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COST EFFICIENCY OF BIOENERGY INDUSTRY AND ITS ECONOMIC DETERMINANTS IN EU-28: A TOBIT MODEL BASED ON DEA EFFICIENCY SCORES

Mohd Alsaleh[1+]
A.S. Abdul-Rahim[2]

[1,2]*Universiti Putra Malaysia, Malaysia*
[1]*Email: moe_saleh222@hotmail.com*

(+ Corresponding author)

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ABSTRACT

This study looks at how increasing efficiency drives the production of the bioenergy in the European Union (EU-28) region. The paper used the Data Envelopment Analysis (DEA) statistical approach to use the cost efficiency (CE) rate of the bio-energy industry of the EU-28 region as a dependent variable of this study in the first stage of analysis. The study's second stage analysis used the Tobit Model to investigate the impact of economic determinants on the CE of the bioenergy industry in the EU-28 region during the period between 1990 to 2013. The results of the second stage panel regression using Tobit model for the EU-28 region during 1990-2013 shows that CE has positive and significant correlations with capital cost (lnCI) and labour cost (lnLI). The results also show that cost efficiency and real interest rate (lnRIR).have a negative and significant relationship. The study showed that gross domestic product (lnGDP) and CE have a positive and significant relationship in the time specific model, but not in the country specific model. In addition, there is significant and positive correlations between CE and both the Interaction Dummy Country factor (Dum_CP) and the Country Dummy factor (Dum). The estimation also showed insignificant correlations between CE and both the Interaction Dummy Time factor (Dum_CP) and the Time Dummy factor (Dum).

Contribution/Originality: This study contributes to the existing literature in investigating the CE 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 CE of the bioenergy industry in the EU28 region during the period between 1990 and 2013.

1. INTRODUCTION

The bio-energy sector is the primary contributor in the EU-28 agenda to meet the National Renewable Energy Action Plan (NREAP) goals by December 31, 2020 and to maintain access for a local green and friendly energy industry. The EU-28 zone has a plan to minimize the reliance on imported energy, regulate an effective balance of trade, decrease the total cost of energy production, develop rural and urban areas, increase the employment rate, evolve knowledge and technology in energy industry, insist on green and friendly energy, and mitigate greenhouse gas (GHG) releases.

The raw material for bio-mass resources in the EU-28 region is forestry wood, agricultural waste, crops waste, and fishery waste. The EU-28 zone needs to enhance the production of bio-energy by improving the quality of the utilized bio-mass and decreasing the total cost of production to achieve an optimal level of output with an attractive price in the energy market. The NREAP's program in 2010 set out a] statement of aims for the EU-28 zone to meet by 2020: mitigation by 20% in GHG release in compare to the scale of emissions at December 31, 1990, mitigation by 20% in the demand of energy from conventional sources and improvement in efficiency.

One early study by Scowcroft and Nies (2011) pointed to the significant contribution of the bio-energy sector in reaching the NREAP aims. Therefore, this paper concentrated on the significant impact of CE as the primary element in the bio-energy sector in facing the risks such as the bio-mass feedstock gap, imported bio-mass, the increase in the bio-mass total production cost, and global warming influences. CE plays a role in economic development which may be implemented by improving the quality of the inputs to increase CE and produce attractive products for the energy markets (Scowcroft and Nies, 2011).

The investigation shows that 39.02- 56.10%of bio-mass equivalent to 66988.8 thousands to 96296.4 thousands GJ (Gigajoule) of energy can be produced for the local market. In order to fill the shortage, the remaining 43.90-60.98% (equivalent to 75362.4 thousands to 104670 thousands GJ of energy), will be imported from foreign markets. Nearly 200 million to 380 million Euro must be spent in order to make up the shortage from oversea markets (Devogelaer and Gusbin, 2009).

The research problem is that the requirement for a CE methodology in the bio-energy sector has become the major approach in preventing the rise of the overall output expense and the bio-energy output's attractiveness in the energy market because of the enhancement of imported bio-energy products to meet the NREAP in 2020 (Alsaleh *et al*., 2017). As highlighted by Bode and Groscurth (2006) the gross expense of bio-energy output increased significantly in period of 2000, 2007, and 2011, by 0.01 hundred, 0.1 hundred, and 0.2 hundred million Euro, respectively (Bode and Groscurth, 2006). The significance and main contribution of this paper is to define the CE factors of the bio-energy sector in the EU-28 zone. It will also define the microeconomic factors, which influence the CE of the bio-energy sector in the EU-28 zone and define the macroeconomic factors that impact the CE of bio-energy output in the EU-28 zone.

