An analysis of eco-efficiency in energy use and CO2 emissions in the Swedish service industries

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Abstract

This study determines the trends in energy efficiency and CO_2 emissions of the Swedish service sector using data at the 2-digit level of aggregation for the Swedish service industry over the period 1993-2008, this empirical study examines eco-efficiency in terms of energy efficiency and CO_2 emissions based on a number of models. The results show that Swedish service industries increased energy consumption and CO_2 emissions during the sample period, whereas energy and CO_2 emission intensities have shown a decrease in recent years. The eco-efficiency model based on data envelopment analysis suggests that Swedish service industries have an excellent potential to increase energy efficiency and reduce CO_2 emissions. Second-stage panel data techniques show that energy taxes, investments and labour productive have a significant and positive influence on energy and CO_2 emission intensities implying that increasing these variables lead to higher energy efficiency and lower CO_2 emission intensity. This analysis demonstrates the importance of designing and applying adequate energy policies that encourage better energy use and management in this industrial sector that include energy taxes and improvement technologies for the goal of achieving a low carbon economy.

JEL Classification: L80, Q4, C33

Keywords: Swedish service industries, CO_2 emissions, energy efficiency, Data envelopment analysis, panel data model

Introduction

Service sector has become an engine of economic growth and is one of the factors used to measure an economy's progress, its development, its quality and its perspectives (Drucker, 2002; Karmakar, 2004; Stern, 2005). In the world, Service industries represent 63.2% of the gross domestic product, occupy 41.9% of the labour force, consume 12% of energy and account for 9% of CO_2 emissions. Between 1974 and 2009, due to the structural changes accompanying the migration from manufacturing to service industries, energy consumption has increased 69% and electricity as main energy source, has increased from 15% to 23% (IEA, 2008 and 2009; CIA, 2011).

In the service industries, several techniques have been applied to study energy use, CO_2 emissions, electricity consumption and barriers to adopting energy saving practices. Mairet and Decellas (2009) analysed energy consumption trends in the French service sector using decomposition analysis, and concluded that the increase in energy consumption was mainly due to growth in the sector. Butnar and Llop evaluated changes in CO_2 emissions from the Spanish service sectors by applying an input–output subsystem approach and structural decomposition analysis. They showed that this sector increased CO_2 emissions mainly because of a rise in the emissions generated by non-services to cover the final demands of services. Collard et al. (2005) analysed the effect of the use of information and communication technologies on electricity intensity in the French service sector using a factor demand model. They found that electricity intensity increased because of the use of computers and software. Schleich (2009) analysed the German context and concluded that limited information about energy use patterns and potential energy efficiency measures are the most important barriers to improving energy efficiency in the service industries.

The goal of this study is to increase the knowledge about energy use and CO_2 emission trends in the service industries. To do so, we apply different econometric approaches to the Swedish service sector in the period 1993-2008. To this end, energy efficiency and CO_2 emissions are analysed using data envelopment analysis (DEA) to assess eco-efficiency in terms of energy use and reduce CO_2 emissions within a production theory framework in which energy is one of the many inputs used to produce desirable or undesirable outputs (Mukherjee, 2008; Zhou and Ang, 2008). The following section describes the data and methodology used in this study. Section 3 presents and analyses the results. The conclusions are presented in Section 4.

Data and methodology

Data

The service industries (excluding electricity, gas and water supply and transportation services), involve activities that take place in buildings used outside of manufacturing, agriculture and households, which comprise offices, banking, education activities, hospitals, retail trade, hotels, restaurants, computer and data processing services, and numerous others (Krackeler et al., 1998; Suh, 2006).

A dataset for Swedish service industries at 2-digit level of aggregation was collected from Swedish statics offices and International Standard Industrial Classification (ISIC Rev. 3.1) for the period 1993-2008. To apply the techniques used in this study, the following variables were obtained: capital input is measured as a stock by taking the value of gross fixed value; labour is measured by the total number of persons employed in service activities; energy is the final energy consumption by service activity measured in Terajoules (TJ); materials are measured by expenditure on materials, and CO_2 emissions are measured in metric tons. All monetary variables are standardised to euro values from 2005.

Methodology

This analysis is conducted in two steps: (i) data envelopment analysis is applied to determine relative efficiencies in energy use and decreased CO_2 emissions, suggesting one model; and (ii) panel data techniques are used to establish factors that may influence trends in the energy efficiency and CO_2 emissions of Swedish service industries.

