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The effect of oil price on factor demands and total factor productivity: energy-intensive manufacturing industries in European countries importing Iranian oil*

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A B S T R A C T

The present study investigates on the impact of oil price on factor demands and total factor productivity of energy-intensive manufacturing industries in 10 European countries importing Iranian oil during 1980-2010. To this end, factor demand system and productivity growth equation were simultaneously estimated by a seemingly unrelated regression equation (SURE) method. Using Delta technique, significance level of converted parameters was examined. It is expected that industries' oil demand will undergo a significant decrease in response to rising oil prices. Cross price elasticity estimates indicated that with rising oil prices, oil demand will be replaced with raw materials in nine countries, capital in eight countries, and labor and other energies in six countries. Mounting oil prices will result in increased total factors productivity and average oil productivity. Estimated rebound effects demonstrated that by implementing energy efficiency policies, consumption of oil and "other energies" will decrease in most countries, due to negative rebound effects, more than what is expected from full realization of the policies.

1. Introduction

Energy is significant factor for its buyers, demanders, and suppliers. Limited energy resources of European countries' limited energy sources make them import the energy they need, and since energy prices are determined by international markets, the impact of increasing energy prices is a critical issue for these countries. "European Energy Strategy" is aimed at both reducing energy dependency and limiting the rising cost of energy.

The policy of reducing energy dependency is accomplished by expanding renewable energy sources and increasing energy efficiency. The purpose of limiting the rising cost of energy is to increase consumers' welfare and firms' competitiveness. Conversely, Europe's Climate

Strategy is aimed at setting a special price for carbon to implement the polluter pays principle and to indicate the real cost of releasing greenhouse gases by burning fossil fuels.

Today, human demand for energy is supplied by oil and gas (more than 70%), coal (15-25%), electricity, and nuclear power (about 10%). Energy required for electricity generation should also be derived from oil, gas, water, or nuclear power. Energies derived from electricity, nuclear, and coal can be usually converted to thermal and mechanical energies. In addition to providing thermal and mechanical energies, oil can be converted to various chemical products and can be used in industrial chemistry, as well.

It is noteworthy that America and Europe alone own 50% of the world's refining capacity, while the percentage drops to less than 8% in the Middle East. Moreover, 160 products can be generated from oil and these products are being sold to oil-producing countries at high prices.

Iran is one of the European countries’ oil suppliers; therefore, as demanders of Iranian oil, manufacturing industries’ reactions in Europe, to changes in oil price are helpful to policy-makers of energy sector in Iran. Furthermore, reactions of European manufacturing industries, as one of the sources of environmental pollution, to oil price (change in oil demand and substitution of oil with other resources) are of paramount importance with respect to global environmental issues.

The present study is aimed at contributing to the literature on energy economics by expanding the model of Roy et al. (1999) through dividing energy into two categories, namely, oil and "other energies" (i.e., electricity, natural gas, and gasoline).

In order to examine the influence of increasing oil price on demand for production factors and total factor productivity of industries, production functions of capital, labor, oil and other energies, and raw materials were considered, and input price of “other energies” was generated through Divisia Index. Using Seemingly Unrelated Regression Equations (SURE), factor demand system and productivity growth equation were simultaneously estimated. Taking technical progress into account, this study affords the opportunity to evaluate inter-factor substitution issues. Additionally, the impact of oil price on total factor productivity and oil productivity was measured.

The following section presents empirical literature on the issue under investigation. Data and methodology are presented in section 3, and section 4 refers to results and discussion. Finally, section 5 concludes the paper.

2. Literature review

As a crucial element, energy has always been considered in production function. Since 1970, with rising energy carriers’ prices, the issue of limited energy resources has come to attention and resulted in significant concentration on energy input in production function. Hence, a great number of studies have investigated energy consumption.

The current research is focused primarily on understanding short-term patterns, particularly on inter-factor and inter-fuel substitutions.

The study conducted by Berndt and Wood (1975) was the first study on the effect of energy and capital on America's economy, which indicated that these two inputs are complementary. After this study, many empirical studies have been done on energy-capital substitution.

Fuss (1977) used Canadian data in industrial sector to show that capital and energy are complementary and confirmed the result obtained by Berndt and Wood (1975).

Griffin and Gregory (1976) employed data of several countries during 1950-1960. Pindyck (1979) collected data from 10 countries (i.e., Canada, France, Italy, Japan, Norway, Sweden, the United States of America, the United Kingdom, Germany, and the Netherlands) during 1963-1973 and demonstrated that energy and capital can be substituted with each other. Literature on capital energy substitution does not show a clear relationship between these two inputs but indicates effective factors in determining the relationship between capital and energy in cross-sectional or time-series studies, totality (Industry-level data) or partiality (firm-level data), and heterogeneity of capital.

With a review of literature on capital energy substitution, Apostolakis (1990) noted that most of the time-series studies indicate that energy and capital are in complementary relationship, while cross-sectional studies suggest that the two inputs are successive in production process. Apostolakis attributed this difference to the fact that time-series studies reflect short-term relations, whereas cross-sectional analyses consider long-term effects.