Increasing the CE of the bio-energy output will help the EU-28 zone to reduce its input cost, input and keep the exact output quantity. Including the effectiveness level of the bio-mass import, workforce, and physical capital in the bio-energy output process can decrease the gross cost of bio-energy generation and generate economically attractive products in the energy market. Thus, this will support the set NREAP goals for December 2020 and 2030. The main objective is determining the economic factors of the bio-energy sector in the EU-28 zone using the Tobit model in the second-stage of analysis based on DEA scores from the first stage. The question of this study is which economic determinants have the highest impact on the CE of the bio-energy sector of the EU-28 zone. The revenue from increasing the bioenergy efficiency is questionable because of the high total cost of the bio-energy output so the requirement completely focuses on the bio-energy CE resolution.

2. LITERATURE REVIEW

In one study (Ilic *et al*., 2014) the assets' input price for bio-fuel output in the Kingdom of Sweden could significantly impact the overall generation price of bio-fuel, the manufacturer's site efficiency and capability, and the release of CO2; thus, CE could create attractive products in the energy market. As pointed in a pertaining paper (Le Truong and Gustavsson, 2014) the capital input cost may affect the gross expense of output and CE of the output procedure in the thermal energy industry based on bio-mass factories in the Kingdom of Sweden. The paper by Le Truong and Gustavsson (2014) also investigated the influence of the inflation rate on the overall expense of output and related efficiency.

As suggested in an earlier study (Pihl *et al*., 2010) according to the techno-economic estimation used for the integration of the bio-mass energy and natural gas energy sectors in the EU zone, capital input expenses and bio-mass pricing have an important impact on improving CE and reducing the overall output expense. Tye *et al*., (2011) stated that the CE of second production bio-ethanol could help people transition to sustainable energy, access friendly energy, decrease GHG, develop rural areas, and achieve economic sustainability in the Kingdom of

Malaysia. Balat and Balat, (2009) stated that the CE of the hydrogen output derived from bio-mass relies significantly on the total production input cost and that it has an important influence on energy economics, environmental pollution, and the energy supply. Balat and Balat (2009) proposed that the hydrogen price can affect the inflation rate when the EU regulations upgrade the marginal rate of the total production cost of bio-fuel.

Svanberg *et al.*, (2013) found in another techno-economic investigation related to the influence of workforce input cost, physical capital input cost, bio-mass feedstock input cost, and rate of inflation on the CE scale of bio-mass combustion and compression, generation, and supplying and provide logistic service considering the Swedish regulations. Svanberg *et al.*, (2013) found that the torrefaction supply chain reaps significant economies of scale up to a plant size of about 150-200 kiloton dry substance per year (ktonDS/year), for which the total supply chain costs accounts to 31.8 euro per megawatt hour based on lower heating value (€/MWhLHV). Hoogwijk *et al.*, (2008) stated that the resource efficiency improvement and decreasing operation and investment costs could contribute greatly in using a cost-efficiency approach in bio-mass output and create a large scale of output with attractive bio-electrical products in energy markets (Hoogwijk *et al.*, 2008).

From a theoretical point of view, this study will base the CE investigation on earlier papers such as; Aigner *et al.* (1977); Antonioli and Filippini (2002); Argimon *et al.* (1997) which measured the productivity of the EU zones by impartially providing statistical CE weight and classifying these weights, respectively. This part will show how the EU zones are the almost optimal frontier in the bio-energy sector. Specifically, a stochastic cost hypothesis was used by applying the production theory of Cobb-Douglas. The DEA approach is used by various studies including Sufian and Kamarudin (2015); Gilani (2015); Omar and Jones (2015) and Sufian and Haron (2008). Therefore, we have used the same approach of a recent paper (Alsaleh *et al.*, 2016) which used the DEA method to calculate the CE, the related decomposition allocative efficiency (AE) and the technical efficiency (TE).

