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ESTIMATING THE REBOUND EFFECT OF TECHNOLOGICAL IMPROVEMENT IN IRAN'S INDUSTRY SECTOR

Abstract:

Rebound effect refers to the phenomenon that energy savings from improvement in energy efficiency are lower than expected due to unintended second-order effects. The main reason of improving energy efficiency is Technological improvement. According to Khazzoom formula, the rebound effect of improving technology is equal to price elasticity of demand so in this research natural gas demand function is estimated. In addition to the economic drivers (natural gas price, price of substituted energy factors, industry value added), there are number of exogenous factors that drive energy demand. This research therefore uses Structural Time Series Model to estimate natural gas demand in Iran`s industry sector during 1988 to 2009 and then Khazzoom rebound effect is calculated. Estimated short run and long run rebound effect in Iran`s industry sector are 63 percent and 133 percent respectively, with a generally increasing UEDT in a decreasing rate. UEDT has upward sloping but level of UEDT is fixed during the period of research so the model is "smooth trend model". Relating to the research findings improving technology in Iran`s industry sector reduces Natural gas consumption up to 37 percent in short run. But in long time period increases Natural gas consumption up to 133 percent. So in short run technological improvement can reduce consumption approximately but in long run price policy reform should be used simultaneously.

Keywords:

Rebound effect , industry sector, natural gas, technological improvement, structural time series model

JEL Classification: C59, L69, Q31

1. Introduction

Iran's industry energy consumption has increased from 1988. In 2009, Iran's energy consumption in the industry sector was 258 million barrels of oil equivalent, while in 1988 only 90.5 million barrels oil equivalent energy was used in the industry sector. Furthermore, among different sources of energy, oil products had the biggest share of consumption in the industry sector in 1988 with 68.95 percent of the total energy consumption in industry sector and the percentage of natural gas usage in industry sector was 17.13 percent. During the 22-year- period, the share of oil products decreased and reached to 25 percent, but the ratio of natural gas in industrial energy consumption increased and got to 61.6 percent of the total energy usage and became the most important source of energy in Iran's industry sector.

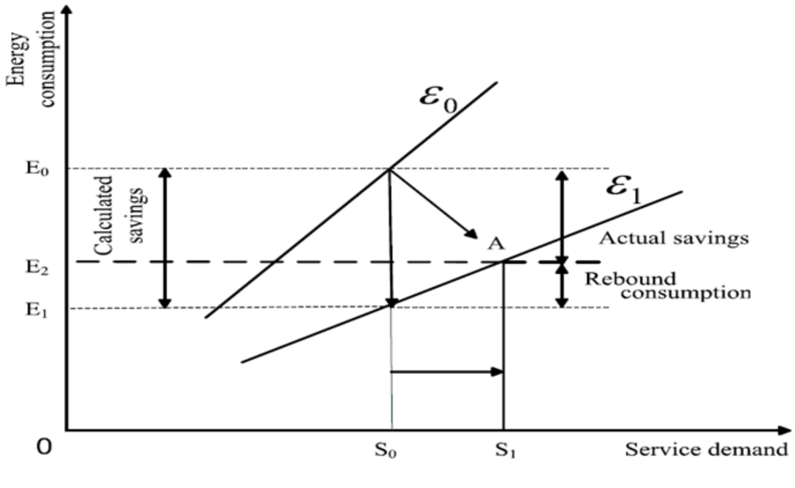
The importance of energy for economic growth, increasing greenhouse gas emission, rising air pollution, as well as the necessity of saving energy for the next generations determine the government to use energy conserving tools in order to optimize energy consumption. Technological improvement was the main treat that Iran's government used during this period, as a result, the efficiency rate of energy consumption in industry sector grew from 370.58 in 1988 to 803.37 billion dollars/oil equivalent energy consumption (at 1997 prices). But, economic growth and increasing the demand for different kinds of consuming goods offset part of the energy saving plan, so the main question is this:"can we reduce energy consumption by improving technology?" The energy rebound effect tells that technological progress not only improves energy efficiency ,but also promotes economic growth therefore raise the demand for energy .In this regard, estimating the size of energy rebound effect in industry sector can help governments to perform proper policies to control the energy usage in industry sector. Estimating the short and long run rebound effect in Iran`s industry sector is the main aim of this paper.