In recent decades, many methodologies have been developed which are employed to explore changes in productivity and in technological developments. The standard growth accounting approach proposed by Solow (1957) for the first time, and the one suggested by Denison (1974, 1979, & 1985) and other researchers later can be used to study long-term trends in energy consumption and its relation to other economic variables.

Hogan and Jorgenson (1991) measured the relation among productivity growth, bias in technical progress, and long-term impact of carbon reduction policy on American economy. They found that despite being insignificant, these small biases may have adverse consequences for productivity of carbon reduction (relative energy price rising) policies in the long run.

Mongia and Sathaye (1998) reviewed the existing literature on productivity growth and technical changes in energy-intensive industries of India during 1947-1998. The objective of their study was to measure the level of Autonomous Energy Efficiency Improvement (AEEI) parameter in Indian industry.

Productivity growth can be measured using three approaches, that is, index values (Kendrick, Solo, and Translog), parametric approach, and cost function estimation. With regard to existing differences in the literature, they concluded that definite judgment about the nature and the extent of productivity growth in energy-intensive industries of India is difficult since productivity growth for all industries should be estimated using a common methodology and a common data source at the same time period.

Roy et al. (1999) used growth accounting and econometric approaches to analyze productivity growth and input trends in six energy-intensive sectors of Indian economy. Rising energy prices reduces energy demand. Likewise, these policies in India could have negative long-term effects on productivity of these sectors. Inter-factor substitution is so poor that these policies may leave medium-term and short-term negative effects on growth.

Sanstad et al. (2006) estimated energy-augmenting technological change in energy-intensive industries of India and South Korea and compared the result with that of America. To this end, translog function was used. The overall findings of this research indicated a considerable discrepancy among industries and countries and decreasing trend toward energy efficiency in a number of cases. Considering methodology and direct comparison of parameterization assessment, the results are functional technical specifications.

Huntington (2010) investigated the role of technical progress in oil demand of OECD countries. He distinguished the role of exogenous technical progress and technical progress caused by price considering other factors associated with time, which may affect oil demand growth. The results confirm that both sources of technical progress works, but improvements resulted from price are fundamentally more significant.

Arnberg and Biorner (2007) studied Danish firm from 1997-1993 using panel data, translog method and linear logit. Their findings showed complementarity between capital and electricity as well as capital and other fuels.

Koetse et al. (2008) suggested that substitution process is time-consuming so long-term elasticity is always greater than short-term elasticity; thus, supplementary in short-term elasticity can be changed to substitution in long-term elasticity.

Nguyen and Streiw ieser (2008) also maintained that using general data instead of micro data produces biased results. They used US micro data at the firm level and found that energy and capital are substitutes for US firms.

Estimating panel data micro- and macro-level in OECD countries, Fiorito and Van den bergh (2011) also showed complementarity between capital and energy.

Kim and Heo (2013) suggested that considering energy as a homogenous input can lead to a significant bias. They found that capital and fuel are supplements, while capital and electricity are substitutes.

Tovar and Iglesias (2013) divided capital into physical capital and working capital and used industry data to show that both capitals and energy are supplements in the long run; however, this relationship is not significant in the short run.

Haller and Hyland (2014) used Irish firms data from 1991-2009. Panel data indicated that there is substitution between capital and energy. In the empirical literature, the issue of inter-fuel substitution is as old as capital – energy substitution, and perhaps it is more important.

Dasgupta and Roy (2015) extended the model proposed by Roy (1992) to study energy-intensive industries of India and found that, during 1973-2012, these industries experienced technical progress along with a reduced share of energy costs (energy savings). Rising energy prices leads to a reduction in energy demand and accumulated technical progress in most industries. Energy and raw materials are substitutes. Energy productivity growth is the result of energy price as well as technical progress.

In this study, in addition to investigating the effect of technical progress on energy demand, the issue of inter-factor substitution with regard to technical progress has also been considered. Furthermore, in this study, energy input is divided into two inputs, namely, "oil" and "other energies".

3. Data and methodology

This study examined 10 European countries where Iran's oil is imported to including Austria, Belgium, Germany, Italy, France, Portugal, Spain, the Netherlands, Sweden, and the United Kingdom.

The investigated energy-intensive industries consisted of industries manufacturing basic metals (basic iron, steel products, and metal casting), non-metallic mineral products (glass and glass products, non-metallic mineral products not classified elsewhere, non-refractory ceramic products, refractory ceramic products and cement), chemical materials (basic chemicals, other chemical products, and synthetic fibers), and paper and paper products. These are known as energy-intensive industries among manufacturing industries of European countries.

The years from 1980 to 2010 were selected as the study period, because KLEM data were only available till 2010.

The required data were derived from OECD, IEA, and EU KLEMS websites. In the present research, information on all countries' industries was collected over time using a combination of cross-sectional and time-series methodologies (panel data).

3.1. Research methodology

General framework of analysis in this study was based on neoclassical theory of producer behavior which analyzes the reaction of industries to minimizing the cost (Berndt and Wood, 1975; Blackroby and Russell, 1976; Jorgenson, 1991). In this study, a product with 5 inputs was considered including capital, labor, oil and “other energies” (i.e. electricity, natural gas, and gasoline), and raw materials. In order separate oil from other energies and consider it an input and to regard “other energies” as another input, a price index can be added to other energies except oil using Divisia index. A Divisia index is a theoretical construct to create index number series for continuous-time data on prices and quantities of exchanged goods.