Various studies including Caves and Barton (1990); Caves (1992); Carlsson (1972); Farsi and Filippini (2004); Färe and Lovell (1978); Suani *et al.* (2012) were analysed to determine their applied approaches and methods pertaining to CE and regression analysis. The previous studies referred to the CE in various regions and terms. The researchers were also employed in various sectors such sustainable energy, traditional energy and other industries. Many studies analysed the CE and the pertaining decomposition TE and AE. Earlier studies also investigated the macroeconomic and microeconomic factors of the CE in various industries. Staub *et al.* (2010) is among the different studies that estimated the CE and the pertaining decomposition TE and AE from 2000 to 2002 in the Brazilian industry. The study by Staub *et al.* (2010) used the DEA approach to calculate the CE weights. Important studies such as Staub *et al.* (2010) also used various panel data regression model specifications like Baltagi and Wu, Tobit and Dynamic, to regress the factors of CE.

One interesting study (Hassan and Hussein, 2003) investigated the CE of many companies' frameworks in Sudan using the DEA approach to compute the CE for the term from 1992 to 2000. Further investigation (Hassan and Hussein, 2003) defined the CE factors by estimating the micro and macro determinants of the CE. Merkert and Hensher (2011) weighted the CE of 58 companies using the DEA approach for the period from 2007 to 2009. They also applied a fixed effect model and Tobit model based on the DEA efficiency findings to apply a regression analysis and define the factors of the companies' CE.

Another interesting study (Tsionas *et al.*, 2014) investigated the CE of the EU zone manufacturers over the world recession from 2005 to 2012 with short-term and long-term influences. Tsionas *et al.*, (2014) used the DEA mathematical approach to calculate the CE and the related decomposition outcome. Regression analysis for the external and internal factors was used to in order to define the most effective variables of CE in the EU's various manufacturing sectors.

The research reviewed are earlier studies implemented by various authors and agencies in various energy industries and regions. Firstly, most of this research has primarily concentrated on experimental relationships pertaining to the scale of CE and related decomposition AE and TE in various sections such as; energy, environment, industries, resource, banking, etc. and economic growth.

Secondly, the researchers focused on issues pertaining to the influence of the macroeconomic and microeconomic of CE weights in various sectors such as; energy, health, finance, institutions, buildings, insurance and banking.

Thirdly, the mathematical facts related to CE weight presented the influence of each weight of CE in the overall expenses of output in various regions worldwide, and showed the importance of CE in the different industries and in terms of economic development.

Finally, various papers have employed various methods and panel data sets in calculating the CE weights in various industries and sections, zones and states across the world. This study will significantly add new experimental facts on the influence of the external and internal economic determinants on the CE of bio-energy generation in the EU-28 zone from 1990 to 2013, to the existing research. This study will also improve our understanding of the subject by comparing the current findings using the Tobit model analysis with previous studies that used different methods.

3. METHOD AND DATA RESOURCE

This research relies on the CE results calculated by one paper (Alsaleh *et al.*, 2016) using the DEA statistical method (Charnes *et al.*, 1978). According to earlier papers such as; Banker *et al.* (1984) and Coelli *et al.* (1998) the created BCC economic model (Banker, Charnes, and Cooper) was used to estimate the CE results. This part elaborates the economic factors of CE as computed by the DEA mathematical approach following previous studies (McDonald, 2009) and Coelli *et al.* (1998) which resulted in the significant impact of external determinants in DEA weights and related decomposition

In many statistical analyses of individual data, the dependent variable is censored, e.g. the number of hours worked, the number of extramarital affairs, the number of arrests after release from prison, purchases of durable goods, or expenditures on various commodity groups (Greene, 2008). If the dependent variable is censored (e.g. zero in the above examples) for a significant fraction of the observations, parameter estimates obtained by conventional regression methods (e.g. OLS) are biased. Consistent estimates can be obtained by the method proposed by Tobin (1958). This approach is usually called the "Tobit" model and is a special case of the more general censored regression model.

Tobit models are a form of linear regression, also called a censored regression model. If a continuous dependent variable needs to be regressed, but is skewed in one direction, the Tobit model is used. The Tobit model allows regression of such a variable while censoring it so that the regression of a continuous dependent variable can happen. It allows the analyst to specify a lower (or upper) threshold to censor the regression at while maintaining the linear assumptions needed for linear regression. In the standard Tobit model (Tobin, 1958) we have a dependent variable y that is left-censored at zero as showed in Equation 1 and Equation 2:

$$Y_{it}^{*} =: X_{it}'\beta + \varepsilon_{it} \quad (1)$$

$$Y_{it} = \begin{cases} 0 & \text{if } Yt_{it}^{*} \leq 0 \\ Y_{it}^{*} & \text{if } Yt_{it}^{*} > 0 \end{cases} \quad (2)$$

