The influence factor analysis of comprehensive energy consumption in manufacturing enterprises

Tso, Geoffrey K. F.; Liu, Fangtao; Liu, Ke

Published in:
Procedia Computer Science

Published: 01/01/2013

Published version (DOI):
10.1016/j.procs.2013.05.097

Publication details:
Tso, G. K. F., Liu, F., & Liu, K. (2013). The influence factor analysis of comprehensive energy consumption in manufacturing enterprises. *Procedia Computer Science*, *17*, 752-758.
https://doi.org/10.1016/j.procs.2013.05.097

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Computer Science 17 (2013) 752 – 758

Procedia
Computer Science

Information Technology and Quantitative Management (ITQM2013)

The influence factor analysis of comprehensive energy consumption in manufacturing enterprises

Geoffrey KF Tso[a], Fangtao Liu[a*], Ke Liu[b]
[a] Department of Management Sciences, City University of Hong Kong, Hong Kong
[b] *Glorious Sun School of Business and Management, Dong Hua University, Shanghai, China*

Abstract

This paper conducts the influence factor analysis of comprehensive energy consumption based on a Chinese manufacturing enterprise. By multiple regression analysis, the sum of energy consumption is positive correlation relationship with enterprise scale, and it is negative correlation with enterprise efficiency. Thus, comprehensive energy consumption is main dependent on aggregate output and enterprise performance accordingly. Under a constant aggregate output, enhance energy management and establish the energy management standards are the best approach to promote energy efficiency on manufacturing enterprises. Finally, the limitation and the future direction of this study are discussed.

Keywords: comprehensive energy consumption; enterprise performance; aggregate output; multiple regression analysis; influence factor tree

1. Introduction

In United Nations industrial development organization working paper, energy efficiency represents an achievement to boost growth by reduction of the energy consumption bill emissions that are contributing to sustainable development [1]. McKinsey Global Institute (MGI) has found [2]: raising energy productivity will be causing the big gains. Energy-saving as a necessary policy needs, enterprise comprehensive energy consumption has attracted wide attention. The analysis on impact factors plays an important role for industrial production. This study is not only concerned with main factors of energy consumption on manufacturing enterprises, but it focuses more on how to control it based on finished production task in order to further reduce the total energy consumption. However, most existing research is based on reducing energy consumption as the goal through various channels [3], such as a novel generic method to model the energy consumption behaviour of machines [4] or by combining art and technology to reduce energy consumption [5]. However, it is risky to

doi:10.1016/j.procs.2013.05.097

only attach importance to the method, while ignoring the reasons. Thus, the analysis of influencing factors is a problem worth exploring for the manufacturing enterprise. Because of manufacturing production, production products must consume the necessary energy. Only based on the thorough research of the main elements on energy consumption, we can take the most scientific approach and reasonable policy to control it.

The purpose of the study was to identify the main influence factors on comprehensive energy consumption and judge the effective approach to control it in manufacturing enterprises. According to the results, establish the best balance relationship between energy consumption and production for enterprise operation management. Nevertheless, some internationally accepted standards and methods do not necessarily fit the actual situation of the individual enterprise. The analysis of enterprise data, combined with the international advance method, may help find the most feasible flow path. On this basis, it is better to derive the energy policy formulation and further empirical research.

The rest of the paper proceeds as follows: section 2 presents the general methodology and experiment design. Experiment results from field investigations are reported and analyzed in section 3. Section 4 concludes.

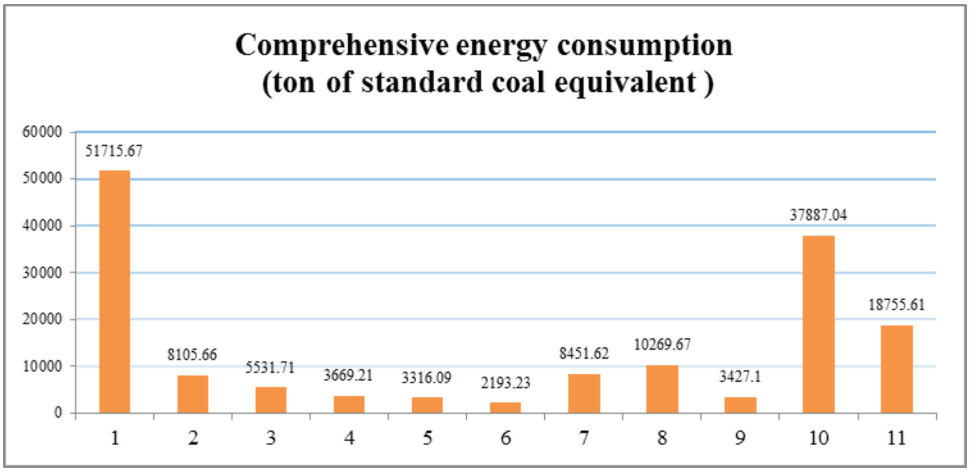
2. Experimental study

2.1. Experimental case

For the study sample, we selected a typical Chinese manufacturing enterprise group that has 11 subsidiary companies in different provinces and more than 22,000 employees. These 11 subordinate enterprises have the similar basic functions and take the same production tasks with certain comparability.

