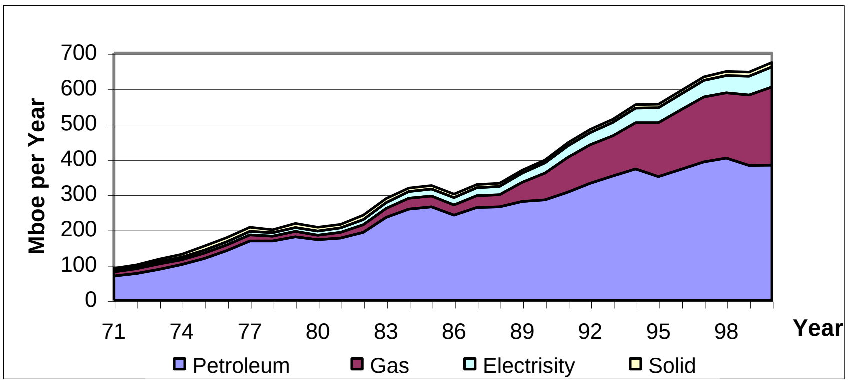
1. All data used in this section are from [25] unless otherwise specified.

Fig-1. Iran's Oil Production and Consumption (1971-2000)



Even though Iran's economy relies heavily on oil export revenues (around 80% of total export earnings, 40%-50% of the government budget, and 10%-20% of GDP) [38], its production has dropped by more than a third from a peak of over 6 million boe/d (barrels of oil equivalent per day) in 1974 to about 3.7 million boe/d in 2000 (see Figure 1). The Iranian oil industry has had many fluctuations since the revolution in 1978 and has faced numerous problems resulting from the destructive Iraq-Iran war (1980-1988) and the economic sanctions.

Fig– 2. Final Energy Consumption



On the other hand, Iran's domestic oil consumption has increased rapidly (about 6.4% per year) during the period 1971-2000, as the economy and population grow (see Figure 1). In 2000, Iran consumed nearly 28% of which produced and it also is forced to import 10.7 million boe petroleum products (mainly gasoline) which cannot produce locally. With an increase in domestic consumption of oil and the reduction for oil production, the share of oil exports has sunk during the last 30 years. This also meant a sharp reduction in Iran's revenue. Without any increase in its oil production capacity, rapid increases in domestic consumption of petroleum products may turn the country into an oil importer.

Petroleum is the main fuel for meeting the total energy requirements in Iran and domestic demands for oil derivates grew rapidly during the period 1971-2000, but its share of total final energy consumption was reduced from 75.91% in 1971 to 56.87% in 2000 (see Figure 2). Iran has turned to natural gas as a substitute for the domestic consumption of petroleum products. The consumption of natural gas increased from 12 Mboe in 1971 to 220.5 Mboe in 2000. That means it grew at nearly 11.7% annually and in 2000 contributed 32.76% of the total energy consumption (in 1971, this value was 13.31%). As oil is the source of more than 80% of the government's foreign currency income, the main policy has been pursued, is the reduction of oil product consumption to enable the country to export petroleum products. This reduction will be achieved by promoting the use of natural gas via the expansion of gas network pipelines.[1] In 2000, electricity accounted for 8.39% of the total energy consumption. The electricity sector is the largest domestic gas consumer in Iran, accounting for about 37.6% of the total in 2000.

Iran is among the countries with largest oil and gas reserves in the world, and arguably has the lowest energy prices. According to (GTZ, [24]) study, among more than 160 countries (with populations exceeding 1 million) Iran and Turkmenistan have the lowest pump prices for automotive diesel fuel (at 2 US cents per liter). At 5 US cents per liter, Iran's super gasoline pump price is the 3rd lowest amount in the world as of November 2000.[2] Both prices are lower than the world market price for crude oil ("Brent") of 19.7 US cents per liter as of November 2, 2000.