The production function is considered as equation (1):

$$Y = F(k, l, o, oe, m, t) \quad (1)$$

k, l, o, oe, m and t refer to capital, labor, oil, other energies except oil (electricity, natural gas, and gasoline), raw materials, and a time variable, respectively. T makes it possible to estimate technical progress and changes in input consumption as a result of a change in technology status. Using the shepherd duality theorem, which is about the duality between cost and production, the minimum total cost function can be obtained through equation (2) (Diewert, 1971):

$$C = Y.G(P_k, P_l, P_o, P_{oe}, P_m, t) \quad (2)$$

C refers to the minimum cost of production, and G refers to unit cost function. P_i is the i^{th} input price. Assuming that translog is specified, for the unit cost function we have:

$$\ln G = \ln \alpha_0 + \sum_i \alpha_i \ln P_i + \alpha_v t + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln P_i \ln P_j + \sum_i \beta_{it} \ln P_{it} + \frac{1}{2}\beta_{vt} t^2 \quad , \quad i,j = k,l,o,oe,m \quad (3)$$

Where,

(i) $\sum_i \alpha_i = 1$

(ii) $\sum_i \beta_{ij} = \sum_j \beta_{ji} = 0 \quad , i \neq j$

(iii) $\sum_i \beta_{it} = 0$

(iv) $\beta_{ij} = \beta_{ji} \quad \forall i \neq j$

(v) $\beta_{it} = \beta_{ti} \quad \forall i$

According to the shepherd's lemma $\frac{\partial G}{\partial P_i} = X_i$, we have:

$$\frac{\partial \ln G}{\partial \ln P_i} = \frac{\partial G}{\partial P_i} \cdot \frac{P_i}{G} = \frac{X_i P_i}{\sum_j X_j P_j} = S_i \quad i,j = k,l,o,oe,m \quad (4)$$

S_i refers to the share of i^{th} input cost. Assuming that translog is specified, the share function of i^{th} input price is:

$$S_i = \alpha_i + \sum_j \beta_{ij} \ln P_j + \beta_{it} t \quad i,j = k,l,o,oe,m \quad (5)$$

The rate of change in total factor productivity (v) indirectly equals to the rate of change in unit cost or price trend (Roy et al., 1999), that is:

$$-v = \frac{\partial \ln G_t}{\partial t} = \alpha_v + \sum_i \beta_{it} \ln P_i + \beta_{vt} t \quad , \quad i,j = k,l,o,oe,m \quad (6)$$

Since we have $\sum_i S_i = 1$, to avoid producing singularity, the equation of share of capital in (5) is deleted. Capital equation’s parameters are calculated using the homogeneity, symmetry, and additivity constraints (constraints i-v). 4 equations of share of production factors along with productivity growth equation were co-estimated considering the constraints (i-v).

In order to address research questions, it is necessary to explain how own price elasticity, cross price elasticity, and oil price impact on oil productivity were calculated. Price elasticity (E_{ij}) is an important parameter in the study of energy consumption pattern of industries and suggests how they balance their input consumption with changing input prices. By estimating own price elasticity of oil (E_{oo}), oil consumption pattern of industries resulted from rising oil prices can be examined. Cross price elasticity (E_{io}) refers to the relationship between oil and other inputs as a result of increasing oil price. If $E_{io}>0$, then oil and the i^{th} input are substitutes and if $E_{io}<0$, oil and the i^{th} input are supplements.

$$E_{ii} = \frac{\partial \log X_i}{\partial \log P_i} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i} \quad (7)$$

$$E_{ij} = \frac{\partial \log X_i}{\partial \log P_j} = \frac{\beta_{ij} + S_i S_j}{S_i} \quad (8)$$

E_{ii} and E_{ij} refer to own price elasticity and cross price elasticity, respectively. Changes in productivity of oil inputs as a result of oil prices can be calculated by equation (9).

$$\eta_{oo} = \frac{\partial \ln\left(\frac{Y}{Xo}\right)}{\partial \ln Po} = -\frac{\partial \ln Xo}{\partial \ln Po} = -E_{oo} \quad (9)$$

η_{oo} refers to average oil productivity elasticity over oil price. Since energy efficiency policies reduce energy demand because of increasing energy efficiency, real price of energy services will be reduced and manufacturers’ demand for energy will increase due to the reduced prices. In other words, there is a Rebound Effect (RE), which is calculated using equation (10) (Chakravarty et al, 2013):

$$RE = 1 + E_{ee} \quad (10)$$

E_{ee} refers to the price elasticity of energy demand.