2. Theoretical background

The idea of energy rebound effect dates back in 1866 , when Jevones (1866) in his book" The coal question" doubted the energy efficiency's positive effect on energy conservation in economic circles. The rebound effect phenomenon was first studied by Brooks and Khazzoom. Brooks (1998) focused on rebound effect at macroeconomic level and believed that energy efficiency can promote economic growth. If the impact of economic growth is large enough, the direct result of improving energy efficiency is more energy consumption. Brooks (1998) summarized research progress on energy rebound effect, including historical experiences, theoretical foundation and empirical support. Khazzoom (1980) pointed out that energy efficiency will usually reduce the marginal cost of energy service. If the demand for energy services sufficiently sensitive to changes in its cost, the actual reduction of energy consumption and reduction of energy consumed by per unit of energy services don't change. Brooks and Khazzoom proposed a hypothesis: improving energy efficiency will release funds to promote more economic growth, thus greatly accelerating the depletion of energy resource.

According to Greening and etal (2000), energy rebound effect increases energy consumption in three ways. *First*, direct rebound effect: the improvement of energy efficiency cut down the effective utility cost of energy, which will increase energy consumption. This mechanism includes two aspects, the substitution effect and the income effect. The substitution effect means energy with decreased effectiveness costs will substitute other production factors, such as capital or labor. In the income effect aspect it should be noted that, the decreasing effective cost of energy raises the real income, therefore increases the demand for energy. In Fig. 1, we assume that ε_0 and ε_1 ($\varepsilon_0<\varepsilon_1$) refer to two levels of energy efficiency for a particular energy service, which are essentially the reciprocals of the slopes of the two lines. If the demand for energy service remains unchanged at S_0, an improvement in energy efficiency from ε_0 to ε_1 will lead to a decrease in energy consumption by $E_0– E_1$. When the energy system more efficient, the real cost of unit energy services fall, so increase in energy service demand from S_0 to S_1. As a result, the actual energy savings from energy efficiency improvement will be $E_0−E_2$ rather than $E_0−E_1$, which implies that a portion of potential energy savings (i.e. $E_2−E_1$) is offset due to the existence of rebound effect.

Fig. 1, explanation of direct rebound effect



Source: wang and etal, 2012

Second, the indirect rebound effect: the decreasing effective utility cost of energy can lower the price of those energy-consuming products; then in the economic system, the demand for these products will increase and therefore total energy demand rises. *Third*, rebound effect of the overall economic system: it means that improvement of energy efficiency can raise the overall demand for energy. The decrease in effective costs of energy can reduce the prices of intermediate and final products. In this regard, it leads to system adjustment of prices in the overall economy, which may narrow the cost gap between production costs of energy-intensive products and those of less energy-intensive products, so the economy will further increase the demand for energy.

Saunders (1992) for the first time employed empirical methods to measure the size of energy rebound effect and concluded that energy efficiency improvement could promote economic growth and the substitution between energy end other factors also can affect the size of energy rebound effect. Saunders (1992) adapted eight types of production and cost functions for exploring how energy efficiency gains affect energy consumption. Saunders' studies are mainly under the neo-classical growth theory framework and systematically sum up the influence of different function form on the size of rebound effect in empirical studies. Khazzoom measured direct rebound effect by using demand price elasticity, and to calculate price elasticity various methods and sample data had been adapted.

