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Deadweight Loss under Market Power and Environmental Inefficiency in an Imperfect Competition: Iran's Energy-Intensive Industries Case

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Abstract

Monopoly and negative externalities are two aspects of market failure that affect the market performance. This study extends the Leibenstein approach, a framework to measure the market performance, which evaluates the social welfare costs of market power and environmental inefficiency. To assess the deadweight loss, we capture pollution impacts, on the market performance in an imperfect competition. In doing so, we assess marginal costs and price elasticity of demand by a Translog function, market power by Herfindahl-Hirschman and Lerner indices, and environmental inefficiency by directional distance functions, at a Cournot competition for Iran's energy-intensive industries at the four-digit ISIC level. Our results demonstrate that the social welfare costs of welfare triangle and economic rent are negligible and include a small amount of welfare costs. Non-ferrous foundry imposes the lowest social cost (1.03% of its production value), and cement, lime and gypsum industries impose the highest social cost (50.7% of their production value). Those industries with more market power pay less attention to the environment. In polluting industries, welfare loss, due to market power, is relatively negligible. However, relatively high cost of social welfare, due to environmental inefficiency, indicates the necessity of levying a green tax to reduce the adverse effects.

Highlights

- For the majority of the industries, welfare loss, is relatively high due to environmental inefficiency.
- In comparison with their production values, welfare loss is relatively negligible due to mark up.
- Those strategies related to monopolist incentives are prior to strategies related to reducing mark-up.
- In an incomplete competitive environment, a pollution control policy probably brings more benefits than a price ceiling policy.

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1. Introduction

Market performance is a key concept that evinces business performance and the effectiveness of producers in a marketplace. It encompasses productive and distributive efficiencies, equitable prices, product performance and technological progressiveness. Market performance is evaluated through various indices such as concentration (e.g., Herfindahl-Hirschman Index), efficiency (e.g., allocative efficiency), diversification (e.g., revenue diversification), justice (e.g., poverty indices) and security (e.g., food security indices).

Market failure influences the performance of the markets. Due to irrational behaviors, immobility, asymmetric information, distributional inequality, externalities, incomplete markets, high concentration, barriers to entry, monopolies and cartels, economies of scale and public goods, free market will no longer be Pareto optimal, that is, the optimal allocation of resources will no longer occur, leaving welfare costs on society.

Two important aspects of market failure that affect market performance are *incomplete markets* and *externalities*.

As Rezitis and Kalantzi (2012) mentioned, *incomplete markets* are of the main disturbances of market performance, in which optimal behavior of producers is in accordance with maximizing individual profit and not social welfare. Aside from standing in a safe margin in comparison with competition markets, market power allows monopolists to increase the prices which results in deadweight loss and thereupon lackluster market performance.

In these markets, the supplier has high pricing power; the production is lower, and the prices are higher. The supply is adjusted in such a way that the monopolist gets the most profit. In a monopoly market structure, the greater the market power, the greater the gap between marginal revenue and marginal cost, leading to greater welfare cost.

Externalities are the next aspect of market failure, occurring when the activities of a firm or individual directly have a negative or positive effect on others, without receiving or paying for it. Such an activity does not take into account the costs or benefits of its activity in its calculations. The consequences of negative externalities on health and environment are usually incontrovertible.

Inspired by Hotelling (1938), Harberger (1954) introduced the welfare triangle concept to measure the deadweight loss of market power, a framework to appraise the market performance. Thereafter, to assess the adverse effects of monopoly structure, a trend of studies has been employed, to criticize and modify this approach[1]. In total, state-of-the-art approach shows that power market has a

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[1] The following papers are remarkable among the mainstream research: Stigler, 1956; Schwartzman, 1960; Kamerschen, 1966; Leibenstein, 1966; Comanor & Leibenstein, 1969; Shepherd, 1972; Worcester, 1973; Posner, 1975; Cowling & Mueller, 1978, 1981; Littlechild, 1981; Jenny & Weber 1983; Masson & Shaanan, 1984; Gisser, 1986; Scherer & Ross 1990; Ellingsen, 1991; Harberger, 1995; Berger & Hannan, 1998; Hines, 1999; Guevara & Maudos, 2004; Yoon, 2004; Lise, et al., 2006; Maudos & Guevara, 2007; Chang, 2007; Ariss, 2010; Twomey & Neuhoff 2010; Kutlu & Sickles, 2012; Garza-García, 2012; Hermalin & Katz, 2013; Shahiki Tash , et al., 2013; Anshelevich & Sekar, 2015; Czerny, et al., 2016; Khan, et al., 2017; Boateng et al. 2018; Manuela et al., 2019.

direct relationship with deadweight loss, and less intervene of governments in the market mechanism has been indicated. However, given different aspects of the applied method, there are conflicts in the literature about the magnitude of loss welfare, so that some conclude the adverse effects are remarkable and some believe it is negligible (Yoon, et al, 2014). Another striking point is that the environmental aspect of market performance is neglected. Maximum energy use occurs in these activities (Yoon, et al, 2014; Goldthau & Sitter, 2019), which results in pollution concentration and climate change (in the long-run), and accordingly recognized as two crises of the twenty-first century (Zhang et al., 2011; Bhuiyan et al., 2018). Given the population growth, energy consumption will be even greater over time (Nejat et al, 2015; Wang & Fang, 2018). That is, not considering the externalities, due to environmental pollution of production activities in evaluating market performance, may lead to inaccurate results. There is another stream which assesses the social cost of pollution, but not simultaneously the adverse effects of monopoly structure[2].