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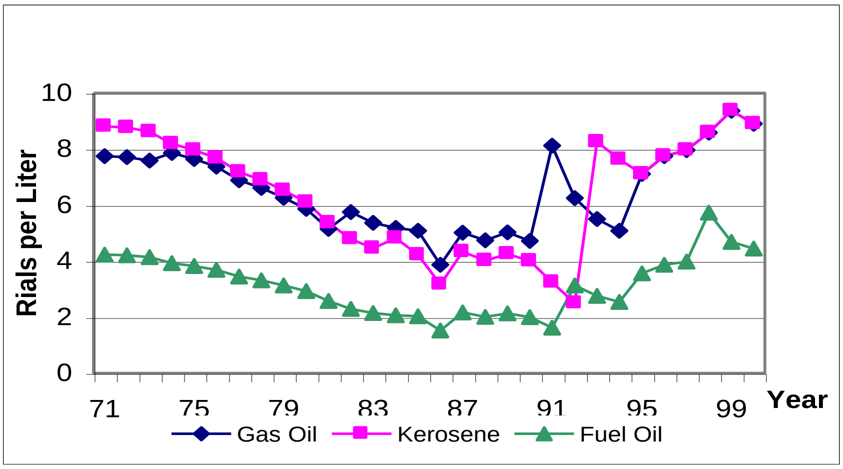
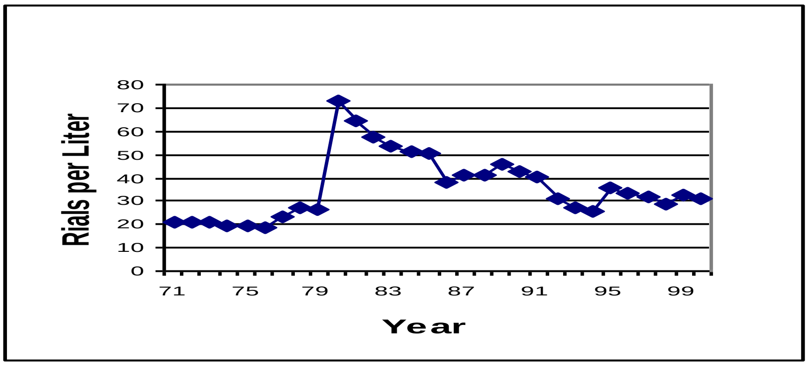
1. Despite the fact that domestic natural gas demand is growing rapidly, Iran has the potential to be a large natural gas exporter due to its enormous reserves. In 2001, Iran produced about 2.2 trillion cubic feet of natural gas. Of this, around 10% is flared, and approximately 30% is reinjected—in part for enhanced oil recovery efforts. Still, the amount of gas that Iran flares and reinjects is indicative of the abundance of this resource in the country [38].
2. In GTZ's survey, local prices for super gasoline and diesel are considered as 385 and 120 IR rials per liter respectively and exchange rate is 1 US $ = 7900 IR rials.

Fig- 3. Real Prices of Petroleum Products (Norm alized with 1990 Price)



For a long time, nominal prices of energy carriers were constant.[1] In the recent years, although the government has implemented a policy of gradual price increases, but the real cost of most of petroleum products(in terms of 1990 rials) in 2000 were relatively constant compare to thirty years ago and the real price of gasoline has a downward trend from 1980 (see Figures 3 and 4).

Fig – 4. Real Price of Gasoline (Normalized with 1990 Price)



1. In Iran, the energy prices are fixed by the Parliament. The average level of the energy carriers' prices would be costly for people, if one takes into account the purchasing power of the people, and this is the main economic, political and social reason for payment of subsidies to consumers [35].

Severe price distortions result in a large amount of waste and inefficiency in energy consumption. Iran's energy intensity increased by an average of 3.45% annually during the period 1971-2000, from 6.7 to 17.1 boe per million rials - measured as the ratio of Total Primary Energy Supply (TPES) to one million IR rials of GDP (in terms of 1990 rials). Also, energy intensity is high in Iran compared to world as well as most other regions in the world (see Table 2). Iran's overall energy intensity, measured as the ratio of TPES to 1000$ of GDP (in 1995 US dollar), was 1.07 toe in 2000, compared to 0.30 toe for world, 0.19 toe for OECD and 0.65 toe for Middle East countries. In 2000, Iran's per capita TPES was 1.77 toe per year. That is high compared to world (1.68 toe) and other non-OECD countries (1.64 toe) but lower than the OECD value of 4.74 toe and Middle East (2.30 toe).

Table - 2. Key Energy Indicators in 2000

Country/Region	**Population (Million)**	**GDP (Billion 95 US$)**	**TPES* (Mtoe)**	**TPES/Pop (toe/capita)**	**TPES/GDP (toe/1000 US$)**
Iran	*63.66*	*104.99*	*112.73*	*1.77*	*1.07*
World	6023.17	34037.02	10109.59	1.68	0.30
OECD	1122.18	27685.45	5316.93	4.74	0.19
Middle East	165.36	580.78	380.34	2.30	0.65
Non-OECD Europe	58.20	133.36	95.28	1.64	0.71
China	1269.26	1204.92	1163.37	0.92	0.97
Asia**	1907.90	1724.53	1122.62	0.59	0.65