3. Methodology

This section presents the main concepts and definitions that can be found in the literature, which are necessary to carry out the econometric analysis to estimate direct rebound effect in the industry sector. Based on the formula that Khazzoom used to estimate rebound effect the efficiency elasticity of the demand for energy ($\eta_\varepsilon(E)$) equals the energy efficiency elasticity of the demand for useful work for an energy service ($\eta_\varepsilon(S)$) minus one. this is the most common definition used as a measure of direct rebound effect for a particular energy service (Khazzoom, 1980; Berkhout and etal. 2000; Dimitropoulos and Sorrell, 2006; Sorrell, 2007):

$$\eta_\varepsilon(E) = \eta_\varepsilon(S) - 1 \qquad (1)$$

Energy savings due to improved energy efficiency will be based on mathematical model predictions just when the energy efficiency elasticity of the demand for useful work for an energy service will be zero ($\eta_\varepsilon(S) = 0$), then the energy efficiency elasticity of the demand for energy must be equal to -1($\eta_\varepsilon(E) = -1$). A positive rebound effect means that the energy efficiency elasticity of the demand for useful work for an energy service will be greater than zero, so if the absolute value of the energy efficiency elasticity of the demand for energy will be less that one it means $\eta_\varepsilon(S) > 1$, which means the demand is elastic, and this situation is called "backfire" (Saunders,1992).

Under certain assumptions, measures of rebound effect can be obtained from price elasticity`s estimation. These assumptions are as follows:(1)symmetry: consumers respond the same way to decrease in energy prices than to improvements in energy efficiency,(2) exogeneity: energy efficiency is not affected by changes in energy price which means that $\eta_{p_e}(\varepsilon) = 0$. Symmetry assumption has key implications because the estimation of direct rebound effect is performed through the estimation of price elasticities. Direct changes in prices can be more predictable than the effect of efficiency improvement (Dargay, 1992; Grubb, 1995). Endogeneity is circularity, as energy efficiency affects energy costs and energy costs affect energy efficiency. This can be addressed empirically through estimation of simultaneous equation models, instrumental variables or analyzing cointegration relations between variables. The following expression can be obtained (Berkhout et al., 2000):

$$\eta_{\varepsilon}(E) = -\eta_{p_e}(S) - 1 \qquad (2)$$

Since it is assumed that energy efficiency is constant ($P_s = (P_E \mid \varepsilon)$; an alternative definition of the rebound effect based on price elasticity of energy demand can be obtained (Dimitropoulos and Sorrell, 2006; Sorrell, 2007). Both equations (2) and (3) are based on assumptions of symmetry and exogeneity:

$$\eta_{\varepsilon}(E) = -\eta_{P_e}(E) - 1 \qquad (3)$$

To show that the equations (2) and (3) are the same, Khazoom used this method:

The energy demand= f (the price of the services that are obtained by using energy resources) →D(p) =f (p) →D(p) =f ($\frac{p^E}{\varepsilon}$)

Where p^E is the price of energy, D(p) energy demand and ε is efficiency index.

$$E = \frac{D(p)}{\varepsilon} = \frac{D(\frac{p^E}{\varepsilon})}{\varepsilon}$$

$$\eta_{\varepsilon}^{E} = \frac{\partial E}{\partial \varepsilon} \cdot \frac{\varepsilon}{E} = \frac{\partial(\frac{D(p)}{\varepsilon})}{\partial \varepsilon} \cdot \frac{\varepsilon}{E}$$

$$= [-\frac{D(p)}{\varepsilon^2} + \frac{1}{\varepsilon} \cdot \frac{\partial D(p)}{\partial \varepsilon}] \cdot \frac{\varepsilon}{E}$$

$$= [-\frac{D(p)}{\varepsilon^2} \cdot \frac{\varepsilon}{E} + \frac{\partial D(p)}{\partial p} \cdot \frac{\partial p}{\partial \varepsilon} \cdot \frac{1}{E}$$

$$\rightarrow \eta_{\varepsilon}(E) = -\eta_{p_e}(S) - 1$$

In the equation (3) the rebound effect equals $\eta_{pe}(E)$, and to estimate this rebound effect an econometric model should be used to estimate the price elasticity. In this research the structural time series model is used to estimate the rebound effect by considering an invisible variable which is technological improvement.

