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Energy Saving, Emission Reduction Efficiency and Control Measures of Industrial Pollution in Henan Province, China

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ABSTRACT

The rapid industrial development in recent years in Henan Province, China, has caused relatively serious environmental pollution. Increasing energy saving and emission reduction efficiency and controlling industrial pollution play an important role in strengthening environmental protection and improving people's living standards. To further analyse the industrial pollution status in Henan Province, estimate the industrial emission reduction efficiency, and propose specific industrial pollution control measures, the current situations and problems of industrial pollution in Henan Province were analysed, and an evaluation index system of industrial emission reduction efficiency was established based on related statistical data on environmental pollutants in China's Statistical Yearbook on Environment from 2000 to 2014. The energy saving and emission reduction efficiency and the slack variables of input-output were estimated by using the DEA-CCR (Data Envelope Analysis) model. Results demonstrated that the discharge of industrial waste gas and industrial wastewater in Henan province showed a rising trend, and the amount of industrial dust emissions and industrial soot emissions were reduced to a great extent. The comprehensive efficiency of DEA-CCR model in 11 years is effective for DEA, and the scale efficiency and comprehensive efficiency are not optimal in the 2000 and 2001. The emission reduction efficiency of industrial pollutants did not reach technical and scale efficiencies in 2006 and 2011. With respect to input indexes, investments in the management of exhaust, wastewater, and other pollutants in 2006 were underused. All five input indexes were underused in 2007. For output indexes, exhaust emission did not reach the effective output in 2006, and the exhaust and wastewater emissions failed to reach the effective output in 2007. The results obtained in this study have important practical significance and theoretical references for comprehending the industrial pollution status and increasing the emission reduction efficiency in China.

INTRODUCTION

The long-term economic development mode of "high consumption, high pollution, and low output" in China is realized at the expense of natural and ecological resources. Pollution caused by rapid industrial development in recent years has become one of the important factors that influence the living environment of human beings. Most environmental pollutions are attributed to industrial pollutions. Hundreds of types of industrial pollutions exist, which mainly include atmospheric, water, and solid waste pollution. Controlling industrial pollution and increasing emission reduction efficiency play an important role in improving economic development and people's living standards.

Henan is a heavy industrial province in China where industries are the main factor that facilitates economic development. However, economic development has introduced considerable industrial pollution problems in Henan Province. During the 11th Five-year Plan, the main industrial pollution in Henan Province was controlled to some extent, the ecological protection level increased gradually, and the basin environmental quality in key areas improved significantly through a series of measures, such as vigorous promotion of engineering construction for pollution control, strengthened environmental protection, and ecological construction in rural areas. Nevertheless, the overall environmental pollution remains serious. Table 1 shows that industrial exhaust and wastewater emissions rose with fluctuations, while industrial dust and smoke emission reduced significantly. In realizing the strategic goal of building a well-off society in a holistic way, improving environmental quality, and significantly reducing the total emission of major pollutants in Henan Province, whether industrial pollution could be controlled well and whether emission reduction efficiency could be increased are the key factors in the 12th Five-year Plan. Therefore, specific control measures that involve estimating the emission reduction efficiency of industrial pollutants in Henan Province have important practical significance and theoretical references.