3.2. Research model and econometric estimations

The model consists of a system of five equations shown in (11) including equations of share of labor cost, oil, “other energies”, raw materials, and productivity growth equation. As mentioned previously, since $\sum_i S_i = 1$, to avoid producing singularity, the equation of share of capital was deleted and $\frac{P_j}{P_k}$ was used instead of P_j.

$$S_i = \alpha_i + \sum_j \beta_{ij} \ln \frac{P_j}{P_k} + \beta_{it} t + \varepsilon_i \quad (11)$$

$$-V = \alpha_v + \sum_i \beta_{it} \ln \frac{P_i}{P_k} + \beta_{vt} t + \varepsilon_v$$

In order to separate oil from other energies and form two categories of input and other input, a price index can be added to other energies except oil using Divisia index. To this end, fuel demand system specified in equation (12) should be estimated. In equation (12), share of the cost function is defined for all forms of energy except oil. Then, using estimated β_{ij} coefficients in (12), Divisia index was calculated according to equation (13).

$$S_i = \beta_i + \sum_j \beta_{ij} \ln P_j + \beta_{iQ} Q \quad i,j = Ng, Go, El \quad (12)$$

$$\ln P_{oe} = \sum_i \beta_i \ln P_i + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln P_i \ln P_{Ej} \quad (13)$$

$i,j = Ng, Go, El$

El refers to electricity. Go refers to gasoline. Ng refers to natural gas, and P_{OE} refers to Divisia price index. Considering constrains (i-v), equality constraint of t coefficient in share of input cost function, and $\ln \frac{P_j}{P_K}$ coefficient in productivity growth equation, equation (11) was estimated separately for each country. The results of this estimate along with standard error values are reported in table (1). R^2 or coefficients of determination of each of the equations are given in table (1). Some R^2s are negative meaning that sum of the squared residuals is greater than that of the total squares, and according to the model, dependent variable is a constant value. Coefficients of the share of capital equation can be obtained using constraints i-v.

4. Results and discussion

The present study was an attempt to investigate the effect of oil price on factor demand and on total factor productivity of energy-intensive manufacturing industries in 10 European countries importing Iranian oil during 1980-2010. To this end, factor demand system and productivity growth equation were simultaneously estimated by a seemingly unrelated regression equation (SURE) method. Significance levels of converted parameters were investigated using Delta technique. The results off this study are presented in the following section.

4.1. The effect of oil price on factor demands

In order to investigate the effect of oil price on factor demands, own price elasticity and cross price elasticity were used. The results are discussed in the following sections.

4.1.1. Oil price as a stimulus for oil demand

Own price elasticity of oil demand in the industries was examined through equation (7). The obtained values and standard error are reported in table (2). Since price elasticity of oil demand is the result of estimated coefficients, the parameters were converted. Elasticities' standard error was calculated based on delta technique and presented in parentheses (See Appendix A, for the explanation of the method).

According to table (2), values of price elasticity of oil demand in energy-intensive industries are significant and negative for all investigated countries. Negative elasticity predicts that increasing oil price significantly reduces oil demand of energy-intensive industries. The calculated elasticity values of some countries are varied. In order to evaluate elasticity differences, a unitary elasticity hypothesis test was used. In cases where elasticity is greater than one, "larger than one elasticity" hypothesis can be used as an alternative test and in cases where elasticity is smaller than one "smaller than one elasticity" hypothesis can be used as an alternative test. The elasticity of oil demand was significantly less than one for Germany, Spain, Portugal and Sweden. Price elasticity of oil demand was significantly greater than one for Belgium, France, the Netherlands and the United Kingdom greater than one elasticity was not found to be significant for Austria and Italy. Therefore, it is expected that every 1% increase in oil price results in a significant oil demand reduction, that is more than 1% in only 4 countries out of 10 countries under investigation. In addition, in 4 out of 10 investigated countries, every 1% increase in oil price reduces oil demand less than 1% with the same rate in two countries.

4.1.2. The possibility of substitution between oil and other inputs

Industries' behavior in response to changes in oil prices cannot be solely analyzed with Own Price Elasticity of oil. Although negative Own Price Elasticity historically shows that oil demand has always been reduced as a result of increasing oil price, it is important to know what effects rising oil price have on industries' demand for other inputs (i.e., capital, labor, oil, other energies, and raw materials). In order to assess this impact, CPE was used. After comparing Morishima Elasticity of Substitution (MES), Allen Elasticity of Substitution (AES), and CPE Frondel (2004) argued that for practical purposes CPE may be preferable compared to other criteria. CPE for demand factors, in response to rising oil prices was estimated according to equation (8). The obtained values and standard error values are reported in Table (3). Elasticities' standard errors were calculated based on delta technique and presented in parentheses CPE sign (+/-) depends on the relationship between two inputs. If two inputs are substitutes, CPE is positive, and if they are supplements, CPE is negative. Considering CPE estimations in response to rising oil prices, it is substituted with raw material in 9 countries, capital in 8 countries, and labor and other energies in 6 countries. As mentioned before, other energies include electricity, natural gas, and gasoline. Empirical studies have shown energy and raw materials substitution as well as energy and capital substitution (Griffin and Greogory, 1976; Hesnanick and Kyer, 1995; Pindyck, 1979).