Measuring eco-efficiency on energy use with DEA. This technique is a nonparametric method for assessing the efficiency of *n* decision making units (DMUs) that consume various inputs to produce different outputs. This technique was proposed by Charnes, Cooper and Rhodes (CCR) in 1979. DEA produces relative rather than absolute measures of technical efficiency for each DMU under consideration because the score of each DMU depends on the performance of the sample of which it is a part (Farrell, 1957; Coelli, 1996; Coelli et al., 2005; Halkos and Tzeremes, 2005).

In this study, one DEA model is suggested to measure eco-efficiency, where a service industry producing a vector of n outputs y from a vector of n inputs $x = (x_1, x_2, \ldots, x_n)$, indicating that the vector y_i

represents the output package and the vector x_i represents the input package of the i_{th} DMU, $i=1\ldots m$. Suppose that input–output data are observed for m DMUs. Constant returns to scale are assumed, this implies that all radial expansions, as well as (non-negative) contractions of the feasible input–output combinations, are also considered feasible.

DEA model evaluates energy efficiency performance within a joint production framework in which both desirable and undesirable outputs are considered simultaneously. Following Zhou and Ang (2008) and Ramanathan (2006), the model considers a production process in which desirable and undesirable outputs are jointly produced by energy and non-energy inputs. Assume that x and y are input and output respectively, with the vectors of energy and non-energy inputs and desirable and undesirable outputs. The model is as follows:

$$\phi^* = max\,\phi \qquad (1a)$$

subject to

$$\sum_{j=1}^{n} x_{mj}\lambda_j \le x_{m0}\ (m = capital,\ labour\ and\ energy) \qquad (1b)$$
$$\sum_{j=1}^{n} y_{pj}\lambda_j \le \phi x_{p0}\ (p = desirable\ output\ and\ undesirable\ output) \qquad (1c)$$
$$\lambda_j \ge 0, j = 1,2,\ldots,n \qquad (1d)$$
$$\phi\text{: } total\ outputs$$

Explaining results through panel data techniques. These techniques are used to determine the factors that might explain differences in eco-efficiency levels across Swedish service industries during the sample period. The results of the DEA model are defined as dependent variables in several panel data models that included multiple determinants of energy efficiency and CO_2 emissions. The DEA scores are log-transformed due to the skewness of the DEA scores and to improve normality. The model used in this study is as follows:

$$RE_{i,t} = \alpha_0 + \alpha_1 ET_{i,t} + \alpha_2 FF_{i,t} + \alpha_3 INV_{i,t} + \alpha_4 PR_{i,t} + \alpha_5 KL_{i,t} + \varepsilon_{i,t} \qquad (7)$$

where $RE_{i,t}$ is the DEA score or energy intensity; $ET_{i,t}$ represents the expenditures in energy taxes applied to the Swedish service industry in period t for service industry i; $FF_{i,t}$ represents fossil fuel consumption; $INV_{i,t}$ are investments; $PR_{i,t}$ is labour productivity, measured as output per worker; and $KL_{i,t}$ is the capital input measured as the capital-labour ratio in period t for service industry i.

Results and discussion

We now show and discuss the results on energy use and CO_2 emissions derived from DEA model explained above to determine the different factors that affect energy consumption and CO_2 emissions in this sector.

DEA Results

Table 1 shows the results of the DEA-model proposed in this study. The average result of the model for the Swedish service industries is 0.722. This result indicates that the Swedish services industries have excellent potential to increase energy efficiency and reduce CO_2 emissions. The model suggests that, on average, the service industries could decrease inputs proportionally by 27.8%, maintain the same levels of desirable output and reduce the levels of undesirable output. These results are consistent with the energy baseline in the 2030 scenario developed by European Commission (2008), which estimated that final energy demand of the service industries is projected to decrease between 30% and 60% in 2030. The findings of the DEA models indicate that several service industries have increased energy efficiencies while decreasing CO_2 emissions. Moreover, results regarding efficiency in energy use and reduce in CO_2 emissions have varied across years and services industries, but they show similar trends with respect to energy intensity and CO_2 emission intensity.

Table 1. Results from DEA model for the Swedish Service Industries

Year	DEA (ϕ)
1993	0.698
1994	0.681
1995	0.732
1996	0.727
1997	0.711
1998	0.694
1999	0.745
2000	0.747
2001	0.733
2002	0.745
2003	0.695
2004	0.718
2005	0.752
2006	0.728
2007	0.691
2008	0.760
Annual Average	**0.722**

Determinants of eco-efficiency in the Swedish service industries

In this section, panel data techniques are applied to explain the observed variation and main factors that determine eco-efficiency across the service industries. The dependent variables are the results of the DEA models.