In this sense, the present study investigates the performance of markets in the presence of market power and negative externalities. For this purpose, we apply an adjusted Liebenstein approach, a framework that measures the welfare losses caused by market power in the present of pollution.

Our case is Iran's manufacturers of *basic metals* and *other non-metallic mineral products* at the four-digit ISIC level, with maximum energy consumption over 2003-2014[3]. In doing so, we adjusted so-called Leibenstein model by considering environmental inefficiency in the component of *x-inefficiency*. Therefore, to calculate the welfare losses due to the market performance, aside from considering welfare costs due to welfare triangle and inefficient use of production resources, inefficiencies in energy consumption are also considered.

The rest of the paper is organized as follows: Methodology is presented in part 2. In part 3, data are analyzed and related indices are calculated. Welfare loss is assessed in section 4. The two last parts are devoted to discussion and conclusion.

2. Methodology

In the framework of adjusted Leibenstein approach, we need four inputs to calculate deadweight loss. First, we specify a Translog function to estimate marginal costs. Next, using directional distance functions, the environmental efficiencies are calculated. Then, Herfindahl-Hirschman and Lerner indices are assessed. Next, we estimate the price elasticity of demand. Finally, using a proved relation, social welfare costs are computed (see Figure 1).

[2] See the following papers:
Clarkson & Deyes, 2002; Pearce, 2003; Ando, 2010; Zhou, et al. 2012; Nordhaus, 2014; Maragkogianni & Papaefthimiou, 2015; Fan, 2020.

[3] 22.8% of energy use in industry has occurred in the process of basic metals production and 28.5% in non-metallic mineral products (Statistical Center of Iran, 2014).

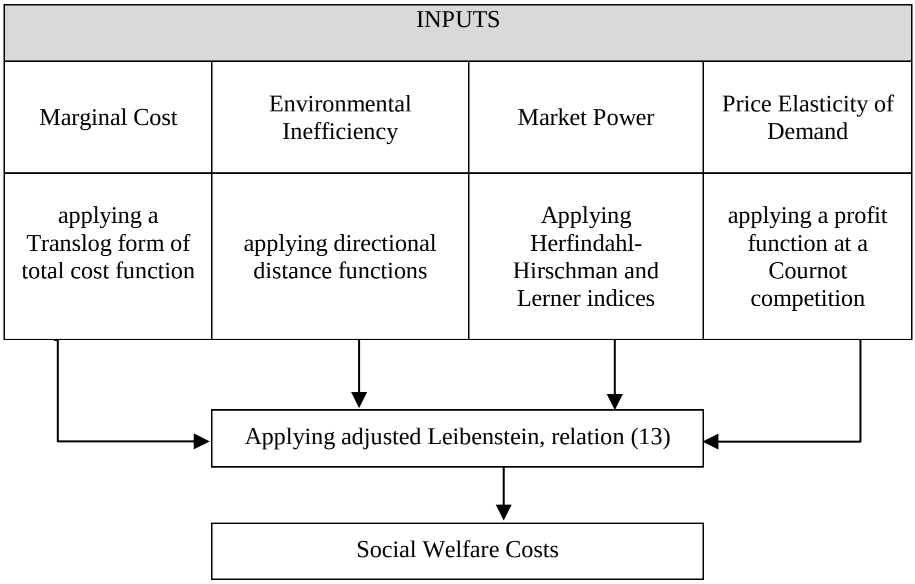

Figure 1. Flowchart of deadweight loss calculation in the presence of market power and pollution

Source*: Authors' framework based on the literature review*

Leibenstein believes there is a positive relationship between the firm size and the welfare loss. As Leibenstein illustrates in a simple example (*Figure 2*), shifting from monopoly to competition has two possible effects: the gradual reduction of price due to a decrease in economic rent *("a" in Figure 2)*; and the gradual reduction of cost due to a decrease in production inefficiency (*"x" in Figure 2*). We define W_a as the partial welfare loss due to the inefficiency of monopoly structure named *allocative-inefficiency* (the area of ABC triangle in *Figure 2*), W_x as the partial welfare loss due to the inefficiency in using resources within the firm that causes a rise in *average cost* name d*x-inefficiency* (the area of C_mC_cDB rectangle*)*, and W_{ax} as the total welfare loss due to both production *x-inefficiency* and *economic rent* (the area of *ADE* triangle).

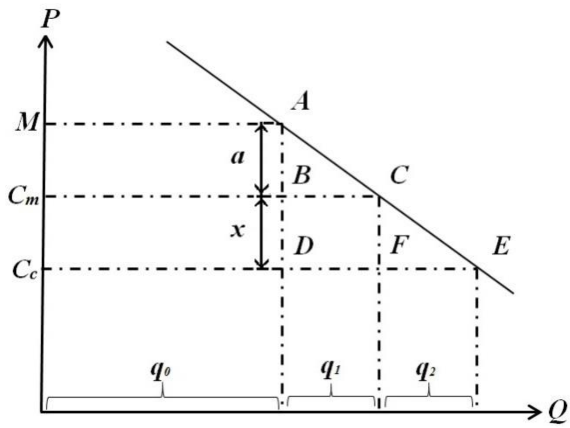

Figure 2. Deadweight welfare loss

***Source**: Comanor & Leibenstein, 1969; Sun et al., 2017*

Assume that there is only inefficiency due to the rise in market price $(W_x = 0, W_a \neq 0)$, the welfare loss is obtained from the ABC triangle, which is the Herberger's idea to calculate the welfare loss of market power:

$$S_j(ABC) = \frac{1}{2} dp_j \times dq_j \tag{1}$$

Where, S_j shows the triangle area of ABC ; p_j and q_j are the price and quantity of good j.