According to the enterprise's statistics yearbook, the data of comprehensive energy consumption and other indicators are all from unified source, as shown in Table 1. The sum of comprehensive energy consumption reached 153322.61 ton of standard coal equivalent totally. Based on the sample data, we conducted the next descriptive analysis, factor analysis and multiple regression analysis. It aims to understand the reason of actual energy consumption and judge the logistic relationship between different factors.

Table 1: The comprehensive energy consumption in each subordinate enterprise



2.2. Hypothesis

In my study, it derives the causal relationship via running a quantitative analysis and to identify the main energy efficiency adoption factors. In manufacturing enterprises, comprehensive energy consumption, amount of the all energy consumed in producing and management operation is usually calculated by the ton of standard coal equivalent in manufacturing enterprises. In manufacturing enterprise, management, technology, produce, fixed assets and cost may play the main factors of the impact on energy consumption.

Management: enterprise performance considers the results of enterprise operation and management in all facets of the enterprise via a closed-loop model, which includes business planning, daily management, financial management, supply chain effectiveness and so on.

Technology: total-factor productivity estimated using a Cobb-Douglas production function [6], called multi-factor productivity is a variable which accounts for effects in total output not caused by traditionally measured inputs. If all inputs are accounted for, then total factor productivity can be taken as a measure of an economy's long-term technological change or technological dynamism [7]. It has also been shown it was always used to reflect the energy conversion efficiency.

Produce: aggregate output represent all goods and services produced in economy the total value of all the goods and services produced, and also reflect the production capacity of enterprises.

Fixed assets: depreciation expense as the portion of a tangible capital asset that is deemed to have been consumed or expired, and can be viewed as an expense.

Cost: comprehensive cost is an amount that has to be paid or given up in order to get something, reflects enterprise financial cost.

To explore the relationship between comprehensive energy consumption and the above indicators, we provided hypotheses to clarify the relationship. Thus, we predicted the following.

Hypothesis 1: Comprehensive energy consumption in manufacturing enterprises will be influenced by these five variables.

H1 (a): Enterprise performance had a significant correlation relationship with energy consumption.

H1 (b): Total factor productivity had a significant correlation relationship with energy consumption.

H1 (c): Aggregate output had a significant correlation relationship with energy consumption.

H1 (d): Depreciation expense had a significant correlation relationship with energy consumption.

H1 (e): Cost had a significant correlation relationship with energy consumption.

The methodology that we use in the paper is the factor analysis that is applied to the energy efficiency barriers used in our study. The principal component factor analysis involves a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components [8]. By principal component factor analysis (see Table 2), the principal components (eigenvalue > 1) had 89.48% cumulative contribution; the figure should be over 85% to reach the common factor scale cumulative proportion effectively [9]. Based on varimax with Kaiser Normalisation rotation, we deduced the two component factors according to the common direction from the indicators, which were defined, respectively as efficiency factor and scale factor.

Table 2: Comprehensive energy consumption factor model

Rotated Component Matrix			Communality (Extraction)
Indicators	Component factor		
	Scale	Efficiency	
Cost	0.94		0.86
Aggregate output	0.93		0.90

Depreciation expense	0.91		0.90
Total factor productivity		0.94	0.89
Enterprise performance		0.86	0.93
Eigenvalue	3.33	1.14	
Percent variance explained %	54.09	35.39	
Cumulative contribution %	38.89	89.48	

To prove the relationship of comprehensive energy consumption, based on the results of factor analysis, we can identify the two common factors in according to eigenvalue and variance explained.

Efficiency factor is consistent with total factor productivity (factor loading is 0.94) and enterprise performance (factor loading is 0.86), reflect the enterprise's management and efficiency.

Scale factor is consistent with cost (factor loading is 0.94), aggregate output (factor loading is 0.93) and depreciation expense (factor loading is 0.91), reflect the enterprise's assets and scale.

Thus, we provided hypotheses that these two factors will play significant roles to influence the energy consumption. Specifically, we adopted the following hypotheses.

Hypothesis 2: Comprehensive energy consumption in manufacturing enterprises may be influenced on the efficiency factor and scale factor.

H2 (a): When efficiency factor was higher, comprehensive energy consumption was lower based on a negative correlation relationship.

H2 (b): When scale factor was higher, comprehensive energy consumption was higher based on a positive correlation relationship.

