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INNOVATION INVESTMENTS AND ENERGY EFFICIENCY IN IRANIAN INDUSTRIES

Abstract:

This paper investigates the effects of innovation investments in Iranian industries including R&D expenditures (disaggregated as domestic and foreign) and ICT investments on energy intensity in three clusters of Iranian industries including small, medium and large size industries. We used the GMM panel method to estimate during 2000-2009 periods. The results show that in all clusters, domestic R&D expenditures have not significant effect on energy intensity, while foreign R&D expenditures induces to decrease considerably energy intensity. Also, ICT investments cause to increase energy intensity. Moreover, as expected, the spillovers from these innovations, especially R&D spillover cause to decrease energy intensity. Overall, in Iranian firms, innovation investments, in particular foreign R&D expenditures play a substantial role to improve energy efficiency.

Keywords:

Energy Intensity, ICT Investments, Domestic R&D, Foreign R&D, Spillovers

1. Introduction

In the recent decades, it is widely recognized that technological change has the potential to improve energy efficiency. At the same time, the role of innovation investments including ICT (Information and Communications Technologies) and R&D (Research & Development) in shaping energy needs and energy consumer behavior has increased tremendously. The broader impact of the rise of these innovations expenditures, especially in advanced economies, has been much underappreciated. In particular, related to this change technological at firm level, is the reduced emphasis on the use of tangible capital such as machinery, equipment and buildings and has been replaced by the greater role for intangible capital such as ICT and R&D (Hao and Ark, 2013).

But, there is a debate that ICT and R&D influence energy intensity in two conflicting effects, so that the net effect is not clear and depends on the relative magnitude of these countervailing forces. First, ICT and R&D can reduce demand for energy through the process innovation—the substitution of a new technology for an old production technology- that brings with it a lower level of energy consumption through increasing efficiency. This effect is called "the substitution effect". Second, ICT and R&D products increases GDP and induced to the economic boost that increase energy consumption. Likewise, ICT and R&D require the installation of new pants and machineries which requires more energy. Therefore it increases demand for energy. This effect is called "the income effect" or "the compensation effect" (Edquist et al., 2001; Romm, 2002; Lei et al, 2012). Whether the positive or negative effects of ICT and R&D on energy intensity dominate, is an unresolved question. In this context, empirical studies are needed to clarify this issue. In other hands, there is a belief that an industry’s technology progress not only depends on internal knowledge input, but also benefits from external technology spillovers .This is important, so that the Knowledge from external spillovers may crowd out internal innovation efforts. Free-riding incentives may induce some industry to reduce their own expenditures in innovation (Lei et al, 2012).

However, studies of the relationship between ICT and/or R&D and energy intensity have been flourishing recently, but they are still scarce. Vanden and Quan (2002) analyzed the factors driving the fall in industrial energy intensity in China during 1997-1999. They found that energy prices and R&D expenditures are significant drivers of declining energy intensity and industry composition are less important. In addition, the impact of R&D spending on energy intensity suggested that firms are using resources for energy saving innovations. Kumar (2003) attempted to identify and measures the factors behind the Indian Manufacturing energy efficiency. He found that R&D activities are important contributors to the decline in firm -level energy intensity. Takase and Murota (2004) examine the effect of IT investment on energy consumption in Japan and the U.S. They distinguish between income and substitution effects. They find the substitution effect to be dominant in Japan, whereas the income effect is dominant in the U.S. Cho et al. (2007) investigate the effects of ICT investment on industries’ electricity consumption in South Korea during 1991- 2003. Their results suggest that ICT investment reduces electricity consumption just in the primary metal products sector, whereas in the service sector and most of the manufacturing sectors it increases electricity consumption. Liu