Let $t_j = \dfrac{dp_j}{p_j}$, and the price elasticity of demand of good j as η_j. Then, we can calculate W_a as follows:

$$dp_j = t_j p_j, dp_j = q_j \eta_j t_j \tag{2}$$

$$W_a = S_j(ABC) = \frac{1}{2} p_j q_j \eta_j t_j{}^2 \tag{3}$$

$$W_a = S_j(ABC) = \frac{1}{2} dp_j dq_j = \frac{1}{2} R_j \eta_j \left(\frac{p - C_m}{p} \right)^2 \tag{4}$$

However, Leibenstein believes that social cost of an industry's performance is beyond the welfare triangle, equivalent to the area of $ADE + C_m C_c BD$:

$$S_j(ADE) + S_j(C_m C_c BD) = W_{ax} + W_x = \frac{1}{2}(a + x)(q_1 + q_2) + x q_0 \tag{5}$$

Where, W_{ax} is the comprehensive index of allocative inefficiency equivalent to the area of the ADE triangle. Furthermore, W_x is the welfare cost due to x-inefficiency in the absence of allocative inefficiency. a and x are defined as Figure 2. W_{ax} is calculated as the following:

$$W_{ax} = \frac{\left(dp \times dq\right)}{2} = \frac{(a+x)(q_1+q_2)}{2} \tag{6}$$

Let again $t_j = \frac{dp_j}{p_j}$, and the price elasticity of demand of good j as η_j:

$$dp_j = q_j \eta_j t_j \tag{7}$$

$$(x+a) = dp_j = t_j p_j \tag{8}$$

$$W_{ax} = \frac{1}{2} p_j q_j \eta_j t_j^{\ 2} \tag{9}$$

$$S_j(ADE) = \frac{1}{2} qp\eta \left(\frac{a+x}{p}\right)^2 = \frac{1}{2} qp\eta \left(\frac{(p-C_m)+x}{p}\right)^2, a = p - C_m \tag{10}$$

W_x is calculated as follows:

$$W_x = q_0 \times x \tag{11}$$

In practice, we can also evaluate "x" as follows:

$$x = 1 - \frac{\hat{u}_c^{\min}}{\hat{u}_c^{b}} \tag{12}$$

Where, $\hat{u}_c^{\min}$ is the industry with the minimum inefficiency, and $\hat{u}_c^{b}$ is the inefficiency of other industries.

Almost all industries produce pollution along with producing production, as Gutiérrez (2008) proves, an economy would be more dynamically inefficient in the presence of pollution which indicates the necessity of taking into account the environmental effects of pollutant activities in assessing market performance. That is, total welfare cost (W_{total}) can be obtained as follows:

$$W_{total} = W_{ax} + W_x = \frac{1}{2} R_j \eta_j \left(\frac{(p_j - mc_j) + \left(1 - \frac{\hat{u}_{Min}^{Env}}{\hat{u}_j^{Env}}\right)}{p} \right)^2 + \left(q_{0i} \times \left(1 - \frac{\hat{u}_{\min}^{Env}}{\hat{u}_j^{Env}}\right)\right) \tag{13}$$

Where,

R_j : Revenue of jth industry,

η_j : Price elasticity of demand of *j*th industry,

p_j : Price of *j*th industry,

mc_j : Marginal cost of *j*th industry,

$\hat{u}_{\min}^{Env}$: Minimum environmental inefficiency,

$\hat{u}_j^{Env}$: Environmental inefficiency of *j*th industry.

3. Empirical Results

Here, we focus on energy-intensive industries including *basic metals* and *other non-mineral products.* After *Food & Beverage* industries, the group of *non-metallic mineral products* has the second rank. More than 23% of the employees work at *basic metals* and *non-metallic mineral products.* The product value of *basic metals* equals 74994 Billion Rial, which has the second place in production industries. The data required for this study are collected from two sources: the Ministry of Energy, and the Statistical Center of Iran include: energy balance sheet, total cost, production, capital stock, raw material, labor and energy of industrial workshop manufacturers with 10 workers or more than 10 workers over 1997-2014[4].

The social costs imposed by NO_x, SO_2, CO, SMP, CO_2 and CH_4, emitted by energy-extensive industries, are extracted and shown in Table *1*. To evaluate the environmental inefficiency, we need the number of polluting factors. Industrial energy consumption of selected industries (gasoline, kerosene, gas oil, fuel oil, liquid gas, natural gas) is also extracted and shown in Table 2.