Source: IEA, Key World Energy Statistics, [34]
* Total primary energy supply (TPES) is made up of indigenous production + imports - exports - international marine bunkers ± stock changes. For the World Total, TPES excludes international marine bunkers.
** Asia excludes china

In 2000, about 72.36% of the total energy consumption met the energy demand of the end-user sector and the remaining 27.64% was used in the energy conversion sector such as electric utilities, petroleum refining, etc. A breakdown of the final energy consumption in 2000 shows that 19.27% energy was used in the industrial sector, 28.59% in the residential/commercial sector, 20.97% in the transport sector and 3.53% in the agricultural sector. The residential/commercial sector is the largest energy-consuming sector, followed by the transport and industry sectors.

2.2 Environmental Situation in Iran

Iran is faced with a litany of environmental problems, many of which the country is only beginning to tackle as the problems reach a crisis point.[1] The biggest environmental problem Iran currently faces is air pollution, especially in the capital city of Tehran, but also in regional cities like Tabriz. The growth of energy consumption together with low quality fuel, obsolete transport vehicle technology and high average life of vehicle fleet, traffic congestion and shortage of adequate public transport and also concentration of industrial sources in close proximity to urban areas are confronting Iranian large cities with serious air pollution problems. The polluted air was blamed for causing several deaths, as well as causing problems for people with asthma, heart, and skin conditions. Overall, approximately 4,000-5,000 Tehran residents are estimated to die every year from air pollution [39]. The levels of emissions of the most important local pollutants in Tehran are well above the World Health Organization (WHO) maximum annual mean guideline levels for air quality (see Table 3).

According to The Study on an Integrated Master Plan for Air Pollution Control in Tehran (JICA, [19])[2], about 1,599,949 tons of pollutants are produced in this city, where 20% of Iran's population lives. Contribution of stationary sources and mobile sources to the total emission of air pollution in Tehran are 29% and 71% respectively, demonstrating the dominance of mobile sources. Concerning the contribution of each pollutant, stationary sources share 97% and 71% in SOx (sulphur oxides) and NOx (nitrogen oxides) while mobile sources share 94%, 70% and 88% in CO (carbon monoxide), HC (hydrocarbons) and SPM (suspended particulate matter) respectively (see Figure 5).

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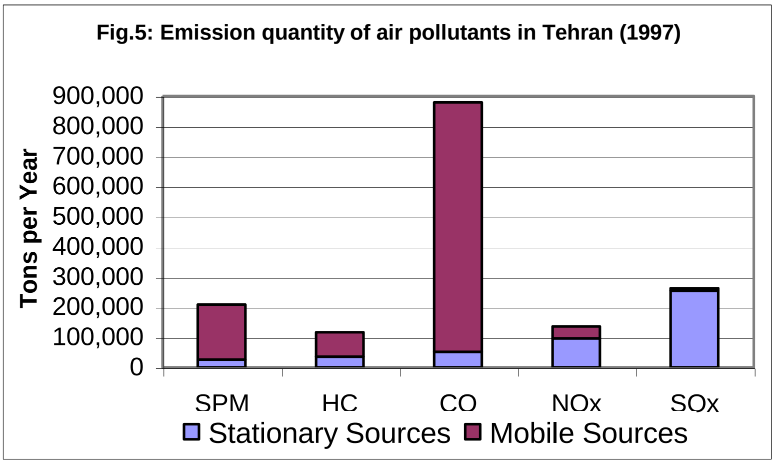
1. In addition to deforestation and desertification issues across much of Iran's arid territory, over-fishing in lakes and rivers has caused a drop in fishing levels; industrial and urban waste water runoff has contaminated a number of rivers and coastal waters and threatened drinking water supplies; wetlands and reservoirs are increasingly being destroyed under the pretext of creating industrial and agricultural lands; and oil and chemical spills in the Persian Gulf and Caspian Sea continue to pollute the seas and harm aquatic life. The Caspian Sea region is faced with a number of environmental problems in the international rush to develop the Caspian's oil and gas [39].
2. It has been carried out by the Japan International Cooperation Agency (JICA) in collaboration with the municipality of Tehran in the period 1995-1997.

