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ESTIMATING THE ECONOMIC DETERMINANTS OF TECHNICAL EFFICIENCY OF BIOENERGY IN EU-28: AN APPLICATION OF TOBIT ANALYSIS

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ABSTRACT

This study identified the effects of economic factors on technical efficiency (TE) rate in the bio-energy section for the European Union zone (EU-28). A Tobit framework estimation was used to investigate the economic factors of TE rate in the bio-energy sector for the EU-28 zone during the period among 1990 through 2013. The findings point that economic determinants have a significant impact on TE rate of the bio-energy sector in the EU-28 countries. The empirical findings suggest that labor input and gross domestic product (GDP) significantly affected the TE of the bio-energy sector in the EU-28 zone through the duration of this paper. The results obviously inviting governors and politicians to investigate the TE rate of the bio-energy sector within the EU-28 zone. This paper gives further facts and details to the senates of the bio-energy sectors, as they require to get a further comprehension of the impact TE has on bio-energy production execution. In addition, the findings of this paper have suggestions for financiers who concentrates significantly on revenues from their direct-investments.

Contribution/Originality: This study contributes to the existing literature in investigating the TE of the bioenergy industry in the EU-28 region. This study uses new estimation methodologies such as the Data Envelopment Analysis (DEA) and the Tobit Model to investigate the impact of economic determinants on the TE of the bioenergy industry in the EU28 region during the period between 1990 and 2013.

1. INTRODUCTION

Eurostat European Commission Database shows a comparison between bioenergy production and consumption in EU region during the period between 1990 and 2013. Bioenergy primary production in developing countries (such as; Czech, Poland, Latvia, Romania, etc.) increased significantly from 5000 TOE (total of oil equivalent) in 1990 to 16500 TOE in 2013, while developing countries gross inland consumption increased from 500 TOE in 1990 to 24750 TOE in 2013. In addition, the CO_2 trend shows unstable reduction during the period between 1990 and 2013; this refers to that bioenergy production is insufficient and could not meet the bioenergy consumption in developing countries. In developed countries (such as; Germany, France, UK, Finland, etc.), the trend of CO_2 emission reduction did not decrease significantly and was unstable during the period 1990-2013. Moreover, bioenergy production trend shows that in developed countries the production increased from 36000 TOE in 1990 to 60000 TOE in 2013. On the other hand, bioenergy gross inland consumption in developed countries during the

period between 1990 through 2013 has increased significantly in comparison with the production trend from the quantity of 37000 TOE to the level of 100000 TOE. This shows that the consumption trend of bioenergy industry was higher than the production and trend. Confirming the insufficient bioenergy production in the EU-28 region to meet the high consumption. The paper problem can be illustrated that a wide conversion from utilising conventional power output to green power, because of various causes as follows: supply and demand conventional power is raising significantly which is leading to higher environmental pollution.

Furthermore, conventional power production may hardly fill up the global need for power. Moreover, according to the report of IEA (International Energy Agency) in 2012, fossil fuel output will attain the highest rate and will not be capable to fill up the world supply and demand (Geheeb, 2007). Moreover, the conventional energy imports price was raised largely influencing the world energy markets. Furthermore, global warming increased by GHG (greenhouse emission) is destroying the sustainable energy sources by threating the environment and natural resource. The international communities need prompt works in energy industry, by transforming from conventional energy to a sustainable green energy (Geheeb, 2007). The above part referred to that efficiency of bio-energy industry have primary influence to the EU-28 countries energy industry. The EU-28 zone bio-energy industry is not working with high efficiency to achieve the goals of National Renewable Energy Action Plan NREAPs on 31/12/2020. The deficiency in bio-energy output has effected badly in many EU-28 countries economy due to; the high demand and incapability of bio-energy supply to fill up the demand requirements. Also, the inability to achieve the NREAPs goals based on the scholar's investigations without proper actions related to the bio-energy importation from various countries. Furthermore, the decrease of the GHG release in the EU-28 zone is not stable because of the unsteady demand, the output of bio-energy is deficient in many sections, which return badly on the demand and the CO2 release (Scowcroft and Nies, 2011). According to Magar *et al.* (2010) EU-28 zone imported bio-mass from various countries to meet the lack of the bio-energy supply and demand which effected on bio-energy market prices.