Table 1. The social costs of energy sector separated by pollutant gas (thousand Rial/ Ton)

Gas type	*NO_x*	*SO_2*	*CO*	*SPM*	*CO_2*	*CH_4*
Cost	*4800*	*14600*	*1500*	*34400*	*80*	*1680*

Source: *Iran Energy balance, 2014*

Table 2. Pollutant gas emission in industrial sector (Ton)

Fuel/gas type	*NO_x*	*SO_2*	*CO*	*SPM*	*CO_2*	*CH_4*
Gasoline	*719*	*80*	*18652*	*69*	*126783*	*5*
Kerosene	*14*	*230*	*75*	*0*	*249955*	*10*
gas oil	*15514*	*48715*	*621*	*4654*	*8742882*	*354*
fuel oil	*62647*	*294034*	*23*	*6265*	*20229656*	*784*
liquid gas	*534*	*2*	*354*	*0*	*816787*	*13*
natural gas	*76603*	*157*	*3043*	*6443*	*48383622*	*862*

Source: *Iran Energy Balance, 2014*

[4] We will provide our data set to researchers interested in replicating our work.

Given the ISIC codes, we have listed 14 energy-intensive industries in Tables 3 and 4. 23% of production value and 53% of energy use value of the industry is devoted to these groups.

Table 3. Selected industries of subgroup of code 26, separated based on ISIC 4-digit codes

ISIC codes	Industry	Number of firms
26	Non-metallic mineral products	
2691	Non-constructional, non-refractory ceramic products	75
2692	Refractory ceramic products	28
2694	Cement, lime and plaster	157
2695	Materials made from concrete, cement and plaster	399
2696	Cutting, shaping & completingthe stone	385
2697	Manufacture of brick	642
2698	Non- refractory fictile and ceramic constructional products	99
2699	Other non-metallic mineral products n.e.c. (manufacture of asphalt)	394

Source: Statistical Center of Iran, 2014

Table 4. Selected industries of subgroup of code 27, separated based on ISIC 4-digit codes

ISIC code	Industry	Number of firms
27	Basic metals	563
2710	Basic iron and steel	210
2721	Basic copper products	19
2722	Basic aluminum products	82
2723	Precious metals and other basic products- except iron, steel, copper & aluminum	55
2731	Foundry of iron and steel	156
2732	Foundry of non-ferrous metals	41

Source: Statistical Center of Iran, 2014

3.1 Marginal Cost Calculation

The first step in measuring social cost is to calculate the marginal cost of production in all industries. In doing so, we need to estimate the total cost function. In order to estimate the total cost function, we employ an equation system including a main Translog cost function along with the functions of demand portion of production factors limited by homogeneity and symmetry constraints. We apply an Iterative Seemingly Unrelated Regression (ISUR) to estimate the parameters of Equation (14) (Zellner, 1962):

$$LnC = \alpha_0 + \alpha_q LnQ + \frac{1}{2}\alpha_{qq}(LnQ)^2 + \sum_{i=1}^{n}\alpha_i Lnp_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij} LnP_i LnP_j + \sum_{i=1}^{n}\gamma_{qi} LnQ \ln P_i + U \quad (14)$$

$$S_i = \frac{\partial LnC}{\partial LnP_i} = \alpha_i + \sum_{j=1}^{n} \beta_{ij} LnP_j + \beta_{iq} LnQ$$

$$\sum_{j=1}^{n} \alpha_i = 1, \sum_{j=1}^{n} \gamma_{iq} = 0, \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} = \sum_{i=1}^{n} \beta_{ij} = \sum_{j=1}^{n} \beta_{ji} = 0$$ *Homogeneity condition*

$$\beta_{ji} = \beta_{ij}$$ *Symmetry condition*

Where,
C: Total cost of the firm,
Q: Total production
S_i: Demand portion of input ith
P_i: the price of input ith

Total cost of the firm is a function of production and input price of labor, energy, raw material and firm's capital inventory.

After obtaining the parameters of Equation (14), we can calculate the marginal cost based on Equation (15):

$$MC = \frac{TC}{Q} \times \frac{\partial LnTC}{\partial LNQ} \tag{15}$$

Where, MC shows the marginal cost, TC is the total cost, and Q indicates production quantities. Tables 5 and 6 show the estimated coefficients of total and marginal cost functions of Iran's energy-intensive industries.

Table 5. Total cost function parameters (Iran's selected energy intensive industries)

$$LnC = \alpha_0 + \alpha_q LnQ + \frac{1}{2}\alpha_{qq}(LnQ)^2 + \alpha_m Lnp_{mt} + \alpha_{wt} Lnp_w + \alpha_e Lnp_e + \alpha_k Lnp_k + \frac{1}{2}\beta_{mm} LnP_m LnP_m +$$
$$\frac{1}{2}\beta_{mw} LnP_m LnP_w + \frac{1}{2}\beta_{me} LnP_m LnP_e + \frac{1}{2}\beta_{mk} LnP_m LnP_k + \frac{1}{2}\beta_{ww} LnP_w LnP_w \frac{1}{2}\beta_{we} LnP_w LnP_e \frac{1}{2}\beta_{kw} LnP_w LnP_k +$$
$$\frac{1}{2}\beta_{ee} LnP_e LnP_e + \frac{1}{2}\beta_{ek} LnP_e LnP_k + \frac{1}{2}\beta_{kk} LnP_k LnP_k + \gamma_{qm} LnQLnP_m + \gamma_{qw} LnQLnP_w + \gamma_{qe} LnQLnP_e + \gamma_{qk} LnQLnP_k + u$$