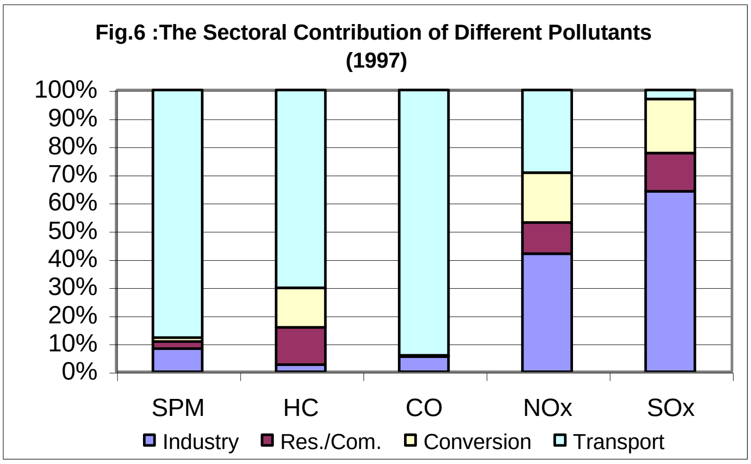
Table - 3. Tehran Compared to the Most Polluted Cities in the World (1995)

Unit: Micrograms per Cubic Meter

Country	City	TSP	NO2	SO2
Iran	*Tehran*	*248*	*n.a.*	*209*
Brazil	Rio de Janeiro	139	n.a.	129
China	Beijing	377	122	90
China	Shanghai	246	73	53
Mexico	Mexico City	279	130	74
Russia	Moscow	100	n.a.	109
India	Delhi	415	41	24
WHO Guideline		**90**	**50**	**50**

Source: Atlas of population and Environment, [17]





As shown in Figure 6, SOx emissions from the manufacturing sector shares 64% of the total, followed by energy conversion of 19% and residential/commercial of 14%. The transport sector shares only 3% in contrast to other kinds of emissions, since this sector uses low sulfur gasoline and diesel oil. The manufacturing sector accounts for about 42% of the NOx produced in Tehran, while the transport, energy conversion and residential/commercial sectors have a share of about 29%, 18% and 11% of the total, respectively.

Like local emissions, greenhouse-gas emissions are a negative externality of energy consumption. In 2000, Iran accounts for about 1.25% of the world's total CO2 emissions [34]. As shown in Table 4, Iranians produced 2.78 kg of CO2 per 1 US$ of GDP (in 1995 US dollar) in 2000, while this value was 0.69 in the World and 0.45 for the OECD countries. Iran's per capita CO2 emissions (at 4.59 tons of CO2 per capita) were significantly lower than the corresponding figure for the OECD (11.09) but higher than the World's value of 3.89.

Table - 4. Iran's CO2 Emissions Data, 2000

Country/Region	**CO2 Emissions (Million tons of CO2)**	**CO2/Pop (t CO2/Capita)**	**CO2/GDP (kg CO2/95 US$)**
Iran	*292.08*	*4.59*	*2.78*
World	23444.15	3.89	0.69
OECD	12449.04	11.09	0.45
Non-OECD Europe	240.46	4.13	1.8
Middle East	986.22	5.96	1.7
China	3052.27	2.40	2.53
Asia*	2153.57	1.13	1.25

Source: IEA, Key World Energy Statistics, [34]

* Asia excludes china.

3. The Model

The model used in this study makes an explicit link between pricing policy and emission outcomes. It combines econometric estimates on how fuel demand responds to price changes with engineering estimates of the link between input use and emissions.

3.1 Fuel Demand

It is assumed that there exists a production function which is weakly separable in aggregate inputs: energy, capital, labor and materials. The assumption of weak separability is often employed in the literature on interfuel substitution (e.g.,[23,15,27,37,6,30,11]). The constraint of separability is imposed to reduce the number of estimated parameters.[1] Under these assumptions, the production function can be described as follows:

$$Q = f[K, L, M, E(E1,..., En)] \qquad (1)$$

where Q, K, L, M, and E stand for output, capital, labor, materials, and aggregate energy input, respectively, and Ei is the energy source i (fuels). Also, the aggregate energy input E is assumed to be a homothetic function of the n-types of energy sources and linear-homogeneous in its components.[2]

Assuming exogenously given input prices, output level, and cost-minimizing behavior, the theory of duality implies that the production structure can be uniquely described by a cost function, which is also weakly separable in the aggregate inputs, and takes the following form:

$$C = C[P_K, P_L, P_M, P_E(P_{E1},..., P_{En}), Q] \qquad (2)$$

where C, P_K, P_L, P_M , and P_E represent the total cost of production, the price of K, L, M, and the price aggregator of energy, respectively. Since P_E is the price per unit of energy, it is also the cost per unit to the optimizing agent. This cost can be represented by an arbitrary unit cost function. The translog functional form is often used in the empirical literature on energy substitution, because of its flexibility in substitution parameters.[3] The translog functional form can be considered as a second-order approximation to an arbitrary twice-differentiable cost function. Assuming translog approximation of the energy cost function, a linear-homogeneous cost