Chang et al. (2008) found that the increase of expenditure on science and technology contributes to the improvement of energy efficiency in high energy consumption industries by using panel data on China’s 29 industrial sectors. Teng (2012) analyzed the effect of R&D (disaggregated as the indigenous R&D, Foreign R&D and Domestic R&D) on the energy consumption intensity in China during 1998–2006.The results show that indigenous R&D contributes to a significant decline of energy intensity in high energy-consuming intensity group and 31 industrial sectors, but has no significant effects on energy consumption intensity in low energy-consuming intensity group. Foreign technology purchased has a significant negative influence on energy consumption intensity only in 31 industrial sectors. Domestic technology transfer has no significant impact on energy consumption intensity in all samples. Sadorsky (2012) examines the relationship between ICT and electricity consumption in emerging countries. His results show a positive relationship between ICT and electricity consumption. Rexhaeuse et al (2014) analyzes the relationship between ICT and energy demand using a panel of 10 OECD countries and 27 industries. The results show that ICT capital is associated with a significant reduction in energy demand. This relationship differs with regard to different types of energy. ICT use is not significantly correlated with electricity demand, but is significantly related to a reduction in non-electric energy demand.

Overall, the empirical findings suggest that the effect of innovation investments including ICT and/or R&D on energy intensity is ambiguous and depends on the relative magnitude of these countervailing forces (the substitution effect or the income effect). Nevertheless, these empirical studies are not abundant, especially in developing countries. In addition papers that analyzed the role of ICT or R&D on energy intensity focus on entire industry sector. But, as the production process, technical standards and the extent of opening up are different in industries with different size, hence it cause to energy intensity of each group is quite different. Therefore, such an analysis is likely most useful at the clusters level. Hence, we attempt to evaluates the effects of innovation investments including ICT investments and R&D expenditures (disaggregated as domestic and foreign) on energy intensity in three clusters of Iranian industries including small, medium and large size industries to present exactly findings for a developing country and cover the literature gap.

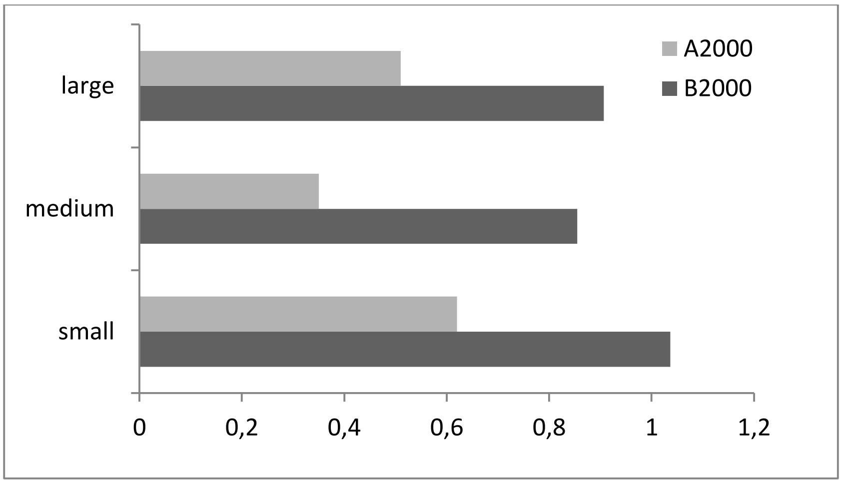
The rest of the paper is organized as follows: Next section overview the trends for energy intensity as well as both ICT and R&D intensities in three clusters of Iranian industries. Section three presents research methodology and data description. In section four, we analyze the empirical results. Last section includes conclusion and recommendations.

2. Overview of Trends in Iranian Industries at the Cluster Level

In this section, we present the overview of trends for energy intensity as well as both ICT and R&D intensities in Iranian industries**.** In order to have clear analysis, we classify total industries to three clusters including small, medium and large size industries. Then we compare the trends for them.