4.2. Bias in technical progress

In share of cost function equation (11), $\beta_{it}(\beta_{mt}, \beta_{oet}, \beta_{ot}, \beta_{kt}, \beta_{lt})$ indicates changes over time in the cost share of i^th input when factor price bias of technological change is constant.β_{kt} was calculated with regard to (i-v) constraints.$\beta_{it} < 0$ refers to the i^th input cost decreases over time with technical progress. In this case, inputs can be saved, and $\beta_{it} > 0$ indicates that inputs are used along with technical progress. The results for each country are presented in table (4).

4.3. The effect of oil price on total factor productivity

According to productivity growth equation in equation (11), oil price coefficient (β_{ot}) predicts oil price impact on technical progress or total factor productivity. $\beta_{ot} < 0$ indicates that rising oil price reduces negative growth rate of total factor productivity or increases positive growth rate of total factor productivity. Oil price impact on technical progress is confirmed by Roy et al. (1999) and Huntington (2010). The results are given in Table (5). Standard errors of the coefficients are shown in parentheses Cost share equation (11), $\beta_{it}(\beta_{lt}, \beta_{kt}, \beta_{ot}, \beta_{oet}, \beta_{mt})$, indicates change in cost share of i^th input overtime when relative input prices are held constant and are referred to as the "factor price bias" of technological change. β_{kt} was calculated considering i-v constraints. $\beta_{it} < 0$ indicates that the i^th input cost decreases over time with technical progress; in this case. inputs can be saved, and $\beta_{it} > 0$ indicates that inputs are used along with technical progress. The estimated β_{ot} values were found to be negative for Austria, Italy, Portugal, Spain, Sweden, and the United Kingdom and significant for Austria, Italy, and Spain. The obtained β_{ot} coefficients for other countries were found to be positive and non-significant.

4.4. The effect of oil price on average oil productivity

Using equation (9), annual oil productivity over oil price ratio (η_{OO}) was estimated. η_{OO} indicates the effect of oil price (P_O) on average oil productivity ($\frac{Y}{O}$). In other words, it shows average oil productivity change rate per each percent increase in oil price. The results are presented in Table (6). As a converted parameter, standard error (η_{OO}) was calculated using Delta technique.

According to Table (6), η_{OO} is positive for all countries, which is indicative of positive impact of oil price on average oil productivity. Goldar (2010) argued that benefits in the average efficiency of energy input are partly because of the actual cost of energy and partly, due to technical progress.

4.5. Rebound effect

Rebound effects (RE) were calculated using equation (10). Since input energy in the current research, was divided into oil and "other energies", REs were estimated for both input groups. The obtained REs based on the two groups of oil and "other energies" are illustrated in Table (7).

Positive and >100% REs refer to conditions where increasing energy consumption (as a result of reducing effective price of energy) is more than a reduction in energy demand as owing to implementation of energy efficiency policy (Backfire). RE=100% refers to condition where increasing energy consumption (as a result of reducing effective price of energy) equals with a reduction in energy demand because of implementation of energy efficiency policy (Full Rebound). Positive and <100% REs refer to conditions where decreasing energy consumption (as a result of reducing effective price of energy) is somewhat compensated by increasing energy consumption owing to implementing energy efficiency policy (Partial Rebound). Zero RE means that energy efficiency policy is fully realized (No Rebound). Finally, when energy efficiency policy decreases energy consumption to more than what is expected, RE is negative (Super conservation); in this case, it can be concluded that energy efficiency policies are over-realized. REs of oil inputs for 6 out of the 10 countries, and "other energies" input for 7 out of 10 countries were found to be negative. Hence, it is predicted that energy efficiency policies lead to protection of resources in most countries.

Table 1 Estimating parameters of production factor demand system and productivity growth equation