1. Separability implies that the marginal rates of substitution between fuels depend only on the use of fuels.
2. While weakly separability and these two assumptions allow for estimation of a demand system with a limited set of parameters, I emphasize that the assumptions themselves are not tested.
3. The use of the translog form in the energy cost function sometimes violates consistency in economic theories, such as concavity and monotonicity. This is due mainly to small shares of one or more inputs and large variations in the relative prices [6]. However, the estimation results of the present study indicate no violation of concavity and monotonicity.

function of the aggregate energy input is represented by a unit cost function of the form:

$$\ln P_E = a_0 + \sum_i a_i \ln P_{Ei} + a_T T + 1/2 \sum_i \sum_j b_{ij} \ln P_{Ei} \ln P_{Ej} + \sum_i b_{it} \ln P_{Ei} T + 1/2 b_{tt} T^2 \quad (3)$$

where P_{Ei} is the price of energy source i and T is the time trend (added to allow shifts in the cost function due to exogenous technological change). By differentiating Equation (3) with respect to each input price, and by using Shephard's lemma, the following cost-share equation of each energy type is obtained:

$$S_{Ei} = \frac{P_{Ei} X_{Ei}}{\sum_{j=1}^{n} P_{Ej} X_{Ej}} = \frac{\partial \ln P_E}{\partial \ln P_{Ei}} = a_i + \sum_j b_{ij} \ln P_{Ej} + b_{it} T \qquad \text{i=1,…,n.} \qquad (4)$$

where S_{Ei} is the cost share of the energy component i.[1] Several restrictions must be satisfied in order for the translog model to represent a well-behaved cost function. The following parameter restrictions are imposed since the factor cost shares must add to one and the cost function must be homogenous of degree one in input prices:

$$\sum_i a_i = 1, \qquad \sum_i b_{ij} = \sum_j b_{ij} = 0, \sum_i b_{it} = 0 \qquad (5)$$

In addition, the symmetry of the Slutsky cross-derivatives of the cost function implies the restriction:

$$b_{ij} = b_{ji} \quad i \neq j \qquad (6)$$

Using estimated parameters, the Allen-Uzawa partial elasticities of substitution (σ) and partial price elasticities of demand for energy components (ε) are computed as [4]:[2]

1. Homotheticity and constant returns to scale assumptions of the aggregate energy input E simplified the model: these two assumptions imply that fuel shares depend on relative fuel prices and time trend only (see [33]).
2. In estimating various elasticities, a word of caution is required. A basic assumption underlying the derivation of the share equations (4) is that in each observation period in the sample there has been a full and complete adjustment of the input mix to the factor prices ruling in that period so that the minimum level of

$$\sigma_{ij} = \frac{b_{ij} + S_i S_j}{S_i S_j}, i \neq j \quad (7)$$

$$\sigma_{ii} = \frac{b_{ii} + S_i (S_i - 1)}{S_i^2} \quad (8)$$

$$\varepsilon_{ij} = \sigma_{ij} S_j, i \neq j \quad (9)$$

$$\varepsilon_{ii} = \sigma_{ii} S_i \quad (10)$$

two energy sources are termed as substitutes (complements) to each other as σ_{ij} is positive (negative).

3.2 The Emission Model

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned) [40].[1]

For the activity, the energy consumption could be used. Consequently, emission quantities of pollutants can calculate as a result of multiplying energy consumption with corresponding emission factors:

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energy cost function is achieved. This is an implausible assumption for many production processes, and actual cost shares probably represent various *lagged* adjustments to changing factor prices. The assumption of instantaneous adjustment is likely to produce biased estimates of the various elasticities [20].

1. Such factors facilitate estimation of emissions from various sources of air pollution. Data from source-specific emission tests or continuous emission monitors are usually preferred for estimating a source's emissions because those data provide the best representation of the tested source's emissions. However, test data from individual sources are not always available (especially in developing countries, where regulatory agencies are often inadequately funded and have less access to technology and trained labor). Thus, emission factors are frequently the best or only method available for estimating emissions, in spite of their limitations. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average) [40].

$$E^P = \sum_i EF_i^P . X_i \qquad (11)$$

where E^P is emissions of pollutant P, EF_i^P is the emission factor for pollutant P, energy source i, X_i is the quantity of fuel consumed. Now the elasticity of emissions to a fuel price change can obtained from Equation (11) as:

$$\frac{\partial E^P}{\partial P_j} \frac{P_j}{E^P} = \frac{1}{E^P} \sum_{i=1}^{n} EF_i^P . X_i . \varepsilon_{ij} \qquad (12)$$

where ε_{ij} is the applicable demand elasticity of fuel i with respect to the price of fuel j (replaced by Equation (9) and (10)).