The biomass importation will raise the raw material cost which will impact the bio-energy generation gross cost. Material cost has a primary influence on the volume of bio-energy production and production total cost in the domestic energy market. The raising of the total expense of the bio-energy output will drive this industry not to compete with other energy industries in market. The question of the research is which economic factors have impacts on the TE of the bio-energy sector in the EU-28 zone. The research objective is to estimate the TE and pertaining economic factors of the bio-energy sections in EU-28 zone for the duration among 1990 through 2013. The significance of the paper indicate to that the increase of the bio-energy industry efficiency may have a primary role to meet the NREAP goals on 31/12/2020 and fill up the shortage among the enhanced consumption and decreased production without any amendment in the goodness and cost of the generated product. The requirement for the TE in bio-energy sector has turned to an important need in the EU-28 zone, because of the lack in bio-energy production and export demand.

To put it simply, the outstanding of bio-energy consumption and import demand in the domestic and international market of bioenergy. The regression analysis can define the influence of economic factors on TE in the bio-energy sector in the EU-28 countries. The purpose for concentrating on the bio-energy efficiency problems is encouraged by the obvious outgrowth of green and friendly energy sector in the EU-28 zone and taking in consideration the necessity to that EU-28 countries have to achieve the NREAPs goals on 31/12/2020. Therefore, issues pertaining to TE for the EU-28 zone ay boost a lot respectively. The main sections of this research paper as follows; firstly, review empirical and theoretical previous studies. Secondly, illustrates the applied panel data regression. Thirdly, will analyse the economic determinants of the bio-energy sector in EU-28 zone for the period 1990 and 2013. Finally, this study will highlight the conclusion and policy implication.

2. LITERATURE REVIEW

This section shows an experiential review of the various economic factors of TE of the bio-energy sector is given according to earlier papers in different regions and sections applying various mathematical to scale the TE. Republic of China is one of the largest countries in energy consumption, one study (Chang *et al.*, 2003) has measure the efficiency of sustainable and conventional energy for the past few decades. The appropriate utilization of sustainable energy applying recent d high technology shall increase efficiency and evolve the sustainable energy main infrastructure too Chang *et al.* (2003). In another research (Winkler, 2003) points that the proper capital investment in sustainable energy and energy TE in Republic of South Africa is significant to reduce the unfavorable environmental, macroeconomic, microeconomic and social influences from sustainable energy generation. One study Scarlat *et al.* (2013) points to that sustainable energy output might be scaled by the used fixed capital in the generation workflow, this is a significant factor in the procedure to convert sustainable energy in various power sections in Italy Republic and meet the 2020 goals of the NREAPs (Scarlat *et al.*, 2013). In a study Shafie *et al.* (2012) referred the bio-electricity generation in Kingdom of Malaysia relies significantly on the updated technology and systems applied in the generation procedure of converting bio-mass inputs into bio-electricity. In an earlier study (Berndes *et al.*, 2009) pertaining to second-generation of bio-fuel manufacturing product, explored that the capability of the technology input and the efficiency of bio-fuel generation has a positive impacts on the bio-fuel economic condition in energy market.

In Kingdom of Malaysia, Tye *et al.* (2011) pointed to that bio-fuel has an important role in reaching social evolution and outgrowth because of the high possibility as the primary energy source for the transport section. Tye *et al.* (2011) highlighted the important role of bio-fuel from bio-mass in Kingdom of Malaysia by decreasing GHG release, securing energy and energy success as fully independent country in energy sector in future. Earlier research Hu and Wang (2006) estimated the bio-mass energy demand and related efficiency for 29 cities in Republic of China during the period from 1995 through 2002. From empirical point of view, there is an important relationship among the grade of efficiency in the bio-mass energy demand and the consumed scale of feedstock, technology, and human resource. Also, there is an important correlation among the efficiency of bio-mass energy demand in every city and the level of economic growth too (Tye *et al.*, 2011). To put it simple, past research Winkler (2003) indicated that the efficiency of the sustainable energy industry had boosted primary the bio-electricity sector to reach the set evolution level and achieve the scheduled goals in different perspectives such as; health, environment, climate and energy. Chang *et al.* (2003) resulted that the bio-energy sector contributed significantly as the major source of green energy from friendly resources through converting bio-mass into bio-energy, thus participating to outgrowth. Based on earlier papers, efficiency level in the renewable and sustainable industry is the main player in economic evolution (Balat and Balat, 2009; Evans *et al.*, 2010; Kythreotou *et al.*, 2012; Shafie *et al.*, 2012; Scarlat *et al.*, 2013; Alsaleh *et al.*, 2016).