3-1. Structural time series model (STSM) and underlying energy demand trend (UEDT)

Technological progress of capital stock is an important factor that influences energy demand. Energy is a derived demand rather than being demanded for its own sake; it is the demand for the services it produces with the capital stock in place at a certain time. So the amount of energy demand is connected to the technology level of the energy appliances to assure the demanded level of services. As a result, technological progress should be taken into account in energy modeling studies (Beenstock and Willcocks, 1981). In the absence of the appropriate way to measure the effect of technological progress on energy demand, it is argued that the effect of technological progress could therefore be observed via response to energy price changes, the price elasticity (kuris, 1983a). At first technological progress was modeled by using a linear trend but Hunt and etal (2003a) argued that in addition to technological change and the change in energy efficiency of the capital stock there are number of additional exogenous factors that will also affect the demand for energy. These include changes in such factors as consumer tastes and preferences, demographic and social structure, environmental regulations, economic structure, etc. So a wider concept of underlying energy demand trend or UEDT introduced that encompassed technical change of capital stock and other exogenous factors and it is unlikely to be linear (Hunt and etal, 2003a).

Harvey’s (1989) STSM decomposes a time series into different components that have direct interpretations. The basic form of structural time series models is where the dependent variable is formulated as a regression of a time trend and a set of seasonal dummies. This can be interpreted as a univariate time series model where the explanatory variable is a function of time and the parameters of the model are time varying. The extension of the univariate model by adding observable explanatory variables produces a multivariate structural time series model (Harvey and Shephard, 1993; Harvey, 1989).

The STSM for quarterly observations in general can consist of trend, cycle, seasonal and irregular components that for the natural log of energy demand (e_t) .Can be formulated as follows:

$$e_t = \mu_t + \psi_t + \gamma_t + \varepsilon_t; \qquad t = 1, \dots, T \qquad (4)$$

Where μ_t is the trend, ψ_t is the cycle, γ_t is the seasonal and ε_t is the irregular and all four components are assumed to be stochastic with disturbances driving them mutually uncorrelated. The trend, seasonal and cycle are all derived from deterministic functions of time and the irregular is white noise. As only annual data is used in this research, the seasonal component can be omitted and because of the inclusion of industrial value-added variable in the model, the cyclical movement is also omitted. Consequently the equation (4) can be re-written as follows:

$$e_t = \mu_t + \varepsilon_t; \qquad t = 1, 2, \dots\dots, T \qquad (5)$$

As the trend component μ_t can be obtained recursively from the following:

$$\mu_t = \mu_{t-1} + s \qquad (6)$$

The linear trend can be converted to a stochastic trend by introducing the stochastic terms as follows:

$\mu_t = \mu_{t-1} + S_{t-1} + \eta_t \qquad \eta_t \sim NID(0, \sigma_\eta^2)$ (7)

$S_t = S_{t-1} + \xi_t \qquad \xi \sim NID(0, \sigma_\xi^2)$ (8)

Where $\eta_t$and ξ_t are mutually uncorrelated white noise disturbances with zero means and variances σ_η and σ_ξ respectively. The term η_t lets the level of trend to shift up and down whereas the term $\xi_t$allows the slope to vary.The larger are the variances the greater is the stochastic movements in the trend component.

The main tool to estimate structural time series models is the state space form, which represents the state of the system by various unobserved components such as trends and seasonals. As new observations become available, the estimates of the unobservable components are updated by means of a filtering process while a smoothing algorithm provides the best estimate of the state at any point within the sample (Harvey and Shephard, 1993).

Hunt and et al (2003), suggest that the structural time series approach is the ideal way to model the UEDT. The major reason being that the STSM permits a stochastically changing unobservable trend that can be combined with a distributed autoregressive lag (ARDL) as follows:

A$(L)e_t$=μ_t+ γ_t+B(L)$y_t + C(L)p_{gt} + D(L)P_{subt}$ (9)

Wheree_t, y_t, p_{gt} and p_{subt} are respectively natural gas demand, the industrial value added, price of natural gas and price of the substituted energy sources index. *A(L) ,B(L), C(L) and D(L) are* polynomial lag operators. B(L)/A(L), C(L)/A(L) and D(L)/A(L) are long run income elasticity of natural gas demand, long run price elasticity of natural gas demand and long run substituted energy resource price elasticity respectively. μ_t , γ_t and u_t are stochastic trend, stochastic seasonal variation and random white noise disturbance form respectively.