Country	The UK	Sweden	The Netherlands	Spain	Portugal	France	Italy	Germany	Belgium	Austria
α_l	0.749346 (0.1063916)	0.298766 (0.3681182)	0.028342 (0.1178974)	0.262188 (0.1129325)	-0.11582 (0.9052487)	0.374584 (0.1229987)	0.134443 (0.0940922)	0.344021 (0.0459975)	0.322569 (0.0624265)	0.381457 (0.0686652)
β_{ll}	0.036832 (0.0172085)	0.060683 (0.0452099)	-0.0368 (0.0189877)	-0.00284 (0.0168299)	0.011931 (0.0913247)	0.004469 (0.0217256)	-0.02065 (0.0196866)	-0.00479 (0.0072315)	-0.00544 (0.0113947)	0.012704 (0.0176144)
β_{lk}	0.022834 (0.014096037)	-0.05928 (0.03886018)	-0.02511 (0.013846889)	0.003293 (0.007365408)	-0.0208 (0.073529165)	-0.03142 (0.018350977)	0.00303 (0.010979565)	-0.00957 (0.006478517)	0.007204 (0.006899071)	-0.01639 (0.009876753)
β_{lo}	-0.00672 (0.006567)	-0.00696 (0.032891)	-0.00087 (0.0042003)	0.003322 (0.0052585)	-0.02487 (0.0246159)	-0.01459 (0.008598)	-0.00551 (0.0058287)	-0.01368 (0.0031367)	0.003717 (0.0044282)	0.00692 (0.0058519)
β_{loe}	0.012365 (0.0065962)	0.044998 (0.0112928)	0.016722 (0.0047743)	0.00437 (0.0027355)	0.005684 (0.0055942)	0.042472 (0.008993)	-0.00449 (0.0017571)	0.013287 (0.0034158)	0.003119 (0.0028062)	0.005676 (0.0040957)
β_{lm}	-0.06531 (0.0174003)	-0.03945 (0.0375576)	0.046057 (0.0193859)	-0.00815 (0.0204061)	0.028052 (0.1129383)	-0.00094 (0.0189151)	0.027626 (0.0162812)	0.014758 (0.0071342)	-0.0086 (0.0112669)	-0.00891 (0.013074)
β_{lt}	-0.0012085 (0.0017587)	0.0006936 (0.0104238)	0.0028131 (0.001388)	0.0023352 (0.0009406)	0.0078223 (0.0167512)	0.0001433 (0.0016857)	-0.0010871 (0.0008812)	-0.0033613 (0.000592)	-0.000685 (0.0007691)	-0.0031585 (0.0005999)
α_k	-0.79028 (0.103246)	-0.88744 (0.57043)	-0.75392 (0.137785)	-0.70205 (0.053709)	1.010383 (1.22649)	-0.88009 (0.134085)	-0.75782 (0.057459)	-0.92388 (0.060556)	-0.86079 (0.066903)	-0.90088 (0.051726)
β_{kk}	-0.00303 (0.036929)	0.01391 (0.103053)	0.049626 (0.041108)	0.021725 (0.046053)	0.027643 (0.933192)	0.015473 (0.040923)	0.020643 (0.03542)	0.017344 (0.019782)	-0.00728 (0.028852)	0.030332 (0.031262)

Source: research findings

Table 1 Continued: Estimating parameters of production factor demand system and productivity growth equation

The UK	Sweden	The Netherlands	Spain	Portugal	France	Italy	Germany	Belgium	Austria
-0.00043 (0.006921)	0.042638 (0.045275)	0.006255 (0.003094)	-0.00494 (0.003474)	0.0159 (0.032459)	0.005011 (0.009518)	-0.00631 (0.004156)	0.010712 (0.004204)	0.007661 (0.004722)	-0.01313 (0.005875)
-0.00038 (0.009736)	-0.05767 (0.016992)	-0.02403 (0.009705)	-0.00185 (0.001409)	0.025138 (0.024516)	0.002471 (0.012024)	0.001524 (0.001211)	-0.0111 (0.004684)	-0.0047 (0.00367)	-0.0049 (0.00357)
-0.019 (0.017473)	0.060398 (0.047282)	-0.00674 (0.023329)	-0.01823 (0.009681)	-0.04789 (0.110547)	0.008461 (0.019375)	-0.01888 (0.009885)	-0.00738 (0.009514)	-0.00288 (0.011856)	0.004087 (0.009509)
-0.00079 (0.002879)	-0.00273 (0.013733)	-0.00613 (0.002354)	-0.00144 (0.000534)	-0.07517 (0.034342)	-0.00111 (0.002086)	-0.00037 (0.000532)	0.004136 (0.000903)	0.000803 (0.001024)	0.003322 (0.000658)
-0.01285 (0.0480109)	0.470978 (0.4727213)	0.031326 (0.026991)	0.058577 (0.045002)	0.21304 (0.3696606)	-0.07343 (0.0625373)	-0.02262 (0.0424761)	0.001558 (0.0288307)	0.047545 (0.0330722)	0.063993 (0.0438034)
-0.00708 (0.0049694)	0.013756 (0.0533966)	-0.00216 (0.0017241)	0.001353 (0.0031934)	0.007664 (0.0127629)	-0.00483 (0.0064025)	-0.00288 (0.0040927)	0.001738 (0.0026972)	-0.00951 (0.0036957)	-0.00404 (0.0076516)
0.0045639 (0.0036504)	-0.0068608 (0.0163958)	0.00000456 (0.0010214)	0.002096 (0.0012571)	-0.001 (0.0033543)	-0.00327 (0.0049848)	-0.00034 (0.0010697)	-0.0028 (0.002179)	-0.00093 (0.002519)	0.004843 (0.0027416)
0.009653 (0.0072457)	-0.04258 (0.0323155)	-0.00323 (0.0044671)	-0.00183 (0.0081976)	0.00231 (0.0318158)	0.01768 (0.0091857)	0.015047 (0.0074555)	0.004031 (0.0042085)	-0.00094 (0.0056758)	0.005413 (0.0086289)
-0.00113 (0.0008791)	-0.00673 (0.014136)	0.000309 (0.0002738)	-0.00082 (0.0004571)	-0.0083 (0.0093206)	0.000414 (0.000911)	-0.0008965 (0.0004259)	0.000347 (0.0004066)	0.000373 (0.0007045)	-0.00245 (0.000907)
0.151328 (0.0544765)	-0.37316 (0.1692677)	-0.03416 (0.0451847)	0.012502 (0.0257052)	-1.4436 (0.5520963)	0.329081 (0.0654519)	-0.01713 (0.0131245)	-0.02187 (0.0438267)	-0.01436 (0.0403206)	-0.01184 (0.0252717)
0.000063 (0.0063072)	0.004896 (0.0077958)	-0.00115 (0.0055397)	-0.00241 (0.0009056)	-0.034 (0.0250353)	0.008974 (0.0077571)	-0.0012 (0.0003867)	-0.00778 (0.0041806)	-0.00219 (0.0039466)	-0.00667 (0.0023879)
-0.01661 (0.0077688)	0.014636 (0.0115369)	0.008453 (0.0070964)	-0.00221 (0.0044703)	0.00418 (0.0068774)	-0.05065 (0.0092137)	0.00451 (0.0022417)	0.008398 (0.0059684)	0.004706 (0.0062802)	0.001045 (0.0043521)
-0.0016 (0.0013884)	0.01046 (0.0050051)	-0.00046 (0.0011766)	0.001245 (0.0003272)	0.070322 (0.0260992)	-0.0011725 (0.0011678)	0.000417 (0.0001319)	-0.00016 (0.0006818)	0.000121 (0.0010362)	0.000255 (0.0003052)
-0.09754 (0.131654)	0.490853 (0.4372867)	0.728409 (0.1599122)	0.368784 (0.1772599)	0.335988 (1.351059)	0.249855 (0.1752023)	0.66313 (0.1248)	0.600176 (0.0946442)	0.50504 (0.1176573)	0.467263 (0.082183)