Figure 1 shows the average energy intensity performance for every cluster in before 2000 (1990-1999) and after 2000 (2000-2009). We calculate energy intensity for every cluster by the ratio of energy consumption (barrel oil) to total outputs (million LCU). The comparison of energy intensity levels for the clusters indicates that they are experienced a considerable decrease after 2000. It may be due to the government policies which encourage the industries to improve their technology by investing on efficient machineries and equipments, especially to use further innovation activities.

Figure1. Energy Intensity in Iranian industries at cluster level
***A2000 and B2000 denotes after 2000 and before 2000, respectively.**



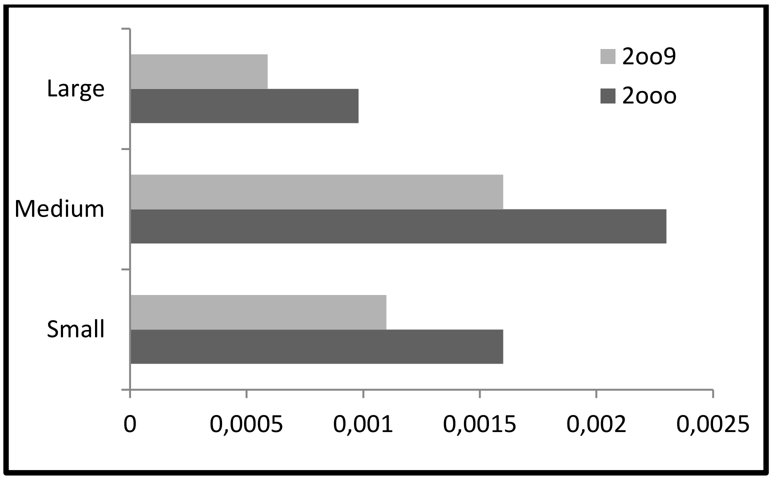
Source: Statistical Center of Iran (2015)

With regarding above, there arises a question whether R&D and ICT strongly contributes to decrease energy intensity levels in Iranian industries, after 2000? Hence, we inspect in continuance the situation of both ICT and R&D intensities for every cluster in 2000 and 2009 (with availability of data). It is necessary to say that we disaggregate total R&D expenditures into two parts including domestic and foreign. Figure 2 show the ICT intensity for each cluster that measured as the ratio of ICT investment to total investment. It is clear that the share of ICT to total investments is tiny. Also, the comparison of ICT intensity indicates that all clusters are experienced a decrease in ICT intensity between 2000 and 2009. This is because ICT infrastructures are not fulfilled at Iranian firms.

Figures 3 and 4 displayed both domestic and foreign R&D intensities for every cluster during studied period. We calculate domestic R&D intensity for each cluster by the ratio of its internal expenditures for technology development and technological innovation expenditures to total expenditures. Also, we calculate foreign R&D intensity for each cluster by the ratio of its funding for purchasing foreign technology to total expenditures. The figures show that in all clusters, domestic R&D intensity is tiny. Also, it decreased between 2000 and 2009. While foreign R&D intensity in all clusters is in higher levels and also it increased between 2000 and 2009 except for small cluster. This overview confirms that Iranian firms have little incentives to spend the domestic expenditures for technology development, presumably because its high costs and it takes too long time. Hence, they prefer to purchase foreign technology.