4. Conclusion

It is assumed that the general relationship for Iran`s natural gas demand in industry sector is given by:

$E_t = f(Y_t, P_{gt}, P_{subt}, UEDT)$ (10)

The irregular, slope and level residuals need to be normally distributed and during the estimation process, it was found that some interventions were need to ensure this condition is maintained. The existence of such interventions in the STSM might be a sign of a structural break and instability over the estimation period and from an economics standpoint, the interventions provide valuable information about certain events and periods that affects natural gas consumption behaviour in industry sector.

In order to maintain the normality of residuals and auxiliary residuals four interventions are included, (1989, 1990, 1999 and 2000) and the natural logarithm of each data is used instead of the data itself to eliminate the possible multicollinearity effect and to narrow the scale of different variables in the model. The detailed estimation results and the diagnostics tests are given in tables and figures (1, 2).

Table1: Iran`s industrial natural gas demand STSM estimates and diagnostics sample 1988-2009

variables	coefficients	t-value	prob
p_{gt}	-0.63304	-11.434	**0.0000**
y_t	0.26111	1.70183	**0.1272**
p_{subt}	0.19985	1.88908	**0.0955**
p_{gt-1}	-0.32333	-3.86094	**0.00480**
y_{t-1}	0.26461	2.72501	**0.02605**
p_{subt-1}	0.27080	4.3649	**0.0024**
e_{t-1}	0.28378	1.9479	**0.0872**
Intervention1989	-0.26063	-5.5525	**0/0005**
Intervention 1990	-0.14809	-5/6869	**0/0004**
Intervention1999	0.12795	8/5164	**0/0000**
Intervention2000	0.05146	6/2213	**0/0002**

Table 2. The diagnostics tests of Iran`s industrial natural gas demand estimated

Hyper parameters		**Goodness of fit**		**Residual diagnostic tests**			
Level	0	**p.e.v**	7/3222e-005	**Std.error**	0/0085	**r(5)**	0/02
Slope	0/0002	**p.e.v/m.d^2**	2/032	**H(2)**	0/21364	**Q(5,3)**	2/4
Irregular	0		0/9904	**DW**	1/9369	**LR-Test(a)**	0/22
			0/9996	**r(1)**	-0/037288		

Notes: Model estimation and all statistics are from STAMP 8.10;