STATE OF THE ART

In recent years, industrial pollution reduction has become a universal environmental management measure throughout the world. Related studies mainly focus on pollution reduction efficiency and how environmental quality can be improved by reducing and limiting pollutant emissions. In estimating pollution reduction efficiency, Tietenberg comprehensively introduced the concept of emission trading. Emission trading means that government can sell pollution emission licenses to enterprises through an auction to achieve maximum pollution control and allow emission rights to be traded between enterprises. Ciampe believed that the energy performance contracting system is a feasible way to save energy (Ciampe 2004). Fisher-Vanden studied key factors to increase energy efficiency according to carbon emission characteristics and technological innovations of enterprises in China (Fisher-Vanden et al. 2006). Hu presented a total factor efficiency evaluation method and used it to evaluate energy efficiency in 29 administrative districts in China from 1995 to 2002 (Hu & Wang 2006). Zhou evaluated energy efficiency in the economic field and calculated changes in energy efficiency under different energy structural combinations by using the data envelopment analysis (DEA) model (Zhou & Ang 2008). Park established the energy saving index system, which represents the production capacity of the manufacturing industry (Park et al. 2009). Bian established an overall evaluation system to assess resources and environmental efficiency in different provinces in China (Bian & Yang 2010). Shi evaluated the overall energy, pure technical, and scale efficiencies in 28 provinces in China (Shi et al. 2010). Xie evaluated the dynamic environmental efficiency of electric power industries in BRICS (Brazil, Russia, India, China and South Africa) by using environmental indexes (Xie et al. 2014). With respect to energy saving and emission reduction measures, countries prefer to control pollution emissions through market economic means under government leadership. Miranda analysed the relationships of environmental tax with petroleum, coal, and natural gas usage in Sweden (Miranda & Hale 2002). Michel studied energy saving projects with government support and evaluated the facilitation of energy saving policies on energy saving programs and the implementation effects of policies (Michel 2004). Nwaobi evaluated the influences of greenhouse gas reduction policies on economic development in Nigeria, determined the effectiveness of carbon tax policies, and found that the carbon emission trading licensing system is an important policy that influences greenhouse gas emission in Nigeria (Nwaobi 2004). Knutsson discussed the collaborative effect of trading green certificate and trading emission permission of greenhouse gases in Sweden (Knutsson et al. 2006). Mayor established a model of aviation carbon tax, domestic travel, and number of international visitors in Great Britain; this model fully proved the influences of different levels of aviation carbon tax on domestic and international tourists and the evaluated effects of aviation carbon tax policies (Mayor & Tol 2007). Gillenwater evaluated the influences of international emission trading policies on economic welfare, CO_2 leakage, and international capital flow (Gillenwater & Breidenich 2009). Rogge analysed the influences of emission trading policies in European countries on technological innovation, energy supply, emission limit, and economic development (Rogge et al. 2011). Levin deemed that carbon emission tax can accelerate the transformation from traditional energy sources to renewable energy sources, and evaluated the influences of state policies on renewable energy sources (Levin et al. 2011). Existing research indicates that the acceleration of urbanization and industrial modernization will produce and discharge abundant industrial pollutants. Controlling industrial pollution emissions and increasing industrial emission reduction efficiency through market means under government leadership play an important role in improving economic development and people's living standards. To analyse industrial emission reduction efficiency in Henan Province more comprehensively, the industrial emission reduction efficiency in Henan Province from 2000 to 2014 was estimated, and specific energy saving and emission reduction efficiency measures were proposed. Furthermore, the improvement direction of industrial emission reduction in Henan Province was presented. Our findings have important practical significance and theoretical references in studying the industrial emission reduction efficiency in Henan Province.

INTRODUCTION TO THE MODEL AND DATA SOURCE

Model Introduction

DEA was proposed by Charnes, Coopor, and Rhodes in 1978. Based on the concept of relative efficiency, DEA calculates and evaluates the relative efficiency of a decision making unit (DMU) through mathematical planning. Unlike other efficiency evaluation methods, DEA cannot determine specific forms of function, and it possesses the absolute advantages to evaluate the multiple input and output of a complicated system.

Suppose that n DMUs exists and each DMU has m inputs and s outputs. X_{ik} is the i^{th} input variable of the k^{th} DMU, and Y_{jk} is the j^{th} output variable of the k^{th} DMU. For the DEA-CCR model, linear planning is shown in Equation (1).

$$\min \theta$$
$$\begin{cases} \sum_{j=1}^{n} X_j \lambda_j \le \theta X_k \\ \sum_{j=1}^{n} Y_j \lambda_j \ge Y_k \\ \lambda_j \ge 0, j=1,2,......n \end{cases} \quad ...(1)$$

Where, $X_k = (X_{1k}, X_{2k}......X_{mk})$
$Y_k = (Y_{1k}, Y_{2k}......Y_{sk})$

The DEA-CCR model is gained under constant returns to scale. θ is the efficiency value of DMU, $0 \le \theta \le 1$. When θ=1, the efficiency of DMU is effective. When θ<1, the efficiency of DMU is ineffective.

Establishment Principles of Index System and Data Source

Establishment principles of index system: A perfect index system must be established under the guidance of scientific principles. On the basis of the original establishment principles of the index system, the principles for establishing this index system were proposed in this paper by combining industrial pollution reduction efficiency.