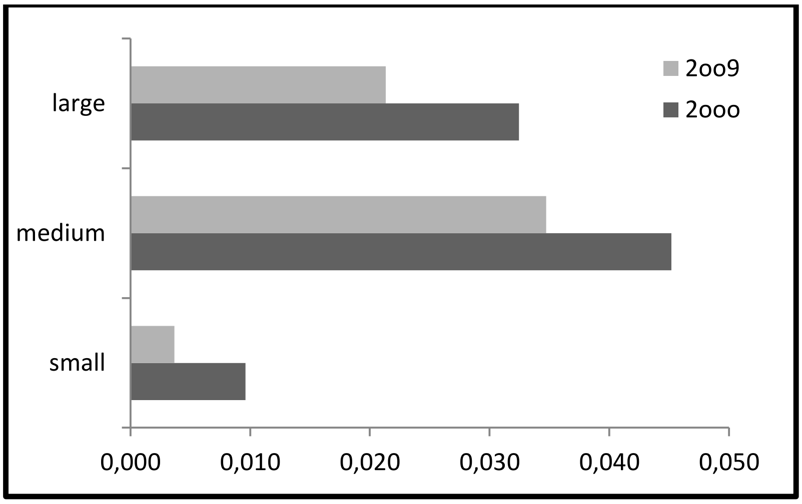
Overall, the figures show that in Iranian firms, energy intensity has decreased after 2000. At the same period, ICT intensity and also domestic R&D intensity have decreased, but foreign R&D intensity has increased. Therefore, it is imply that the foreign R&D play a major role for rising energy efficiency in Iranian firms.

Figure2. ICT Intensity in Iranian industries at cluster level



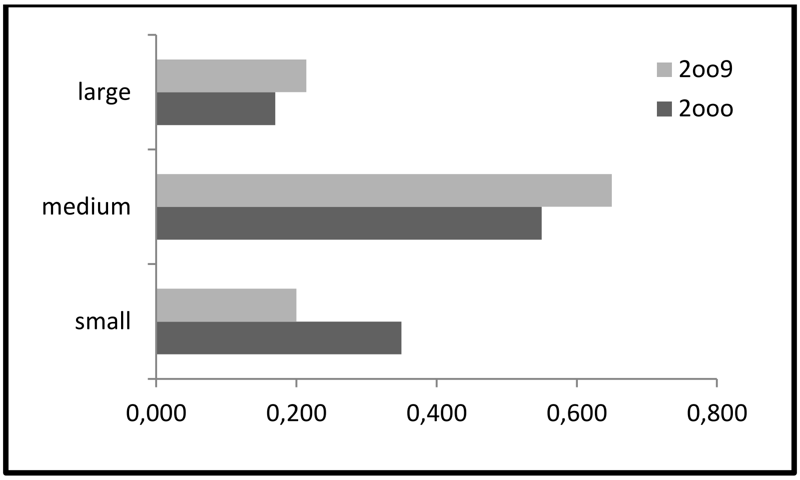
Source: Statistical Center of Iran (2015)

Figure3. Domestic R&D Intensity in Iranian industries at cluster level



Source: Statistical Center of Iran (2015)

Figure4. Foreign R&D Intensity in Iranian industries at cluster level



Source: Statistical Center of Iran (2015)

3. Methodology and Data description

3. 1. Model Specification

We use a Cobb-Douglas production function as follows:

$$Q = A\,K^{\propto}\,L^{\beta}\,E^{\gamma} \tag{1}$$

Where Q is the output, A is the total factor productivity (TFP), K is the capital stock, L is the employment, E is the energy consumption. Assuming constant returns to scale, Production Cost can be expressed as follows:

$$C(P_K, P_L, P_E, P_M, A) = A^{-1} P_K^{\beta_K} P_L^{\beta_L} P_E^{\beta_E} P_M^{\beta_M} Q \tag{2}$$

Where P_L, P_K, P_E, and P_M are defined as the prices of labor, capital, energy and raw materials, and also β_L, β_K, β_E and β_M represent the related price elasticity, respectively. According to Shepard's lemma, after making P_E-derivation, eq. (2) can be changed to the following as:

$$E = \frac{\beta_E A^{-1} P_K^{\beta_K} P_L^{\beta_L} P_E^{\beta_E} P_M^{\beta_M} Q}{P_E} \tag{3}$$