2.3. Methodology

We will use the Pearson correlation analysis to determine the causal relationship between each indicator and comprehensive energy consumption and verified the assumption H1.

Multiple regression analysis is used to establish regression relationships between indicators and comprehensive energy consumption. Meanwhile, it is judged the effectiveness of two factors and tested the hypothesis H2.

On this basis, to verify the results of the H1 and H2, constructing the influence factor tree is to select the final key indicators or factors and define their effectiveness.

3. Results

3.1. Pearson correlation analysis

Using Pearson correlation analysis (see Table 3), we can test the hypothesis as follows. Enterprise performance had a significant negative correlation relationship with comprehensive energy consumption ($p<0.01$); aggregate output and comprehensive cost had a significant positive correlation relationship with comprehensive energy consumption ($p<0.01$). Thus, H1 (a), H1 (c) and H1 (e) were not rejected.

Table 3: correlation analysis between comprehensive energy consumption and relative indicators

	Enterprise performance	Total factor productivity	Aggregate output	Depreciation expense	Cost
Enterprise performance	1				
Total factor productivity	.733*	1			

Aggregate output	-.517	-.252	1		
Depreciation expense	-.424	-.394	.828**	1	
Cost	-.506	-.312	.866**	.882**	1
Comprehensive energy consumption	-.790**	-.450	.811**	.588	.772**

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

3.2. Multiple regression analysis

The concept behind a regression model is very simple, but the interpretation of the coefficients is not the simple linear regression. By multiple regression analysis, comprehensive energy consumption as dependent variable had a significant regression relationship with aggregate output (p-value < 0.01) and enterprise performance (p-value < 0.05). Because R^2_{adj} is 0.81 and F test is 27.87 (p-value<0.01), it proved the model had a good fitness and significant. By collinearity statistics test, tolerance is 0.73 and VIF is 1.37, it showed there was no multicollinearity between two variables.

$$Y= 151005.473+ 0.002\times X_1 - 1753.777\times X_2 \quad (1)$$

Y: Comprehensive energy consumption
X_1: Aggregate output (p-value < 0.01)
X_2: Enterprise performance (p-value < 0.05)

Aggregate output is scale factor while enterprise performance is efficiency factor, we can test the hypotheses about the relationships between energy consumption and aggregate output and enterprise performance. If aggregate output is constant, when enterprise performance was higher, comprehensive energy consumption was lower based on a negative correlation relationship. If enterprise performance is constant, when aggregate output was higher, comprehensive energy consumption was higher based on a positive correlation relationship. Thus, H2 (a) and H2 (b) are not rejected.

There are two approaches to reduce the energy consumption of the manufacturing enterprises. Based on the constant aggregate output, to enhance enterprise performance is helped to reduce energy consumption; based on the current enterprise performance, to reduce aggregate output is helped to reduce energy consumption. However, in according to the needs of development, based on the existing enterprise scale, to improve the performance is the best effective approach to control the comprehensive energy consumption. Nevertheless, the other indicators can be further analysed, which also can affect the energy consumption.

3.3. Influence factor analysis

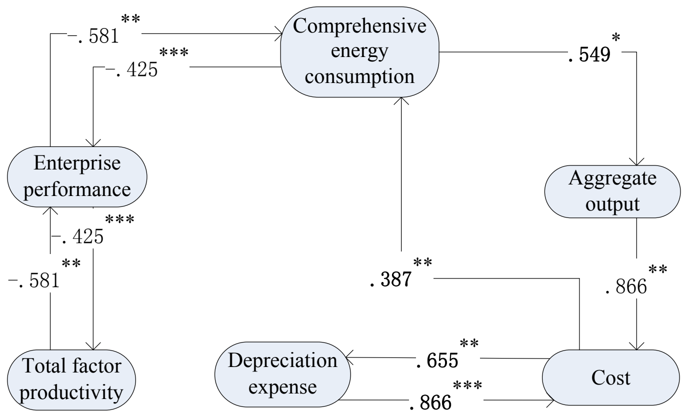


Figure 1: Constructing the influence factor tree by multiple regression analysis

In manufacturing process, how to judge the energy efficiency maximization and the optimized combination is an important research topic [10]. By multiple regressions analyze the influencing factors, results from the regression models showed the relationship from each influencing factors to comprehensive energy consumption as given in Figure 1. We used standardized regression coefficient as a causal relationship connected the variables (see Table 4). The optimal multivariate regression model shows the correlation relationship (R^2_{adj}, F test, p-value) between each variable. Thus, we can safely conclude that the comprehensive energy consumption is main dependent on aggregate output and enterprise performance. The aggregate output is influenced by cost in maximum extent, and enterprise performance is dependent on the total factor productivity and comprehensive energy consumption simultaneously.