Figure1: Estimated Underlying Trend of Nautral Gas Demand in Iran`s Industrial

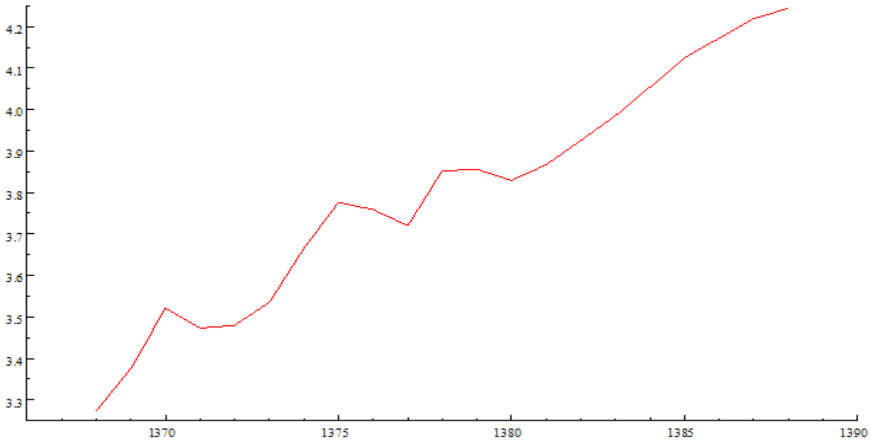
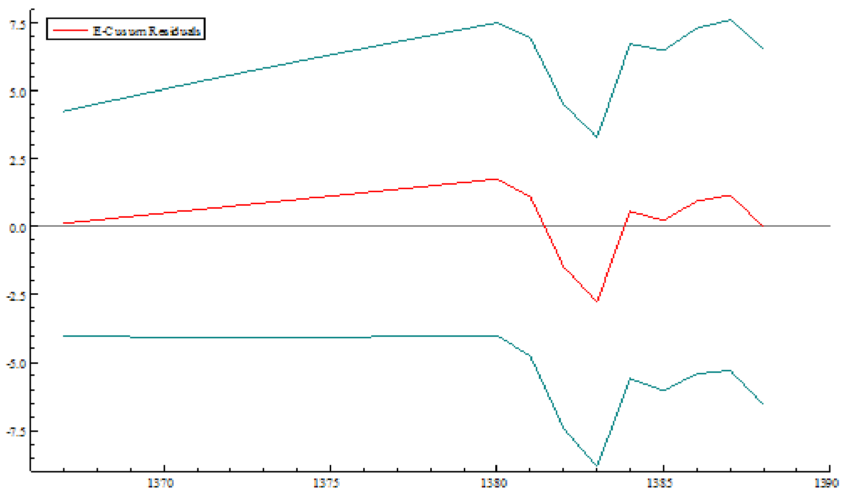


Figure 2: CUSUM test for the stability of parameters



The estimated UEDT from this procedure is non-linear given the estimated hyper-parameters and the figure1. It can be seen that the estimated stochastic trend`s level is zero but its slope is increasing during this period. This situation in underlying energy demand trend is called "Smooth Trend". It shows that the effectiveness of technological progress in Iran’s industry sector is fleeting and by improving the technology the natural gas consumption in energy sector decreases for a short time. But as consumers inure to the new situation the natural gas consumption in industry sector increases. By using the equation (3), the direct rebound effect in short run and long run can be estimated (-0.37) and (0.33) respectively. The Khazzoom short run and long run rebound effect are (0.63) and (-1.33) respectively.

These estimations show that in the short run by progressing the industrial sector`s technology the consumption decreases, but in the long run not only the decrease dose not happen but also the consumption will increase by 33 percent and contradicts the goal of the technological progression policy. Increasing the rebound effect to more than one (or 100 percent) in the long run indicates that unreasonable economic restructuring hindered the energy efficiency improvement therefore blocking the energy conservation of the industry sector.

5. Policy recommendations

Based on the results from this study, we give the following policy recommendation. The existence of the energy rebound indicates that energy efficiency improvement does not necessarily result in energy consumption reduction. It should be supplemented by economic instruments. The existence of the energy rebound effect highlights the importance of market-oriented measures to energy conservation, such as energy pricing reforms and energy resource taxes. The importance of energy price reform is reflected in the following aspect: According to energy substitution theory, energy and capital within an economy system or a specific sector are inter-substitutive under certain conditions. Specifically, with energy costs increase, more capital would be put in developing energy-efficient technologies, which would probably reduce energy consumption. However, if energy prices remain unchanged, an increase in energy efficiency cuts the real cost of energy, which will lead to an increase in energy demand. In this regard, the rebound of energy demand just makes the actual energy saving (due to energy efficiency improvement) less than anticipated.

On the contrary, raising energy prices can provide incentives for firms and individuals to undertake energy conservation efforts. The climbing energy prices can raise the energy costs, which just stimulate the enthusiasm in energy saving and emission reduction. For industrial sector, energy saving due to energy efficiency improvement can offset the cost rising caused by energy price rise. When energy efficiency is improved and the overall cost of energy does not decline, the size of energy demand rebound will be relatively small; at the same time, higher energy prices can also constrain the increase in energy demand. Therefore, raising energy prices may be more effective in achieving energy saving.

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