Parameter	*Coefficient*	*Prob*	*Parameter*	*Coefficient*	*Prob*
α_0	*-1.25721*	*0.5704*	β_{ww}	*0.22805*	·
α_q	*0.182561*	·	β_{we}	*-0.01782*	*0.0189*
α_{qq}	*-0.00635*	*0.2661*	β_{wk}	*-0.00152*	*0.5102*

Table 5(Continued). Total cost function parameters (Iran's selected energy intensive industries)

Parameter	Coefficient	Prob	Parameter	Coefficient	Prob
α_m	0.369912	0.1446	β_{ee}	0.120368	٠
α_w	0.755678	٠	β_{ek}	0.001109	0.6025
α_e	0.34557	0.0037	β_{kk}	-0.00156	0.1169
α_k	0.010251	0.7861	γ_{qm}	0.009496	0.2985
β_{mm}	0.374498	٠	γ_{qw}	-0.00529	0.3653
β_{mw}	-0.2314	0	γ_{qe}	0.001475	0.7323
β_{me}	-0.03688	0.0098	γ_{qk}	-0.00097	0.4753
β_{mk}	0.001369	0.8183			

$$MC = \frac{C}{Q} \times (1.182561 - 0.00635Q + 0.009496LnP_m - 0.00529LnP_w + 0.001475LnP_e - 0.00097LnP_k)$$

Source: *Research finding*

Table 6. Marginal costs parameters in Iran's selected energy intensive industries

Four-digit codes of ISIC	Industry	Marginal cost (MC)
2691	Non-constructional, non-refractory ceramic products	0.709
2692	Refractory ceramic products	0.893
2694	Cement, lime and plaster	0.465
2695	Materials made from concrete, cement and plaster	0.692
2696	Cutting, shaping &completing the stone	0.731
2697	Manufacture of brick	0.576
2698	Non- refractory fictile and ceramic constructional products	0.637
2699	Other non-metallic mineral products n.e.c. (manufacture of asphalt)	0.706
2710	Basic iron and steel	0.696
2721	Basic copper products	0.636
2722	Basic aluminum products	0.808
2723	Precious metals and other basic products- except iron, steel, copper & aluminum	0.672
2731	Foundry of iron and steel	0.741
2732	Foundry of non-ferrous metals	0.892

Source*: Research finding*

According to Table 6, “Cement, lime and plaster” (code 2694) and “refractory ceramic products –heat insulators” (code 2692) industries have the lowest and highest marginal costs, respectively.

3.2 Measuring Environmental Inefficiency

To measure environmental inefficiency, we use an output directional distance function. Chung et al. (1997) introduced directional distance output function. In these functions, it is possible to reduce undesired output and increase desired output simultaneously (Yu et al., 2017; Oliveira et al., 2017; Wang et al., 2019). The directional vector is shown as $g=(g_v,-g_u)$. Function "g" is defined as a directional distance function, assumed a firm projected on the efficient frontier (i.e., production possibility set) (Yaqubi et al., 2016). Using an output directional distance function, the firm’s environmental inefficiency, k', is modeled as Equation (16) (See Figure 3):

$$D(x^{k'},v^{k'},u^{k'};g)=\max\beta$$
$$s.t.(v^{k'}+\beta g_v,u^{k'}-\beta g_u)\in P(x) \qquad (16)$$

Where, $D(.)$ is a directional distance function, x shows input vector, v indicates desirable output vector, and u shows pollution or undesirable output vector, respectively.

This mathematical programming can give us environmental efficiency scores, needed to assess the deadweight loss of industries.

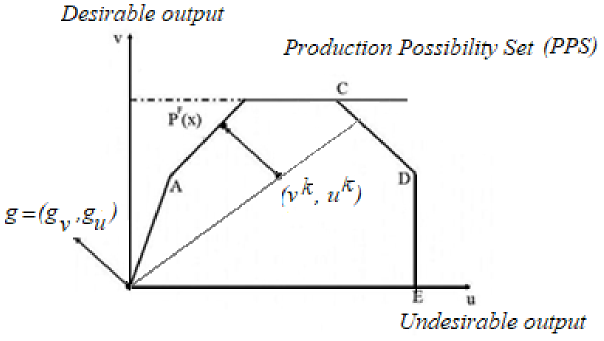

Figure 3. A directional output distance function
Source: *Yaqubi, et al., 2016*

We can use linear programming to solve Equation (16):

$$D(x^{k'},v^{k'},u^{k'};g)=max\,\beta \qquad (17)$$
$$\sum_{k=1}^{K}\omega_k u_{kj}=u_{k'j}-\beta g_{uj}, j=1,\dots,J$$

$$\sum_{k=1}^{K} \omega_k x_{kn} \leq x_{k'n}, n = 1, \dots, N$$

$$\sum_{k=1}^{K} \omega_k = 1$$

$$\omega_k \geq 0, k = 1, \dots, K$$

Where, x specifies the input vector; v indicates desirable output vector; u denotes undesirable outputs; g shows the exogenous vector of (-1,1), so that ($g_v = 1$) and ($-g_u = 1$); ω is the intensity variable. First constraint describes the strong disposability property of desirable output, while the second one represents the weak disposability property of undesirable outputs. The third constraint introduces strong disposability property of inputs. The last constraint points out the convex combination among the selected industries.