Table 2 shows the results of the regression analysis for eco-efficiency from the DEA model. The specifications of the test to determine the proper panel data model indicate that, a random effects model is the most appropriate. The estimations of residuals for random effects suggest the presence of heteroscedasticity and serial correlation that must be corrected with maximum likelihood estimation for random effects.

The results show that higher energy taxes, investments and productivity lead to higher eco-efficiency in terms of energy efficiency and reduce CO_2 emissions, while higher fossil fuel consumption reduces eco-efficiency. In addition, the capital-labour ratio demonstrates a complementary relationship between energy and production factors.

Energy taxes have a positive effect on eco-efficiency in terms of energy use and decreasing CO_2 emissions. In the Swedish service sector, these taxes include the fuel and electricity taxes and the CO_2 tax. This taxation system is considered one of the most innovative and effective of those applied around the world because the taxes were indexed and linked to the consumer price index in Sweden.

Table 2. Results of the regression analysis for eco-efficiency (DEA model)

Parameters	DEA model	
	Random effects	MLE
Constant	-0.212 (0.232)	-0.217 (0.233)
Energy Taxes	0.056*** (0.015)	0.057*** (0.015)
Fossil fuel consumption	-0.086*** (0.028)	-0.085*** (0.028)
Investments	0.010 (0.007)	0.010 (0.006)
Labour productivity	0.115*** (0.021)	0.114*** (0.021)
Capital-labour Ratio	-0.144*** (0.021)	-0.143*** (0.021)
F-test statistic	F(18, 280) = 127.60 0.000 *Reject OLS*	
LM test Prob > $chibar^2$	$chibar^2(01)$ = 1448.08 0.000 *Reject OLS*	
Hausman test Prob>chi^2	$chi^2(5)$ = 8.19 0.1461 *Reject FE*	
Test for heteroscedasticity [a] Prob > chi^2	LR $chi^2(18)$ = 328.48 0.000	
Wooldridge test for autocorrelation[b] Prob > F	F(1, 18) = 16.744 0.000	
No. Obs	304	304

***Notes**: Figures in the parentheses are standard errors. *** Significant at the 1% level, **Significant at the 5% level, * Significant at the 10% level.*

[a]If Prob > $chibar^2$ < 0.05, indicate heterocedasticity.

[b]If Prob > F > 0.05, indicate no serial correlation.

Fossil fuels are included in the analysis to determine the role of this fuel in eco-efficiency. The results indicate that a decrease in fossil fuel consumption generates higher eco-efficiency in the form of higher energy efficiency and lower CO_2 emissions in the Swedish service industries. In other words, improved energy efficiency and decreased CO_2 emissions from Swedish industries has been generated by a shift from fossil fuels to low carbon or cleaner fuels, such as electricity.

Investments likely have a positive effect on eco-efficiency but are not significant because investments in the service sector have not primarily attempted to improve energy use or decrease CO_2 emissions. Labour productivity has a positive and significant effect on eco-efficiency, indicating that service industries with higher labour quality of have higher energy efficiency and lower CO_2 emissions.

All of the findings in this study are important for designing suitable energy policies to increase energy efficiency and decrease CO_2 emissions in the service industries. The design and application of various strategies and policy instruments are important because energy consumption have grown the quickest in this sector and have driven the increase in total energy consumption and CO_2 emissions for the whole Swedish industrial sector.

Conclusions

This paper analysed eco-efficiency in terms of energy use and CO_2 emissions in the Swedish service industries during the period of 1993-2008 using DEA and panel data models. The tests used in the different techniques applied in this study demonstrate that the methods are adequate to generate consistent, robust and reliable estimates in the analysis of energy efficiency and CO_2 emissions from DEA.

The results of the DEA analysis indicate that energy efficiency and CO_2 emission intensity varied across years and service industries. Several service industries have increased eco-efficiency by increasing energy efficiency and decreasing CO_2 emissions, especially in recent years. However, this sector has the potential to further improve energy efficiency and decrease CO_2 emissions. The results of the panel data techniques suggest that increased energy taxes, investments and productivity generate higher eco-efficiency, while higher fossil fuel consumption generates lower eco-efficiency. The capital-labour ratio shows a complementary relationship with energy.

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