Table 4: Multiple regression models

	Multiple regression models	R2adj	F/ p-value
1	$Y_{\text{Comprehensive energy consumption}}=151005.473+0.002\times X_{\text{Aggregate output}}-1753.777\times X_{\text{Enterprise performance}}$	0.807	21.871**
2	$Y_{\text{Aggregate output}}=4596463.868+27.830\times X_{\text{Cost}}$	0.749	26.900**
3	$Y_{\text{Enterprise performance}}=83.567+1.328\times X_{\text{Total factor productivity}}+0.000\times X_{\text{Comprehensive energy consumption}}$	0.754	16.352**
4	$Y_{\text{Total factor productivity}}=-16.659+0.262\times X_{\text{Enterprise performance}}$	0.538	10.466*
5	$Y_{\text{Cost}}=-15624.409+10.531\times X_{\text{Depreciation expense}}+2.773\times X_{\text{Comprehensive energy consumption}}$	0.846	28.447***
6	$Y_{\text{Depreciation expense}}=4367.503+0.055\times X_{\text{Cost}}$	0.779	31.668***

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

4. Discussion and conclusion

Under a constant aggregate output, enhanced energy management by enterprise performance is important within business strategy and that the quantification and assessment of energy consumption for the manufacturing industrial sector and energy efficiency are input indicators to be used in improvement and optimization processes within sustainability development [11]. The energy management standards established, providing guidance for manufacturing enterprises, is an effective control approach. And it needs to integrate energy efficiency into their management practices and experience [12], including fine-tuning production processes and improving the energy efficiency of industrial systems. In addition, investments in energy efficiency and energy management innovation [13] are the best approach to promote energy efficiency on manufacturing enterprises.

This study mainly focuses on data gathered from single enterprise, whose results may not generalize across different manufacturing industries. Thus horizontal comparison in different manufacturing industries is needed in future research. Using only the year of data, the study is not sufficient on the longitudinal research. Multi-year vertical comparison in a period is valuable in the future research. The transformation of the equation and the combination of the regression model, are the focus in next step. How to further reduce the energy consumption via improving management approach is also the focus in the next stage of research.

Reference

[1] Cantore, N., 2011. Factors affecting energy efficiency adoption in the manufacturing sector in developing countries. United Nations industrial development organization working paper 15; p. 105.

[2] Park, C., W., Kwon, K., S., Kim, W., B., Min, B., K., Park, S., J., Sung, I., H., Yoon, Y., S., Lee, K., S., Lee, J., H., Seok, J., 2009. Energy consumption reduction technology in manufacturing — A selective review of policies, standards, and research, International Journal of Precision Engineering and Manufacturing Issue 5, volume 10 ; p. 151-173.

[3] Dietmair, A., Verl , A., 2009. A generic energy consumption model for decision making and energy efficiency optimisation in manufacturing. International Journal of Sustainable Engineering issue 2, volume 2; p. 123-133.

[4] Holmes, T., G., 2007. Eco-visualization: combining art and technology to reduce energy consumption. C&C '07 Proceedings of the 6th ACM SIGCHI conference on Creativity & cognition; p. 153 – 162.

[5] Farell, D., Remes, J., 2009. Promoting energy efficiency in the developing world. McKinsey& Company

[6] Cantore., N, Velde, D., W., te., 2011. Promoting energy efficiency in developing countries – new evidence based on firm analysis. United Nations industrial development organization working paper 15; p. 32.

[7] Bai, Y., P., Niu, J., P., Hao, Y., P., 2012. Research of Regional Energy Efficiency Based on Undesirable Outputs and Its Influential Factors: A Case of Western China. Energy Procedia.

[8] Stevens, J., 2002. Applied Multivariate Statistics for the Social Sciences. 4th edn. Mahwah, NJ: Lawrence Erlbaum Associates.

[9] Stevens, J., 2002. Applied Multivariate Statistics for the Social Sciences. 4th edn. Mahwah, NJ: Lawrence Erlbaum Associates.

[10] He, Y., X., Tao, W., J., Zhang, S., L., Li, Y., Li, F., R., 2007. Factors Decomposition of Energy Intensity: The case of Liaoning province in China, International journal of systems applications, engineering & development issue 3, volume 1.

[11] Martínez, C., I., P., 2010. Factors influencing energy efficiency in the German and Colombian manufacturing industries, Energy Efficiency.

[12] Cantore, N., 2011. Factors affecting energy efficiency adoption in the manufacturing sector in developing countries. United Nations industrial development organization working paper 15; p. 105.

[13] Cantore, N., 2011. Factors affecting energy efficiency adoption in the manufacturing sector in developing countries. United Nations industrial development organization working paper 15; p. 113.