If $D(x^{k'}, v^{k'}, u^{k'}; g) = 0$, the industry operates efficiently, in case of $D(x^{k'}, v^{k'}, u^{k'}; g) > 0$ industry's operation is environmentally inefficient. The environmental efficiency scores are obtained from Equation (18) (Chung et al., 1997; Shahabinejad et al., 2013):

$$D(x, v, u) = \frac{١}{\left(١ + D(x^{k'}, v^{k'}, u^{k'}; g)\right)} \tag{18}$$

We use an *R* package (Team, 2013), to calculate the environmental efficiency of selected industries. The results are reported in Table 7:

Table 7. Iran's Energy-intensive industries inefficiency scores

Four-digit codes of ISIC	*Industry*	*Inefficiency level*
2691	*Non-constructional, non-refractory ceramic products*	*0.69*
2692	*Refractory ceramic products*	*0.38*
2694	*Cement, lime and plaster*	*0.94*
2695	*Materials made from concrete, cement and plaster*	*0.15*
2696	*Cutting, shaping &completing the stone*	*0.22*
2697	*Manufacture of brick*	*0.98*
2698	*Non- refractory fictile and ceramic constructional products*	*0.54*
2699	*Other non-metallic mineral products N.E.C. (manufacture of asphalt)*	*0.77*
2710	*Basic iron and steel*	*0.34*
2721	*Basic copper products*	*0*
2722	*Basic aluminum products*	*0*

Table 7(Continued). Iran's Energy-intensive industries inefficiency scores

Four-digit codes of ISIC	*Industry*	*Inefficiency level*
2723	*Precious metals and other basic products- except iron, steel, copper & aluminum*	*0.20*
2731	*Foundry of iron and steel*	*0.15*
2732	*Foundry of non-ferrous metals*	*0*

***Source**: Research finding*

As shown in Table 7, “Basic copper products” (code 2721), “Basic aluminum products” (code 2722) and “Casting of non-ferrous metals” (code 2732) industries have the lowest; and “brick”, “Cement, lime and plaster” manufacturing industries have the highest environmental inefficiency.

3.3 Measuring the Price Elasticity of Demand

In the majority of previous studies, elasticity of demand for all industries is considered 1; while it means marginal income is zero which, in turn, causes bias in the welfare cost results. In monopolistic, oligopoly, and monopolistic competition market structures, firms are expected to get a price higher than marginal cost of production (MC) through market power (See Figure 4):

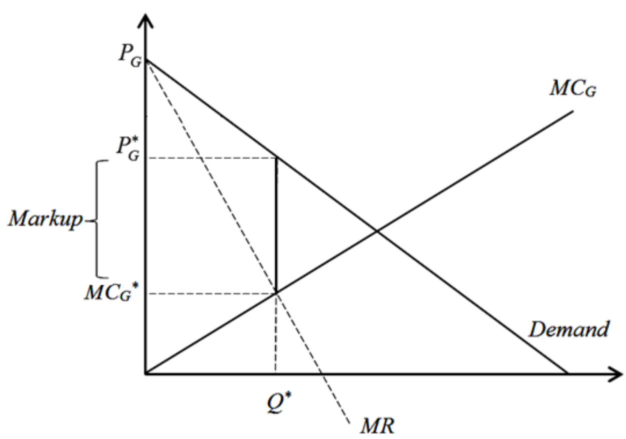

Figure 4. The gap between price and marginal cost (MC)
***Source:** Shahiki Tash et al, 2013*

To describe the industry structure, we use a Cournot competition pattern. It is proved that the profit function of a Cournot model can be written as Equation (19) (Varian, 2006):

$$\pi_i = p_G(q_i + Q_{-i})Q_i - TC_i \tag{19}$$

Where, π_i is profit of firm *i*, P_G is the price of firm *i*, Q_{-i} is the product quantity of all active firms in the market (except firm *i*), *Q* is the total production in the market, and TC_i is total costs of the firm *i*. Since all firms are assumed to have similar cost structure, subscript *i* could be dropped; then maximizing profit function gives us $MC = MR$ from first order condition, which is as Equation (20) for *n* firms:

$$p_G(Q) + Qp'_G(Q)\frac{q}{Q} = MC_G \tag{20}$$

Using Equation (20), Lernerindex, known as Price-Cost Margin (PCM) approach, is obtained as Equation (21) (Lerner, 1934):

$$L_H = \frac{P_G - MC_G}{P_G} = \frac{S}{\eta} \tag{21}$$

Where, L_H is the Lerner index, MC_G is firm's marginal cost of production, *S* is the market portion of firm and, η is the price elasticity of demand equal to $\eta = -\frac{\partial Q}{\partial P} \times \frac{P}{Q}$.