Here the subscript i = 1, . . . , N indicates the observation of the country, Y_{it}^{*} is an unobserved (latent) variable, X_{it} is a vector of explanatory variables, β is a vector of unknown parameters, and ε_{it} is an disturbance term. The term "economic factors" highlights determinants that can impact the weight of CE of a region or member state. In the applied regression analysis, the CE weights of dependent factors computed through the DEA approach are estimated on a panel data set with country criteria and time criteria factors in the Tobit regression model. A previous study (Banker and Natarajan, 2008) showed that using more than one stage estimation, firstly by using a first-stage DEA mathematical analysis to compute the efficiency weights and then using a second-stage estimation, can be a suitable analysis of the regression coefficients. By using the CE weights as dependent variables, we expand Equation 2 and estimate the econometric model as showed in Equation 3 below:

$$CE_{it} = \alpha_i + \beta_{it} (\ln CP_{it} + \ln LP_{it} + \ln GDP_{it} + \ln RIR_{it} + Dum + Dum\_CP) + \varepsilon_{it} \qquad (3)$$

While (CE_{it}) points to the cost efficiency of i member state during the term t provided through the DEA approach, (lnCP) points to log of physical capital input cost, (lnLP) indicates to log of workforce input cost, (lnGDP) refers to the log of gross domestic product, (lnRIR) points to log of rate of real interest, (i) is the members states number, (t) is the study period, (α_i) refers to the constant term, and (β) highlights the vector of coefficients, (ε_{it}) indicates the error term, (Dum) highlights the country specific and time specific dummy variables.

4. RESULTS

In Model 1, the lnCP factor showed a significant and positive relationship with CE and was statistically significant at the 0.10 level, as can be seen in Table 1. The lnLP determinant highlights a significant and positive relationship with CE and was statistically significant at the 0.05 level. In Table 1, the lnGDP determinant showed a positive relationship with CE. Model 1 showed that the lnRIR determinant had a significant and negative correlation with CE and and was statistically significant at the 0.01 scale.

To find the country criteria impact in Model 1 we created the country dummy factor (Dum) with 1 related to developed member states and 0 related to developing member states. To have robustness in the findings we created the interaction dummy factor (Dum_CP) to investigate the influence of development and lnCP on CE. The findings state that there is a significant and positive correlation between the Dum CP and CE at the 0.01 statistical level. The findings showed that a 0.10 enhance in lnCP may increase the CE weighting by 3, a 0.10 enhance in lnLP may increase the CE weighting by 3, a 0.10 enhance in lnRIR may decrease the CE weighting by 0.4, a 0.10 enhance in Dum may increase the CE weighting by 80, and that a 0.10 enhance in Dum_CP may increase the CE weighting by 5.

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

Model 1. CE Panel Data Analysis Estimation for EU-28 Region 1990-2013	
Determinants	**Tobit**
Constant	1.412*** (0.000)
lnCP	0.036* (0.076)
lnLP	0.038** (0.016)
lnGDP	0.029 (0.146)
lnRIR	-0.040*** (0.000)
Country Dum	0.839*** (0.004)
Dum_CP	0.057*** (0.000)

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

In Model 2 the time dummy variable (Dum) was added in order to investigate if there are time specific influences in the data when the p-value is lower than 0.05 as can be seen in Table 2. Based on an earlier study (Ai *et al.*, 2015) the Tobit approach is a sufficient repressor and gives further facts to boost Model 2 in regards to the positive correlation among the CE weighting and the lnLP at the 0.05 statistical level. It also showed a positive and significant correlation among the lnGDP and CE at the 0.01 statistical level. Model 2 presented a significant and negative correlation among lnRIR and CE at the 0.01 statistical level. It also showed a significant and positive correlation among lnCP and CE weight at the 0.10 statistical level. There was also significant and positive correlations between CE and both the Dum_CP and Dum. The findings highlighted that a 0.10 enhance in lnCP may increase the CE weighting by 2. A 0.10 enhance in lnGDP may increase the CE weighting by 6 as the largest contributor, and a 0.10 enhance in lnRIR could decrease the CE weighting by 5. A 0.10 enhance in lnLP could increase in the CE by 3.