4. Model Estimation and Data Issues

There is a multi system of energy prices in Iran. For example, there is a double system of oil products prices, for power stations and for other consumers. For natural gas and electricity, the sale prices are different by sector (household, industry, commercial and agricultural). The commercial sector pays the highest prices, while the prices for the agriculture sector are the lowest. Also, prices for households are less than industrial customer prices.

The average tariff of electricity and natural gas for industrial sector (based on the quantity of energy sold and the revenue earned) are obtained from the Iran’s Power Generation and Transmission Management Organization (TAVANIR) and the National Iranian Gas Company, respectively. The data on oil products prices are obtained from the National Iranian Oil Refining and Distribution Company (NIORDC) and the Ministry of Energy (MOE).

Fuel consumption data are taken from the sources mentioned above. For the quantity of electricity, I do not take into account electricity generated by manufactures for their own use.

The emission factors by fuel combustion are obtained from The Study on an Integrated Master Plan for Air Pollution Control in Tehran [19]. The emission factors are calculated for different sectors and different individual fuels in Iran. These calculations assumed electricity is not polluting in industrial sector because manufacturing industries are a consumer of electricity at end-use.

Table – 5. Energy Groupings in this study

Categories	Light Petroleum Products (LPP)	Heavy Petroleum Products (HPP)	Natural Gas	Electricity
Energy Sources	Gasoline	Gas Oil	Natural Gas	Purchased Electricity
	Kerosene	Fuel Oil		
	LPG			

I aggregate energy sources into four categories: Heavy Petroleum Products (HPP), Light Petroleum Products (LPP), natural gas and electricity (see table 5).[1] These categories are defined by three considerations: (i) assumed economics of substitution: LPP, HPP, natural gas and electricity allow reasonably homogenous inputs in each group, thus representing relevant choices for the firm; (ii) modeling objective: the four categories also differ sufficiently in terms of pollution coefficients; (iii) demand system estimation: four categories yield few enough parameters and high enough fuel cost shares, to successfully estimate a demand system.

Table – 6. Emission Factors in Industry Sector
Unit: gr/Gj

	LPP	**HPP**	**Natural Gas**
Sox	71.30	895.60	1.00
NOx	152.61	170.61	73.00
CO	1900.28	12.40	7.00
HC	78.76	9.00	1.00
SPM	52.25	66.20	6.00

Table 6 presents emission factors by HPP, LPP and natural gas combustion in industry sector. In this study, the pollution coefficient for HPP and LPP are calculated as weighted averages of their components. Table 6 indicates that natural gas has the lowest emission factors for all type of pollutants. For SOx, NOx and SPM, HPP have higher emission factors rather than that of LPP. For CO and HC, LPP have the highest of emission factors among others.

1. With a negligible share of energy demand attributed to coal and sparse coal price data, coal is not considered in this study.

In estimating cost-share equations of energy components (4), only n-1 of the share equations are estimated, because the sum of all shares must necessarily equals to unity, in the estimation, one of the cost share equations is dropped from the system to avoid disturbance covariance matrix from being singular. The Zellner's iterative seemingly unrelated regression equations (SURE) technique is employed to estimate the share equations to get efficient estimates.[1] The estimation is based on time-series data covering the period from 1971 to 2000 (30 years).

5. Empirical Results and Discussion

Parameter estimates and the corresponding t-statistics for the translog model are provided in Table 7. The results indicate that the model provides a relatively good fit in terms of the t-statistics. In addition, conventional R-square measures for the share equations are between 0.946 and 0.977.

Before proceeding with the analysis it is necessary to establish whether the estimated translog system is well behaved or not. A cost function is well behaved if it is concave in input prices and if the fitted cost shares are strictly positive (implying monotonicity of costs with respect to fuel prices).