Since, cost structure and market share structure of all firms are assumed to be equal to $\left(S_i = \frac{1}{n}\right)$, the Herfindahl-Hirschman Index (HHI) is calculated as Equation (22):

$$H = \sum_{i=1}^{n} S_i^2 = \frac{n}{n^2} = \frac{1}{n} = S \tag{22}$$

Using (21) and (22), Lerner index is rewritten as Equation (23):

$$L_H = \frac{H}{\eta} = \frac{P_G - MC_G}{P_G} \tag{23}$$

We can calculate the price elasticity of demand as Equation (24):

$$\eta = \frac{1}{\left(\frac{p - MC}{P}\right)} H = \frac{1}{\left(\frac{p - MC}{P}\right)} \left(\sum S_i^2\right) \tag{24}$$

Our results are reported in Table 8:

Table 8. HHI index and price elasticity of demand for Iran's energy-incentive industries

4-digit codes of ISIC	*Industry*	*Herfindahl-Hirschman Index (HHI)*	*Absolute value of industry's elasticity (η)*
2691	*Non-constructional, non-refractory ceramic products*	0.0405	0.1462
2692	*Refractory ceramic products*	0.1628	0.3735
2694	*Cement, lime and plaster*	0.0296	0.0434
2695	*Materials made from concrete, cement and plaster*	0.0103	0.0368
2696	*Cutting, shaping &completing the stone*	0.0061	0.0177
2697	*Manufacture of brick*	0.0033	0.0059
2698	*Non- refractory fictile and ceramic constructional products*	0.0258	0.0679
2699	*Other non-metallic mineral products n.e.c. (manufacture of asphalt)*	0.0084	0.0235
2710	*Basic iron and steel*	0.1147	0.4278
2721	*Basic copper products*	0.5195	1.2024
2722	*Basic aluminum products*	0.1959	0.7622
2723	*Precious metals and other basic products- except iron, steel, copper & aluminum*	0.0759	0.3231
2731	*Foundry of iron and steel*	0.0622	0.2814
2732	*Foundry of non-ferrous metals*	0.2837	1.3770

***Source**: Research finding*

As shown in Table 8, *basic copper products*, *foundry of non-ferrous metals* and *basic aluminum products* have the highest share, whereas *manufacture of brick*, cutting, *shaping & completing the stone* and also *other non-metallic mineral products* have the lowest concentration in Iran's energy-intensive industries.

"non-ferrous metals foundry" industries (code 2732) with the price elasticity of 1.377 and "basic copper products" industries (code 2721) with the price elasticity of 1.20 are the most elastic industries, "brick manufacturing" (code 2697) with the price elasticity of 0.0059 and "cutting, shaping &completing stones" (code 2696) industries with the price elasticity of 0.017 are the the most inelastic industries among selected (energy-intensive) industries.

3.4 A Comparison Between Market Power and Environmental Inefficiency

Relying on the price-cost margin approach, based on Equation (23), in Table 9, Lerner indices for Iran's energy-incentive industries are calculated.

Table 9. Market power and environmental inefficiencies of Iran's energy-incentive industries

4-digit codes of ISIC	Industry	Lerner index	environmental inefficiency
2691	*Non-constructional, non-refractory ceramic products*	0.2770	0.69
2692	*Refractory ceramic products*	0.4359	0.38
2694	*Cement, lime and plaster*	0.6820	0.94
2695	*Materials made from concrete, cement and plaster*	0.2799	0.15
2696	*Cutting, shaping &completing the stone*	0.3446	0.22
2697	*Manufacture of brick*	0.5593	0.98
2698	*Non- refractory fictile and ceramic constructional products*	0.3800	0.54
2699	*Other non-metallic mineral products N.E.C. (manufacture of asphalt)*	0.3574	0.77
2710	*Basic iron and steel*	0.2681	0.34
2721	*Basic copper products*	0.4321	0
2722	*Basic aluminum products*	0.2570	0
2723	*Precious metals and other basic products- except iron, steel, copper & aluminum*	0.2349	0.2
2731	*Foundry of iron and steel*	0.2210	0.15
2732	*Foundry of non-ferrous metals*	0.2060	0

***Source**: Research finding*

As shown in Table 9, industries of *cement, lime & plaster*, *manufacture of brick* and *refractory ceramic products* have the highest monopoly power, respectively. However, *foundry of non-ferrous metals*, *foundry of iron and steel*, *precious metals and other basic products- except iron, steel, copper & aluminum* industries impose the lowest market power.

Furthermore, the correlation between market power and environmental inefficiency is 0.692, i.e. the higher the market power, the lower the environmental performance. That is, those industries with more market power pay less attention to the environment. In other word, wherever there is little government oversight on the activities, incompatible with public welfare e.g., less developed countries, producers maximize their profits through polluting the environment and impose monopoly power.

4. Deadweight Loss

Finally, we can calculate the welfare costs of environmental pollution in energy-intensive industries using Equation (13). The results are reported in Table 10.

Table 10. Social welfare costs of environmental pollution and welfare triangle for selected industries

Four-digit codes of ISIC	Leibesnstein's environmental welfare costs (million Rials)	Welfare costs due to environmental x-inefficiency (million Rials)	Welfare costs caused by welfare triangle or economic rent (million Rials)	The percentage of welfare costs from the production value using environmental Leibenstein method	The percentage of welfare triangle costs from the production value
2691	843134	775739	11508	44.57	0.0061
2692	289131	248593	7805	28.89	0.0078
2694	8251034	7885731	100368	50.70	0.0062
2695	839957	819526	9752	13.51	0.0016
2696	387783	384463	1061	19.13	0.0005
2697	1415785	1408769	1475	49.98	0.0005
2698	3076478	2934062	35840	37.41	0.0044
2699	2091671	2059796	5779	42.86	0.0012
2710	37845405	29755504	2476615	31.91	0.0209
2721	1609781	0	1609781	7.35	0.0735
2722	128316	0	128316	1.36	0.0136
2723	870573	697248	78716	20.22	0.0183
2731	651963	550796	47413	15.02	0.0109
2732	9623	0	9623	1.03	0.0103

***Source**: Research finding*

As reported in Table 10, compared to costs caused by environmental x-inefficiency, the social welfare costs of welfare triangle and economic rent are negligible and include a small amount of welfare costs. "non-ferrous metals" (code 2732), "basic aluminum products" (code 2722) and "basic copper products" (code 2721) industries with welfare costs of 9623, 128316 and 1609781 million RLS, respectively, have the lowest social welfare costs compared to their production value (less than 10% of production value); and this is due to their environmental efficiency. However, if welfare triangle is considered as the criterion (Harberger suggestion), then costs arisen by rent of "cutting, shaping & completing stone" (code 2696) and "brick manufacturing" (code 2697) industries will be lower than others.