Earlier studies; Caves (1992); Caves and Barton (1990); Carlsson (1972); Debreue (1951); Farrell (1957); Färe and Lovell (1978); Gumbau-Albert and Maudos (1996); Hawdon (2003); Lovell (1993); Perelman (1995); Ramanathan (1999); Sun *et al.* (2015); Tugcu (2013); Winkler (2003); Yudistira (2004); Sufian and Habibullah (2011) investigated the impact of macroeconomic and microeconomic factors on efficiency level in the developing and developed economy. Sufian and Habibullah (2011) applied a DEA data envelopment analysis mathematical approach to compute the TE of the industry in Republic of China during the period 2000 and 2008. In the employed regression analysis for the selected panel data set in Sufian and Habibullah (2011) finding shows that external economic factors have an important influence on the TE in the industry of China Republic. Prior research Lee (2009) is interested one between various papers which computed the efficiency of 173 financial firm in 2005 through using the DEA approach. Another interested paper (Lee, 2009) applied the regression analysis approach to estimate the impact of various factors, like; investment profit, human capital input, and total production cost on the scale of efficiency.

In previous paper, related to another industry in Kingdom of Malaysia during 2002-2004, Sufian (2008) defined the significant influence of external economic factors on the TE rate through applying regression analysis and DEA approach to calculate the TE rate as dependent determinant. In previous research, Campi *et al.* (2015) investigated the impact of factors on energy efficiency for the duration among 2008-2011 in Spanish firms through applying a regression analysis method. Previous research Sufian and Habibullah (2013) investigated the TE alteration in Kingdom of Malaysia through using DEA mathematical approach to compute the TE and applying the regression analysis approach. The study Sufian and Habibullah (2013) resulted a significant influence of economic factors on the TE level of investment industry in Malaysia during the Asian economic crisis.

3. METHODOLOGY AND DATA

Cobb Douglas (CD) theory was evolved and investigated in compare with other assumption and hypothesis in 1947. In its highest common use for production function CD = F (PC, WF) of 1 output with 2 inputs. The theory in Equation 1 can be framed according to the former study for research (Coma and Douglas, 1928). Where they result in their paper (Coma and Douglas, 1928) "A Theory of Production", suggesting that the shape in Equation 1 and Equation 2 pertaining to the correlation among one output E and two inputs; physical capital PC and workforce WF.

$$CD = A\ PC^{1/4}\ WF^{3/4} \tag{1}$$

$$CD = F\ (PC, WF) \tag{2}$$

Depending on earlier studies Sufian (2008); Sufian and Habibullah (2013); Sufian and Kamarudin (2015) and Alsaleh *et al.* (2016); Alsaleh *et al.* (2017); Coelli *et al.* (1998) among others, the current study uses the TE results as the dependent variable and indicator for the bio-energy sector development in the EU-28 zone. In regards to the factors of TE which calculated by the DEA mathematical approach. Early papers McDonald (2009) and Coelli *et al.* (1998) have suggested various studies of how macroeconomic factors may be involved in a DEA estimation. In the regression analysis, the TE findings calculated through the DEA method are estimated on a set of economic factors on the Tobit approach. In a significant development, early paper Banker and Natarajan (2008) gave clarifications that the application of a regression analysis using DEA approach to compute the TE yields solid methods of the regression coefficients. Following one study Sufian (2008) we apply a Tobit model estimation as written in Equation 3:

$$CD^{*}_{i,t} = \delta I_{i,t} + \mathcal{L}_{i,t}: \quad CD^{*}_{i,t} = CD_{i,t},\ \text{if}\ CD^{*}_{i,t} \geq 0\ \text{and}\ CD_{i,t} = 0 \tag{3}$$

While ($CD_{i,t}$) points to the production efficiency based on the case of member state (i) at specific time (t), ($I_{i,t}$) refers to the matrix of the economic factors, (δ) indicates to the coefficient vector, ($\mathcal{L}_{i,t}$) points to the term of random error and tracking statistical noise, (i) refers to the member state, (T) points to the year and (N) related to the observation number in the panel data. By using the TE findings as the dependent determinant in Equation 4, we extend Equation 3 and estimate the below second stage analysis:

$$TE_{it} = \alpha_i + \delta_{it}\ (lnCI_{it} + lnLI_{it} + lnGDP_{it} + lnRIR_{it} + lnDum + lnDum\_LI) + \mathcal{L}_{it} \tag{4}$$

While (TE_{it}) points to the TE of (i) member state in the year (t) resulted by the DEA approach, (lnCI) indicates to the log of physical capital, (lnLI) refers to the log of workforce number, (lnGDP) points to the log of Gross Domestic Product, and (lnRIR) shows the log of real interest rate, (Dum) points to dummy factors, (i) is the member state number, (t) is the studied duration, (α_i) indicates the constant term of member state specific impact, (δ) refers to the coefficients vector, and ($\mathcal{L}_{it}$) error terms . According to previous studies; Banker and Natarajan (2005); Banker and Natarajan (2008) and Banker *et al.* (2010) second-stage estimation is used to examine the relationship among the TE and economic factors.