Source: research findings

Table1

Continued: Estimating parameters of production factor demand system and productivity growth equation
Source: research findings

Country	β_{mm}	β_{mt}	α_v	β_{vt}	R^2_l	R^2_o	R^2_{oe}	R^2_m	R^2_v
Austria	-0.00164 (0.0156459)	0.002028 (0.001104)	-0.97602 (0.4663296)	-0.00709 (0.0294142)	0.3422	0.0400	0.1355	0.0413	0.0003
Belgium	0.007715 (0.0209105)	-0.00061 (0.0017171)	-1.34768 (0.3958583)	0.064536 (0.0252891)	0.0687	0.1706	-0.1563	0.0180	0.0693
Germany	-0.01981 (0.0150553)	-0.00096 (0.0011378)	-0.35944 (0.2226329)	-0.02213 (0.0144073)	0.3021	0.1000	0.0013	0.0671	0.0240
Italy	-0.0283 (0.0216543)	0.001932 (0.0010183)	-1.27638 (0.2786365)	0.062237 (0.0181358)	0.1189	0.1055	0.1524	0.1311	0.1085
France	0.025446 (0.0266591)	0.00201 (0.0016316)	0.121993 (0.745923)	-0.01709 (0.0361537)	0.3620	0.0045	-2.5999	0.4479	0.0048
Portugal	0.013344 (0.1672621)	0.005323 (0.0222628)	-4.0894 (1.252022)	0.184358 (0.0577164)	-0.4743	-1.2222	-129.376	-0.0879	0.4314
Spain	0.030418 (0.0321027)	-0.00132 (0.0015648)	-0.84408 (0.3400216)	0.052853 (0.0213662)	0.2640	0.0201	0.1520	0.0267	0.0634
The Netherlands	-0.04454 (0.0265354)	0.003469 (0.0018924)	-0.67025 (0.3312466)	0.014878 (0.0206415)	0.1815	0.0580	-0.7687	0.1523	0.0056
Sweden	0.006989 (0.0438741)	-0.00169 (0.010658)	0.882295 (2.051504)	-0.05991 (0.0949753)	0.8715	-0.4006	-1.4285	0.2204	0.0194
The UK	0.091276 (0.0213879)	0.004732 (0.0020422)	-0.57838 (0.352948)	-0.00797 (0.0228673)	0.2278	-0.4477	0.0586	-0.0317	0.0022

Table 2

Price elasticity of oil demand (E_{oo}) in energy-intensive European manufacturing industries

Country	Austria	Belgium	Germany	Italy	France	Portugal	Spain	The Netherlands	Sweden	The UK
E_{oo}	-1.017 (0.0324)	-1.207 (0.018)	-0.90 (0.018)	-1.008 (0.032)	-1.08 (0.016)	-0.81 (0.015)	-0.92 (0.013)	-1.117 (0.049)	-0.67 (0.237)	-1.82 (0.054)

Source: research findings

Table 3

CPE and industrial response to rising oil prices for production factors demand

country	Austria	Belgium	Germany	Italy	France	Portugal	Spain	The Netherlands	Sweden	The UK
E_{lo}	0.4238 (0.019)	0.3593 (0.014)	-0.0979 (0.009)	-0.1888 (0.0215)	0.1598 (0.03)	0.2231 (0.117)	-0.1647 (0.020)	0.3366 (0.015)	0.1670 (0.108)	-0.4357 (0.0183)
E_{ko}	-0.0896 (0.0399)	0.339 (0.336)	0.2431 (0.0365)	0.5295 (0.0348)	-0.007 (0.084)	0.5311 (0.211)	0. 3930 (0.020)	0.0465 (0.021)	0.9846 (0.315)	0.0611 (0.062)
E_{mo}	0.5817 (0.0178)	0.5189 (0.010)	1.013 (0.008)	0.6254 (0.0136)	0.8507 (0.016)	0.3379 (0.057)	0.5874 (0.0159)	0.4693 (0.008)	-0.3669 (0.068)	1.6152 (0.015)
E_{oeo}	0.3974 (0.1935)	-0.024 (0.1721)	-0.031 (0.044)	0.0226 (0.085)	-0.22 (0.401)	0.0009 (0.1917)	0.1389 (0.059)	0.0163 (0.040)	-0.1903 (0.575)	0.1042 (0.076)