By setting $P_Q = P_K^{\beta_K} P_L^{\beta_L} P_E^{\beta_E} P_M^{\beta_M}$ and dividing both sides on Q, the energy intensity equation is extracted as follows:

$$EI = \frac{E}{Q} = \frac{\beta_E A^{-1} P_Q}{P_E} \tag{4}$$

According to Hu and Wang (2006), TFP is depends on knowledge capital. Hence, to capture the influence of knowledge capitals including both ICT and R&D on energy intensity, we assumed the TFP is a function of them. Also, we disaggregate total R&D into two part including domestic R&D ($R\&D^d$) which include internal expenditures for technology development and technological innovation expenditures) and foreign R&D ($R\&D^f$) which include funding for purchasing foreign technology. Therefore, we set TFP function as follows:

$$TFP = e^{\,g(ICT, R\&D^d, R\&D^f)+\varepsilon} \tag{5}$$

By replacing of eq. (5) in eq. (4) and taking logarithm on both sides, we get energy intensity equation for industry i as follows:

$$\ln(EI)_{it} = \alpha + \beta \ln(ICT)_{\mathrm{it}} + \gamma \ln(R\&D^d)_{it} + \delta \ln(R\&D^f)_{\mathrm{it}} + \theta \ln(\frac{\mathrm{P_E}}{\mathrm{P_Q}})_{\mathrm{it}} + \varepsilon_{it} \tag{6}$$

Given, this is possible that there are the various channels through which an industry may benefit from R&D and ICT spillovers from other industries (inter- industry spillovers). Of course, knowledge spillovers are not necessarily associated with an economic transaction and can be facilitated by technological linkages between sectors. Therefore, we consider their spillovers effects on energy efficiency by setting $\text{R\&D}^{\text{S}}$ and ICT^{S} variables in eq. (6), hence, we get:

$$\begin{aligned}\ln(EI)_{it} = \alpha_i + \alpha_1 \ln(ICT)_{\mathrm{it}} + \alpha_2 \ln(R\&D^d)_{it} + \alpha_3 \ln(R\&D^f)_{\mathrm{it}} + \alpha_4 \ln(\frac{\mathrm{P_E}}{\mathrm{P_Q}})_{\mathrm{it}} \\ + \alpha_5 \ln(R\&D^S)_{it} + \alpha_6 \ln(ICT^S)_{it} + \varepsilon_{it}\end{aligned} \tag{7}$$

Where, $\text{R\&D}^{\text{S}}$ and ICT^{S} are the related spillovers that show the volume of external R&D and ICT expenditures that causes the spillovers effects, respectively.

Ultimately, according as we implied, as the production process, technical standards and the extent of opening up are different in the industries, hence energy intensity of each sector is quite different. Thus, such an analysis is likely most useful at the clusters level. Therefore, we classify total industries to three clusters including large, medium and small size industries. Then, we estimates eq. (7) for each cluster.

3.2. Data Description

As implied before, we attempt to evaluate the effects of innovation investments including ICT investments and R&D expenditures (disaggregated as domestic and foreign) as well as the related spillovers on energy intensity in three clusters of Iranian industries including small, medium and large size industries. The final regression model for each clusters, is follows from eq. (7). Data are annual and extracted from statistical center of Iran. The studied period is selected during 2000-2009, considering availability of data. The Data description is as follows:

EI_{it} denotes energy intensity of industry i at time t. Energy intensity is calculated as the ratio of energy consumption (barrel oil) to output (million LCU); α_i are industry-fixed effects; ICT denotes ICT intensity that is calculated as the ratio of ICT investment to total investments; $R\&D^d$ is domestic R&D intensity that is calculated as the ratio of internal expenditures for technology development and technological innovation to total expenditures; $R\&D^f$ is foreign R&D intensity that is calculated as the ratio of funding for purchasing foreign technology to total expenditures; $\frac{P_E}{P_Q}$ is the energy relative price that is calculated as the ratio of the fuel and power price index to producer price index. Also, $R\&D^S$ and ICT^S are their related spillovers, respectively. R&D^S for an industry i defined as the ratio of the difference between R&D expenditures for total industries and the industry i to the difference between their total expenditures. ICT^S for an industry i defined as the ratio of the difference between ICT investments for total industries and the industry i to the difference between their total investments. Final, ε_{it} is disturbance terms assumed to be white-noises and uncorrelated.