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

Model 2. CE Panel Data Analysis Estimation for EU-28 Region 1990-2013	
Determinants	**Tobit**
Constant	0.196 (0.601)
lnCP	0.029* (0.058)
lnLP	0.037** (0.023)
lnGDP	0.064*** (0.000)
lnRIR	-0.050*** (0.000)
Time Dum	0.381 (0.473)
Dum_CP	0.013 (0.601)

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

5. DISCUSSION

Earlier research Alsaleh *et al.* (2017) used the Oriented Least Square (OLS), Fixed Effect (FE) and Random Effect (RE) Models in regression analysis with DEA results for bio-energy sector in the EU-28 zone. Model 1 and Model 2 findings aligned with the outcomes of the earlier study Alsaleh *et al.* (2017) showing that the high lnCP like assets, investment, and feedstock, etc., are able to become sufficient capital because of the increment in benefits, like an enhance in bio-energy generation output and a reduction in the overall generation expense as aligned with one interesting study (Le Truong and Gustavsson, 2014). The Model 1 and Model 2 findings are consistent with the outcomes of the earlier study by Alsaleh *et al.* (2017) that stated that the high lnLP can upgrade the bio-energy sector's CE because of the provided benefits like the increase in bio-energy generation products, reduction in the overall expense of production, and the increase in economic attractiveness in the energy sector. Hence, the higher the lnLP like courses, classes, education, etc., the higher CE we may gain, as found by prior interesting studies; Balat and Balat (2009); Staub *et al.* (2010) and Bourke (1989). In agreement with earlier research by Alsaleh *et al.* (2017) Model 1 estimations confirmed that the high level of economic outgrowth lnGDP and improvement indexes can generate further advantages like enhancing bio-energy productions, minimizing the overall manufacturing expenses of products and creating greater economic attractiveness in the energy market.

According to an earlier study (Perry, 1992) the lnRIR may be revised to impact the firm's productivity positively or negatively. Thus, in Model 1 and Model 2, a high scale of lnRIR can impact the profitability and investment of bio-energy sector negatively. This can create deficiency because of the gap in upgraded instruments, talents and factories which is consistent with the findings of previous research (Alsaleh *et al.*, 2017). In Model 2, Dum and Dum_CP show positive correlations with CE. This means that the suitable economic condition in the study duration is inverted by raising the generation volume and capacity of the EU-28 zone and reducing the cost of production becomes possible because of usage of the optimal CE approach.

The EU global liquidity problem in EU financial markets during the period 2007-2009 would lead to rapid increases in asset prices, upward pressure on European exchange rates, easy access for imported inflation to the EU financial markets, and high limitation for capital flows. The banks' lending to private investors in the EU was negatively affected and showed as decreasing industrial and manufacturing output, decline in EU trades, the increase in the unemployment rate, the significant increase in the fiscal deficit, and gross public debt.

6. CONCLUSION AND POLICY RECOMMENDATIONS

The findings can assist stakeholders in the bio-energy sector whose primary goal is to gain maximum revenue from their business. To put it simply, stakeholders can focus on the possible CE weighting of bio-energy sector in the early stage of their investment. The findings can lead stakeholders to set up appropriate programs and platforms to generate sufficient lnCP and gross fixed capital formation. It is rational to predict that proper decision making can also impact the overall generation expense of the bio-energy sector in the EU-28 zone and the economic attractiveness of products.

This study has made it easier for policymakers to understand the primary influence of the lnGDP as the highest contributor in determining the CE weighting as it can achieve a sufficient scale of AE in the bio-energy sector in the EU-28 zone. Therefore, the lnGDP determinant may contribute significantly in the process of greater CE weighting in the bio-energy sector of the EU-28 zone in the near future.

The findings invite stakeholders, policymakers, and firm directors in the bio-energy industry to review the CE weighting in the EU-28 zone. This is necessary due to the significance of the CE approach for leading the EU-28 zone to become independent in a highly significant green and friendly sources of energy. To improve the CE of the bio-energy sector in the EU-28 zone's in regards to inefficient member states, decision makers should improve the input and input costs and work further to improve the lnCP.

The results provide significant directions and recommendations for financial advisors and directors of the bio-energy sector, as they analyse the influence of lnCP on the weighting of CE in the bio-energy sector. Hence, the bio-energy sector in the EU-28 zone should consider all possible channels related to high technological factories, technology, qualified bio-mass and bio-waste, upgraded machines, and the latest upgraded equipment that enhance the CE level in countries with low level of efficiency.

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