Source: research findings

Table 4

Bias technical progress

Country	Austria	Belgium	Germany	Italy	France	Portugal	Spain	The Netherlands	Sweden	The UK
Labor	Saving	Saving	Saving	Saving	Using	Using	Using	Using	Using	Saving
Capital	Using	Using	Using	Saving	Saving	Saving	Saving	Saving	Saving	Saving
Oil	Saving	Using	Using	Saving	Using	Saving	Saving	Using	Saving	Saving
Other Energies	Using	Using	Saving	Using	Saving	Using	Using	Saving	Using	Saving
Materials	Using	Saving	Saving	Using	Using	Using	Saving	Using	Saving	Using

Source: research findings

Table 5

the effect oil price on total factor productivity

Country	Austria	Belgium	Germany	Italy	France	Portugal	Spain	The Netherlands	Sweden	The UK
β_{ot}	-0.0024 (0.0009)	0.0003 (0.0007)	0.0003 (0.0004)	-0.0008 (0.0004)	0.0004 (0.0009)	-0.0083 (0.0009)	-0.0008 (0.0004)	0.0003 (0.0003)	-0.0067 (0.0141)	-0.0011 (0.0008)

Source: research findings

Table 6
The effect of oil price on oil productivity

Country	Austria	Belgium	Germany	Italy	France	Portugal	Spain	The Netherlands	Sweden	The UK
η_{oo}	1.017 (0.0032)	1.027 (0.018)	0.90 (0.018)	1.008 (0.032)	1.08 (0.016)	0.81 (0.015)	0.92 (0.013)	1.117 (0.049)	0.67 (0.237)	1.82 (0.054)

Source: research findings

Table 7
Rebound effects (%)

Country	Austria	Belgium	Germany	Italy	France	Portugal	Spain	The Netherlands	Sweden	The UK
RE_o	-1.7 (0.032)	-2.07 (0.018)	10 (0.018)	-0.8 (0.032)	-8 (0.016)	19 (0.015)	8 (0.013)	-11.7 (0.049)	33 (0.23)	-82 (0.054)
RE_{oe}	-45.6 (0.02)	-13.5 (0.03)	-10.9 (0.03)	-8 (0.069)	73.4 (0.018)	-192 (0.006)	-9 (0.034)	-1.9 (0.189)	20 (0.046)	4.8 (0.028)

Source: research findings

5. Conclusion

This study was aimed at investigating the effect of rising oil price on factor demands and total factors productivity of energy-intensive manufacturing industries in 10 European countries importing Iranian oil during 1980-2010. To this end, factor demand system and productivity growth equation were simultaneously estimated by a seemingly unrelated regression method.

Given the price elasticity of oil demand in European energy-intensive manufacturing industries importing Iranian oil, it seems that rising oil price can significantly reduce the industries oil demand which in turn brings about effectiveness for their price-based policies.

The results indicate that rising oil price increases total factor productivity growth in energy-intensive manufacturing industries in Austria, Italy, Portugal, Spain, Sweden and the United Kingdom. The effect was found to be significant for Austria, Italy, and Spain and for other countries, it was found to be negative but non-significant.

Considering CPE, with rising oil prices, it will be replaced with raw materials in nine countries, capital in eight countries, and labor and other energies in six countries. Therefore, it is expected that with rising oil prices and reducing demand for oil, oil will be replaced with other factors. Significant and positive effect of oil price on average oil productivity is confirmed in all countries.

According to estimation of negative REs (for oil), it seems that energy efficiency policies (oil) reduce oil consumption to more than what is expected from full realization of the policies and result in an improved environmental situation. Finally, it should be noted that rising oil prices reduces oil demands of European energy-intensive industries both through technical progress and principle of demand and inter-factor substitution. These findings are deemed important for Iran as an oil supplier of these countries. Accordingly, it is recommended that Iran follow development strategies such as exporting crude oil, petrochemical products, natural gas and electricity instead of exporting crude oil and selling raw materials.

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Appendix

Delta technique is a method for estimating moments of random variables functions. In econometrics, this method is useful for estimating standard error of converted parameters. This technique extends a function of the random variables usually by a one-step approximation in its average range and then calculates its variance.

$G(x) \cong G(mu) - (x - m)\acute{G}(mu)$

X is a random variable with mu as its average; $\acute{G}(0) = \frac{dG}{dX}$.

$Var\big(G(X)\big) \cong Var(X) * [\acute{G}(mu)]^2$

If we are dealing with a Vector of variables:

$Var\big(G(X)\big) \cong \acute{G}(mu)Var(X)[\acute{G}(mu)]^{\mathrm{T}}$

T refers to a transposed operator.