The method used is the Dynamic Panel Data Technique**.** A reliable solution for the efficient estimation of dynamic panels was set by Arellano and Bond (1991) by using the Generalized Method of Moments (GMM). This estimator has become extremely popular, especially in the context of empirical dynamic research, because it allows relaxing some of the OLS assumptions. The Arellano and Bond estimator corrects for the endogeneity in the lagged dependent variable and provides consistent parameter estimates even in the presence of endogenous right-hand-side variable. It also allows for individual fixed effects, heteroskedasticity and autocorrelation within individuals (Roodman, 2006). Consistency of the GMM estimator depends on the validity of the instruments. As suggested by Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998), two specification tests are used. Firstly, Sargan/Hansen test of over-identifying restrictions which tests for overall validity of the instruments and the null hypothesis is that all instruments as a group are exogenous. The second test examines the null hypothesis that error term ε_{it} of the differenced equation is not serially correlated particularly at the second order (AR(2)), Ones should not reject the null hypothesis of both tests.

4. Empirical Results

Before estimating the above model for each cluster, an important step is to test for unit roots with stationary covariates. Hence, we used the Im, Pesaran and Shin (IPS) unit root test that assumes the series is non-stationary. Table 1 presents the results of the Im, Pesaran and Shin (IPS) unit root test. The results show that all variables in all clusters are stationary at the level. In other word, all variables are integrated of order (0).

Table 1: IPS unit root test at level for the industries clusters

Variables	Large industries	Medium industries	Small industries
$ln(\mathrm{EI})$	-4.60(0.000)*	-3.94 (0.000)	-3.23 (0.000)
$ln(\mathrm{ICT})$	-4.28 (0.000)	-3.84 (0.000)	-2.02 (0.021)
$ln(R\&D^d)$	-2.40 (0.008)	-2.17 (0.014)	-1.73 (0.041)
$ln(R\&D^f)$	-3.51 (0.000)	-1.63 (0.051)	-1.97 (0.024)
$ln(\frac{\mathrm{P_E}}{\mathrm{P_Q}})$	-6.22 (0.000)	-3.27 (0.000)	-2.64 (0.007)
$ln(R\&D^s)$	-5.87 (0.000)	-3.26 (0.000)	-3.65 (0.000)
$ln(ICT^s)$	-3.46 (0.000)	-1.77 (0.038)	-1.78 (0.036)

** Figures in parentheses are prob.*

Table 2 reports the results of estimations for three clusters of industries as small, medium and large size industries. The findings imply that in small size industries, ICT intensity has a positive effect on energy intensity, but this effect is not statistically significant. Also, despite of domestic R&D intensity has not significant effect on energy intensity, but foreign R&D intensity has a considerable negative and significant on energy intensity; so that a percent increase of it causes to decrease energy intensity to 0.33 percent. Likewise, as expected, the spillovers from ICT and R&D have negative and significant effects on energy intensity; so that a percent increase of them induces to decrease energy intensity to 0.035 and 0.45 percent, respectively.

Moreover, in medium size industries, ICT intensity has a tiny positive and significant effect on energy intensity; so that a percent increase of it causes to increase energy intensity to 0.006 percent. Also, despite of the effect of domestic R&D intensity on energy intensity is not significant, but foreign R&D intensity has a strong negative and significant on energy intensity; so that a percent increase of it decreases energy intensity to 1.24 percent. Likewise, the spillovers from ICT and R&D have negative and significant effects on energy intensity; so that, a percent increase of them induce to decrease energy intensity to 0.09 and 2.56 percent, respectively.