This study gathers database related to bio-energy sector from EU-28 member states, for the term from 1990 through 2013. The primary sources utilized to collect the secondary data for this paper are EUROSTAT official

website generated and updated by the EU Commission and WBD (World Bank Data) which gives all required database pertaining to bio-energy sector. All employed input; capital and raw material, and output; primary production of bioenergy in TOE tonnes of oil equalised variables were transformed to Thousand TOE tonnes of oil equivalent using the following equation; Thousand TOE=TOE*1000 and all database pertaining to expenses were converted from Billion EUR to Billion USD for comparability.

4. RESULTS AND DISCUSSION

Model 1 shows the influence of specific-country determinants and environmental (external) economics determinants on the TE rate in the EU-28 zone starting from 1990 till 2013 see Table 1. Following previous study Anastasopoulos (2016) Tobit estimator is highly sufficient and aligned with findings of previous study Alsaleh *et al.* (2017) regarding the positive correlation of lnCI and TE. Moreover, shows that lnLI impact positively and significantly on the dependent variable TE at the 1% statistical level. Also, GDP positively and significantly influence the TE at the statistical level 1%. In addition, presents the negative and significant correlation between RIR and the TE at the statistical level 1%. Model 1, shows country dummy variable (Dum) which gave the value 1 for first world countries (developed) and the value 0 for second world countries (developing). The results of Tobit model indicates that economic development condition can positively and significantly impact the TE rate at 10% statistical level. The result suggested that 10% increase in lnLI can enhance the TE level by 5. In addition, 10% raise in the lnGDP may enhance the TE rate by 6. Also, 10% reduce in the lnRIR may enhance the TE by 3.

Table-1. Summary of Tobit panel regression Model 1 for the EU-28 region during 1990-2013.

Model 1. TE Panel Data Analysis Estimation for EU-28 Region 1990-2013	
Determinants	**Tobit**
Constant	−0.695** (0.036)
lnCI	0.009 (0.108)
lnLI	0.053*** (0.000)
lnGDP	0.064*** (0.000)
lnRIR	−0.037*** (0.000)
Country Dum	0.192*** (0.003)
Dum_LI	0.010 (0.372)

- Note: ***, ** and * indicate significance at the 1%, 5%, and 10% levels respectively
- Values in parentheses are P-values

Model 2 regressed the factors of TE rate in EU-28 region for the term starting from 1990 to 2013 (see Table 2). According to previous papers (Anastasopoulos, 2016) the Tobit estimator is highly efficient and consistent with results of previous study that there is positive correlation between lnCI and TE. Also, shows that GDP positively and significantly influence the rate of TE at 1% statistical level. In addition, lnLI positively and significantly affect the TE rate at 1% statistical level. Furthermore, Table 2 provide evidence that lnRIR significantly and negatively impacts the TE rate at 1% statistical level.

Table-2. Summary of Tobit panel regression Model 2 for the EU-28 region during 1990-2013.

Model 2. TE Panel Data Analysis Estimation for EU-28 Region 1990-2013	
Determinants	**Tobit**
Constant	1.805*** (0.000)
lnCI	0.032 (0.171)
lnLI	0.005*** (0.000)
lnGDP	0.041*** (0.000)
lnRIR	−0.044*** (0.000)
Time Dum	0.166 (0.126)
Dum_LI	0.008 (0.101)

- **Note:** ***, ** and * indicate significance at the 1%, 5%, and 10% levels respectively
- Values in parentheses are P-values

The result suggested that the raise of lnLI by 10% can raise the TE percentage by 0.5. Also, 10% enhancement in the lnGDP may lead to enhance the TE level by 0.4. Furthermore, 10% raise in the lnRIR should decrease the TE rate by 0.04. In Table 2, the findings for EU-28 region during the term 1990 and 2013 indicates to the significant influence of the economic growth and period specification on the TE rate.