Table – 7. Parameter Estimates for the Translog Model

al 7.305952 (1.472909)	bll 0.073677 (9.091095)	blh -0.011210 (-1.300670)	blg -0.030767 (-4.124668)	ble -0.031700	blt -0.005280 (-1.466623)	R^2 = 0.974 D.W.=1.22
ah 15.04854 (3.138376)	bhl -0.011210 (-1.300670)	bhh 0.123605 (6.990152)	bhg 0.009787 (0.789935)	bhe -0.122182	bht -0.010558 (-3.011863)	R^2 = 0.977 D.W.=1.43
ag -11.63836 (-6.994133)	bgl -0.030767 (-4.124668)	bgh 0.009787 (0.789935)	bgg 0.057841 (3.398038)	bge -0.036861	bgt 0.008709 (7.102016)	R^2 = 0.946 D.W.=1.75
ae -9.71613	bel -0.031700	beh -0.12218	beg -0.036861	bee 0.19074	bet 0.00713	

Note: t-statistics are in parentheses. Fuels are l=LPP, h=HPP, g=gas, e=electricity.

Monotonicity of the cost function was checked by determining if the fitted values of the fuel cost shares were positive. The check of these showed that the translog form generated positive cost shares. Further, concavity in input prices requires that the bordered Hessian is negative semi-definite. A sufficient condition for a matrix to be negative (positive) semi-definite is non-negative (non-positive) eigenvalues. The check of these at each observation showed that, the model was well behaved in terms of concavity.

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1. It should be noted that the estimates obtained are asymptotically equivalent to maximum likelihood estimates (See [42]).

In Table 8 the partial fuel price elasticities are presented. All elasticity estimates have been calculated at the mean value of the fitted cost shares over the period 1971 to 2000.

Table - 8. Partial Fuel Price Elasticities for the Translog Fuel Demand System

	Price of LPP	Price of HPP	Price of Gas	Electricity Tariff
Demand for LPP	-0.388	0.326	-0.097	0.159
Demand for HPP	0.136	-0.292	0.115	0.041
Gas Demand	-0.176	0.502	-0.269	-0.057
Electricity Demand	0.074	0.046	-0.015	-0.106

All of the own price elasticities are negative, so the results do not violate the postulates of cost-minimizing factor demand theory. Interfuel substitution dominates even though complementarity exists between LPP and natural gas and weak complementarity between natural gas and electricity.

The computed price elasticities of fuels' demand (ε_{ii} and ε_{ij}), reported in Table 8, are found to be less than unity for all fuels. This implies that, in general, other things remaining unchanged, the demands for fuels in industry sector are inelastic with respect to changes in fuel prices.[1]

Among the four fuels, the demand for LPP is found to be most responsive to its own price, followed by HPP, natural gas and electricity. Maybe because the first three are used primarily for heating purposes exhibit substitutability characteristics.[2] The opposite description is the case for electricity, used primarily for lighting and motive power.

1. Presumably this is not surprising: as mentioned earlier, fuel consumption is highly subsidized. Thus, not only is there low variability in fuel prices, because of the subsidy the share of energy in the total cost of firms is negligible.
2. Among them, LPP is a much more expensive fuel on a thermal basis (it should be used only where there is no possibility of using an alternative fuel), so its own price elasticity is highest among others.

Table - 9. Emission Elasticities

	Price of LPP	Price of HPP	Price of Gas	Electricity Tariff
SOx	0.134	-0.289	0.114	0.042
NOx	0.094	-0.220	0.084	0.042
CO	-0.336	0.268	-0.078	0.146
HC	-0.047	-0.072	0.038	0.081
SPM	0.109	-0.255	0.101	0.045

I now turn to the remaining stage of the model. The partial fuel price elasticities used to determine emission elasticities, as shown in Table 9. To illustrate, one could increase the price of HPP to reduce SOx, NOx, HC and SPM emissions. A 10 percent price increase for HPP would reduce total emissions of SOx by nearly 2.89 percent—an impressive contribution to any air pollution control program. This value for NOx, HC and SPM emissions were 2.2%, 0.72% and 2.55%, respectively. Also, a 10 percent price increase for LPP would reduce total emissions of CO and HC by 3.36% and 0.47%, respectively.