Furthermore, in large size industries, ICT intensity has a tiny positive and significant effect on energy intensity; so that a percent increase of it causes to increase energy intensity to 0.003 percent. Also, despite of the effect of domestic R&D intensity on energy intensity is not significant, but foreign R&D intensity has a relative strong negative and significant on energy intensity; so that a percent increase of foreign R&D intensity decrease energy intensity to 0.89 percent. Likewise, the spillovers from both ICT and R&D have negative and significant effects on energy intensity; so that, a percent increase of them induce to decrease energy intensity to 0.04 and 1.98 percent, respectively.

Overall, we can result that in Iranian firms, ICT investments causes to increase energy intensity. In other words, income effect is dominant. Also, Domestic R&D expenditures have not significant effect on energy intensity, while Foreign R&D expenditures induce to decrease considerably energy intensity. In addition, as expected, the spillovers from these innovations, especially R&D spillover cause to decrease energy intensity.

As mentioned before, the GMM estimator checks for the validity of the moment conditions by performing the Sargan test for over-identification, and tests for serial correlation of the differenced error term. As can be seen from the corresponding *p*-values of these tests, reported at the bottom of Table 2, the null hypothesis of the validity of instruments cannot be rejected. Also, the first- and second-order serial correlation tests show that there exist negative first-order serial correlations and no evidence of second-order serial correlation in the differenced error terms.

Table 2: the results of GMM estimation for the industrial clusters.

Variables	Large industries	Medium industries	Small industries
Lagged $\ln(EI)$	-0.41(-2.24)*	-0.52 (-2.87)	-0.38 (-2.54)
$ln(\mathrm{ICT})$	0.0037 (1.77)	0.0063 (1.91)	0.0051 (1.35)
$ln(R\&D^d)$	-0.018 (-1.22)	-0.0082 (-1.41)	0.0015 (0.83)
$ln(R\&D^f)$	-0.89 (-3.43)	-1.24 (-2.85)	-0.33 (-1.69)
$ln(\frac{\mathrm{P_E}}{\mathrm{P_Q}})$	-0.022 (-1.87)	-0.063 (-2.23)	-0.031 (-2.20)
$ln(R\&D^s)$	-1.98 (-3.12)	-2.56 (-4.38)	-0.45 (-2.64)
$ln(ICT^s)$	-0.041 (-1.75)	-0.092 (-1.93)	-0.0355 (-1.88)
First order (p-value)^1	0.002	0.000	0.000
Second order (p-value)^2	0.25	0.28	0.21
Sargan test (p-value)	0.45	0.38	0.41

** Figures in parentheses are t- statistics.*

[1] The null hypothesis is that the instruments are not correlated with the errors.

[2]The null hypothesis is that the errors in the first difference are not serially correlated of second order.

5. Conclusion

This paper investigates the effects of innovation investments including ICT investments and R&D expenditures (disaggregated as foreign and domestic) on energy intensity in Iranian industries. Since, in the production process, technical standards and the extent of opening up are different in the industries, hence energy intensity of each sector is quite different. Therefore, such an analysis is likely most useful at the clusters level. Thereby, we classify total industries to three clusters including small, medium and large size industries.

The findings reveal that in three clusters, ICT investment induces to weakly increase energy intensity. Of course, this effect is not significant in small size cluster.
Surely, the estimated coefficients are somewhat depend on diffusion of ICT technologies in firms. However, this result confirms that the income effect is dominant in Iranian firms. Also, despite of the effect of domestic R&D expenditure on energy intensity is not significant in any clusters, but foreign R&D expenditure induces to decrease energy intensity in three clusters, considerably. It is because the share of foreign R&D expenditures is very more than another. In other words, Iranian firms have little incentives to spend the domestic expenditures for technology development and technological innovation, presumably because its high costs and it takes too long time. Thus they prefer to purchase international technology. Furthermore, as expected, the spillovers effects of these innovation investments led to reduce energy intensity in three clusters. Of course, the R&D spillover effect is very greater than ICTs.