Furthermore, "cement, lime and plaster" (code 2694), "brick manufacturing" (code 2697), "non-structural, non-refractory ceramic products" (code 2691) and "asphalt manufacturing" (code 2699) industries with the cost 50.7%, 49.98%, 44.57%, and 42.86 % of their production value respectively, have the highest welfare costs.

5. Discussion

In the process of industrialization, paying no attention to market performance and environmental conditions, imposes social costs which endanger sustainable development and has adverse impacts on long-run benefits of industrial activities through environmental degradation (pollution) and market concentration (market power or monopoly). How policy makers take an appropriate reaction to market performance and monopoly structures of energy-intensive activities, highly depends on the awareness of welfare loss quantities. In this sense, we assessed social welfare costs due to monopoly structures in energy-intensive industries by extending the so-called Leibenstein approach. The results showed that welfare loss due to welfare triangle (i.e., *mark up* or increasing the prices of production as a result of incomplete competition) is in accordance with the previous studies, that is, imposed costs are negligible in comparison with their production values. As an example, in subgroup of "cement, lime and plaster", the ratio is about 0.6%. However, the welfare loss due to *x-inefficiency*, which involves not optimal using factor production along with environmental considerations, is relatively high. We found out the main factor of lackluster performance of market structure of industrial activities, with regard to environmental issues, origins from reducing incentives in efficient use of available resources. In other words, as we implicitly considered the pollution through environmental inefficiencies, a researcher should take it into account in the process of market power assessment. Unlike the results of previous studies, welfare loss due to *x-efficiency* (which involves environmental performance) is relatively high for the majority of the industries. For example, given the lack of pollution control systems e.g., green taxes, and being in a safe margin, industries of "cement, lime and plaster" impose about 196.5 million Dollars (8251034 Million Rials) to Iran society. That means levying a proper pollution tax along with an appropriate strategy to break the monopoly structure brought about 196.5 Million Dollars. This is almost true for other industries.

6. Concluding Remarks and Policy Implications

Energy-intensive industries have adverse effects on environment. Our results indicated that the production of *basic metals* and *other non-metallic mineral* *products* have led to the highest levels of consumption and thus the highest emission. By capturing the pollution impacts in terms of environmental inefficiency, we revealed that the intensity of inefficiency in non-competitive markets is higher than the so-called Leibenstein Triangle.

What is the implication of these results? First, it is necessary to capture the pollution externalities through considering environmental inefficiency *in x-inefficiency* component. Applying environmental inefficiencies instead of allocative inefficiencies, increases calculated social costs considerably which indicate not capturing the pollution effects may lead to misleading results. This is specifically important, because in the process of economic and population growth, increasing production would result in increasing pollution. Second, in policy making with the goal of declining welfare loss, those strategies which are related to monopolist incentives are prior to those strategies which are related to reducing *mark-up* (Figure 3). That is, in an incomplete competitive environment, a pollution control policy probably brought more benefits than a price ceiling policy. In this regard, Hu et al., (2014), Xu et al., (2016) and Geng et al., (2017) provide useful policy insights into balanced social welfare and emissions, and Zhou et al., (2018) show that levying an optimal pollution tax rate would reduce the social welfare loss. In the presence of monopoly structure, a green tax pattern is also recommended by Lee (1975), which shows how a pollution tax would be applied, when there is a degree of market power among the polluters.

Nevertheless, we should keep in mind that taking a policy has external effects on other markets, that is, the policy with better results, can be more clearly recommended by general equilibrium models (e.g., CGE and DSG models).

Despite this fact, in calculating social welfare costs, we considered pollution along with market power impacts, we only took into account air pollution in our case study. The sewage of energy-intensive factories can be notable. Another point that should be mentioned is that, although we have to consider a lot of assumptions in modeling of a general equilibrium model, its significant strength is to take the interactions of all markets. This study is categorized as a partial equilibrium model, and ignores such interactivity. With a variety of pollution and monopoly types in the energy-intensive industries, there is no comprehensive study applying such an approach to assess Iran’s social welfare costs, being a suitable context for future research.

The proposed approach can be particularly useful for developing countries, possible to concentrate on the market power. Indeed, taking both market power and environmental inefficiencies in calculating the performance of a market, help us to internalize the externalities through more accurate compensation of the victims.

Finally, considering the diverse market structure of the energy-intensive industries, the answer to the following question can also be a subject of future studies: Which is more optimal to decrease these adverse impacts? A market-based instrument (e.g. *green taxes* or *cap & trade*), or a non-market-based approach (e.g., imposing policies and regulations).

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