By assuming that electricity is not polluting in industry sector, emission elasticities with respect to electricity tariffs are positive. Also, a rise in the price of LPP or gas will lead to an

Table - 10. Fuel's Share in Emissions

Unit: percent

	LPP	HPP	Natural Gas
SOx	0.48	99.50	0.02
NOx	4.89	89.78	5.34
CO	89.64	9.61	0.75
HC	34.41	64.59	1.00
SPM	4.53	94.28	1.19

increase in the SOx, NOx and SPM emissions. This may have the following reasons: With considering quantities of fossil fuels consumed in industry sector and relevant emission factors, each fuel's role in emissions can calculated (see Table 10). As shown in Table 10, HPP are responsible for 99.5% of the total emissions of Sox—HPP have an abnormally high share in energy consumption.[1] This value for NOx and SPM were about 90% and 94%, respectively. On the other hand, the demand elasticity of HPP to the prices of LPP and gas was positive (see Table 8). The positive cross-price elasticities between LPP and natural gas and HPP may imply that HPP used in process heat can be easily switched to LPP and gas, as in the case of dual-fueled boilers. Therefore, a rise in the price of LPP or gas will not only reduces its own demand, but will also lead to an increase in the demand for the HPP.

Complementarity between LPP and natural gas and the primary role of LPP in the emission of CO (about 90%), could be an acceptable reason for negative emission elasticity of CO with respect to gas price. Share of LPP in the emission of HC is not negligible (about 34%), so a rise in the price of LPP can yield positive environmental effects. Maybe substitute between natural gas and HPP and the primary role of HPP in the emission of HC, result in positive emission elasticity of HC with respect to gas price.

6. Summary and Conclusions

In developing and transition economies, the restricted technical and administrative capacity in regulatory agencies, the shortage of financial resources, and limited institutional and administrative resources to monitor and enforce emission controls strengthen the case for indirect instruments with product charges, over direct instruments through marketable permits and emission fees. These reasons are particularly important when polluters are many and possess private information.

Product charges are relatively easy to administer for at least two reasons. First, quantities of goods are usually much easier to monitor than quantities of emissions. Second, product charges operate through government tax collection institutions rather than environmental regulatory institutions, and in most developing countries, the former are more established and effective than the later. Studies show that taxation of fuels can be a powerful indirect instrument for controlling air pollution because of the association between fuels use and emissions.

In Iran, fuel's consumption is highly subsidized and energy prices have for several years been below opportunity costs as measured by border prices. Distorted price regime imposes a heavy weight on economic efficiency and government budgets. Over-consumption, due to excessively low prices,

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1. In industry sector, the share of HPP of total fuel consumption was about 77.13% (at means). This value for natural gas, LPP and electricity were about 10.71%, 4.70% and 7.46%, respectively.

decreases the availability of fuels for export and increases import requirements. Funds supporting subsidies could be redirected to social benefits and income redistribution. So, eliminating energy subsidies should enhance overall economic performance, and its removal are likely to provide at least some environmental benefits.

The present study examined the impact of fuel price increases—removing energy subsidies—on the emissions of air pollutants in the industry sector. This is done by using the model that makes an explicit link between pricing policy and emission outcomes. The model provides estimates of emission elasticities.

In Iran lack of urban planning controls has enabled industrial sources of air pollution to be built and often in close proximity to densely populated residential areas. In the capital city, the industrial sector accounts for about respectively 64% and 42% of the total SOx and NOx produced—the levels of emissions in Tehran are well above the WHO guidelines. Emission elasticities with respect to heavy petroleum products prices are respectively -0.289, -0.220, -0.072 and -0.255 for SOx, NOx, HC and SPM in industry sector. Also, a 10 percent price increase for light petroleum products would reduce total emissions of CO and HC by 3.36% and 0.47%, respectively.

The environmental effects of removing energy subsidies are relatively complex. They can be positive and negative. If removing energy subsidies results in substitution towards dirtier fuels, they have negative environmental effects. The interfuel substitution analysis showed that: the own-price elasticities were negative for all fuels, and light petroleum products and natural gas were substitutes for heavy petroleum products in industry sector. On the other hand, heavy petroleum products have primary role in SOx, NOx and SPM emissions, due to high share of them in energy consumption. Thus, a rise in the price of light petroleum products or natural gas will not only reduce its own demand, but will also lead to an increase in the demand for the heavy petroleum products, which can lead to higher airborne emissions of SOx, NOx and SPM. If the policy objective is to reduce these emissions, increased prices for heavy petroleum products can deliver such reductions. For CO, the suggested policy would be somewhat different, since light petroleum products are relatively more important. Price increases for light petroleum products can be part of a strategy to reduce this pollutant. Price increases for light and heavy petroleum products will lead to reduction of HC emissions.

Finally, removing subsidies for petroleum products consumption can satisfy multiple objectives, including: (i) raising government revenue for general expenditure purposes; (ii) promoting efficient use of resources through avoiding economic distortions; (iii) reducing the environmental externalities of fuels consumption; (iv) greater availability of oil for export; (v) increased energy security as the time-line for reserves is lengthened.

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