5. DISCUSSION

In consistent with previous study Alsaleh et al. (2017) Models 1 and Model 2 shows positive and significant relation between lnLI and TE level at the 1% level. This might have a different effect in directorships of the development status of the country. Therefore, in Model 1 we made interaction dummy variable to show the impact of lnLI and the country development status on the TE level. The coefficient on the interaction dummy variable Dum_LI is positive, telling us that we have a positive impact on lnLI and development status on the TE level. In Model 2, dummy variable Dum and interaction dummy variable LI_Dum factors had a positive coefficient, to put it simple, there is a positive relationship between Dum, LI_Dum and TE in the bio-energy sector, which is aligned with previous papers; (Berndes et al., 2009; Sufian and Habibullah, 2011; Meriküll et al., 2012). The EU-28 zone can react variously to the exact TE factors because of the various terms impact (Nielsen, 2011). Thus, we divided the EU-28 zone into Model 1 members specific and Model 2 terms specific for period from 1990 through 2013. Also, in the long-duration of this research from 1990 through 2013, lots of internal, external facts happened in the EU-28 zone, such as; 1990s economic crisis, Koyoto-Protocol agreement in 1997, recent economic skeleton of EU zone in 2000, financial recession in various periods such as: 2007, 2008, 2009, and NREAPs goals by 2020, which influenced the TE of EU-28 zone variously during the term from 1990 through 2013.

Model 1 and Model 2 indicates that the lnCI factor has a positive correlation with TE. Aligning with earlier study Alsaleh et al. (2017) Model 1 and Model 2 shows positive relation among lnCI and TE rate. The regression outcomes in Model 1 and Model 2 can propose that the evolved capital input like; plants and technology, are more sufficient to provide privilege, like raised bio-energy generation product, characteristics and more advantages from various sources of traditional energy aligned with an earlier paper (Scarlat et al., 2013). Bio-energy sector in EU-28 zone relies largely on labour and human capital to enhance the related production. Anyhow, that explains in Model 1 and Model 2 the high importance of lnCI factor in the total production process (Batool and Zulfiqar, 2013). Accordingly, in Model 1 we have created interaction dummy variable to shows the impact of labour input in developing and developed countries on the TE level. Matching with prior study, Model 1 and Model 2 indicates to that ln GDP influence positively and significantly the TE at the 1% statistical level (Alsaleh et al., 2017). Model 1 and Model 2 shows that lnGDP has positively and significantly impacted the TE value in the bio-energy sector in the EU-28 zone; the great the economic outgrowth, the larger TE rate. Model 1 and Model 2 estimation results propose that a higher percentage of economic outgrowth and evolvement indexes leads to higher benefits, like increasing bio-energy outcomes, greater goodness products, larger privilege in the energy market, and high rate of job creating, in line with the former study (Chang et al., 2003). Corresponding with previous study, Model 1 and Model 2 shows that lnRIR negatively and significantly affect the TE at 1% statistical level (Alsaleh et al., 2017). lnRIR factor may have an insignificant influence like an amendment in the IR and significant effect such as enhancing the capital that affects bio-energy sector efficiency. Several former papers (Molyneux and Thornton, 1992; Demirgüç-Kunt and Huizinga, 1999; Pasiouras and Kosmidou, 2007) have resulted that improper change of lnRIR has a negative influence. Thus, implementing improper changes to the IR may disturb the process and lead to negative impact on the capital input (Perry, 1992).

6. CONCLUSION AND RECOMMENDATION

The study addressed a number of significant issues using Tobit model in second-stage based on DEA scores. First of all, most of the investigated microeconomic determinants were resulted to contribute in bio-energy output

but lnLI giving the largest contribution. On the other hand, lnCI factor does not participate significantly in comparison with lnLI. Second macroeconomic factor is lnGDP, which was the highest significant external factor that participated to enhancing the TE rate in comparison with lnRIR. Thus, the lnGDP positively and significantly impact the TE in Model 1 and Model 2 to provide the highes contributor in the TE rate comparing with lnRIR. The findings showed in this paper obviously that TE affected significantly by specific country factors in bio-energy sector in EU-28 zone. Thus, with optimal utilization of available input factors and appropriate designing to deal with external economic factors, TE of bio-energy sector can be raised largely. Hence, our findings do not encourage more enhancing in the space of the factories, because in more increase in space will only give lower increase in production for every proportional increase in inputs, providing from the reality that EU-28 bio-energy sector was generating at minimizing returns to scale among the duration 1990 through 2013, but our findings suggest higher works to be provided to the investors and regulators regarding to achieving sufficient productivity, evolvement in administrative and talent expertise, efficiency allocation of input and highest capacity scale in generation of bio-energy sector in EU-28 zone, which may ease trends for renewable competitiveness on bio-energy sector in the nearest decades.

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