Overall, in Iranian firms, innovation investments, in particular foreign R&D expenditures play a substantial role to improve energy efficiency. Therefore, this study suggests that industries should make decisions in order to develop innovation capacity and also promote energy saving technology through cooperation and technology transfer should be strengthened simultaneously. Of course, it justifies the necessity of governments' intervention aimed by implementing the policies to intensify industries to expand such investments, especially in developing countries.

References

Arellano, M. & Bond, S; (1991), *" Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations* ", Review of Economic Studies, 58 , 277-297.

Arellano, M. , and Bover, O. (1995), Another Look at the Instrumental Variable Estimation of Error-Components Models. Journal of Econometrics, 68 (1) : 29–51.

Baltagi, B. H.(2005), " Econometric Analysis of Panel Data ", third ed, John Wiley and Sons Press.

Blundell, R. , and Bond, S. (1998) , Initial Conditions and Moment Restrictions in Dynamic Panel Data Models. Journal of Econometrics, 87(1) : 115–143.

Blundell, R., and Bond, S. (2000), GMM Estimation with persistent panel data: an application to production functions, Econometric Reviews, Taylor and Francis Journals, 19(3) : 321-340.

Cho, Y., Lee, J., and Kim, T. Y. (2007). The impact of ICT investment and energy price on industrial electricity demand: Dynamic growth model approach. Energy Policy, 35(9) :4730-4738.

Cohen, W. and Levinthal, D., “Innovation and Learning: The Two Faces of R&D,” Economic Journal, 99: 569-596

Edquist, C., Hommen, L., and McKelyey, M., (2001). " Innovation and Employment: Process Versus Product Innovation ". Edward Elgar, Cheltenham.

Hall, H., Mairesse, J. and Mohnen, P. (2009), Measuring the Returns to R&D, Working Paper 15622, National Bureau of Economic Research.

Hao, J. X. and Ark, B., (2013). Intangible Investment and the Intensity of Energy Use. NEUJOBS Working Paper NO.34

Hu, J-L and Wang, SH-CH (2006), Total-factor Energy Efficiency of Regions in China, Energy Policy, 34(17) : 3206-17.

Kumar, A ; (2003), " Energy Intensity: A Quantitative Exploration for Indian Manufacturing ". SSRN Paper No. 468440.

Lei,R. , Zhang, Y. , and Wei, W. , (2012). International Technology Spillover, Energy Consumption and CO2 Emissions in China. Low Carbon Economy, 3: 49-53

Liu, N. and Ang, B. W. (2007). Factors Shaping Aggregate Energy Intensity Trend for Industry: Energy Intensity versus Product Mix, Energy Economics, 29 : 609–635.

Popp, D. (2001). The Effect of New Technology on Energy Consumption. Resource and Energy Economics, 23 : 215–239.

Rexhaeuser, S., Schulte, P. and Welsch, H., (2014). ICT and the Demand for Energy: Evidence from OECD Countries. Discussion Paper No. 13-116

Romm, J., (2002). The Internet and the new energy economy. Resource, Conservation, and Recycling, 36 (3) : 197–210.

Sadorsky, P., (2012). Information communication technology and electricity consumption in emerging economies. Energy Policy, 48: 130-136

Takase, K., and Murota, Y., (2004). The impact of IT investment on energy: Japan and US comparison in 2010. Energy Policy, 32 (11): 1291–1301.

Teng, Y., (2012), Indigenous R&D, Technology Imports and Energy Consumption Intensity: Evidence from Industrial Sectors in China. 2012 International Conference on Future Energy, Environment, and Materials, Energy Procedia, 16: 2019-2026.

Vanden K.F., Jeferson G.H., Hangmei L., Quan T; (2002), What is Driving China's Decline in Energy Intensity, Resources and Energy Economics, 26: 77-97

Wooldridge, J. M.; (2002), Econometric Analysis of Cross-Section and Panel Data, MIT Press, Cambridge Massachusetts.