***1. Representativeness*:** The evaluation index system must be able to explain practical problems in industrial pollution reduction efficiency in Henan Province, China. Unrelated factors or factors that are less correlated with industrial pollution reduction efficiency are overlooked.

***2. Consistency*:** Evaluation indexes should be consistent with the evaluation goal. The evaluation goal is an important basis to establish the index system and should be determined first during systematic evaluation. Therefore, as another important component of evaluation activities, the evaluation index system should be combined with the evaluation, and evaluation indexes should be used to select the factors that can be used to evaluate the goal achievement.

***3. Comprehensiveness*:** Evaluation indexes should reflect the comprehensive industrial pollution reduction efficiency in Henan Province. Therefore, attention should be paid to reliability and comprehensiveness when choosing evaluation indexes.

***4. Operability*:** All chosen indexes should be easy to understand and use, and they should be able to obtain actual values easily. The actual values of evaluation indexes could be obtained either by actual data analysis or quantization based on existing methods. If the actual value of one index could not be obtained by the above two methods or other methods, then the index could not be used as the evaluation index.

Data source: Five input indexes were used in this paper: investment for exhaust management in Henan Province (X1, RMB 10,000), investment for solid waste management in Henan Province (X2, RMB 10,000), investment for wastewater management in Henan Province (X3, RMB 10,000), investment for other pollutants' management in Henan Province (X4, RMB 10,000), and number of completed projects in Henan Province in the current year (X5, projects). Four output indexes were used: exhaust emission in Henan Province (Y1, 100 millions of standard m^3), solid

Table 1: Industrial waste emissions in Henan Province from 2000-2014.

Year Pollutants	Industrial exhaust emission (100 millions of standard m^3)	Industrial wastewater emission (10,000 tons)	Industrial dust emission (tons)	Industrial smoke emission (tons)
2000	7436	109241	817734	691000
2001	9239	110152	705490	644511
2002	10645	114431	682472	623069
2003	11992	114224	733777	633713
2004	13103	117328	725411	705000
2005	15498	123500	704346	857000
2006	16770	130158.09	564000	725000
2007	18890.39	134344.32	415000	637200
2008	20264	133144.12	287000	532243
2009	22186	140325	249100	521000
2010	22709	150406	227000	474000
2011	23041	138800	201412	465124
2012	23541	137400	198451	452141
2013	24012	130788.77	189547	445974
2014	24874	128000	184574	435474

Data were collected from China's Statistical Yearbook on Environment (2001–2015) waste emission in Henan Province (Y2, 10,000 tons), wastewater emission in Henan Province (Y3, 10,000 tons), and gross industrial production (Y4, RMB 100 millions). All data were collected from related chapters in China's Statistical Yearbook (2001-2015) and China's Statistical Yearbook on Environment (2001-2015). The study period was from 2000 to 2014.

EMPIRICAL STUDY

Estimation of industrial pollution reduction efficiency: Industrial pollution reduction efficiency in Henan Province, China, was estimated by DEAP2.1. The estimated results in different years are listed in Table 2.

In Table 2, the comprehensive efficiency of pollution reduction is equal to the product of pure technical and scale efficiencies. Pure technical efficiency refers to the relationship between input elements and outputs. In this paper, pure technical efficiency refers to the influences of unit investment for pollution reduction on gross industrial production and exhaust, wastewater, and solid waste emissions. Scale efficiency refers to the influences of unit investment for optimal allocation on outputs. Returns to scale refer to influences of scale-up of input elements on gross outputs. Viewed from the aspect of comprehensive efficiency, the comprehensive efficiency in the CCR model reached the optimal value (1) in 11 years, thereby indicating that it reached DEA efficiency. In other words, both scale and technical efficiency are realized simultaneously. Industrial pollution reduction in Henan Province in 2000 and 2001 is a DMU of technical efficiency. However, it failed to achieve the optimal comprehensive efficiency because the scale efficiency did not reach its optimal point. Industrial pollution reduction in Henan Province in 2006 and 2011 did not reach technical and scale efficiencies. In other words, it failed to achieve DEA efficiency.

Slack variables of industrial pollution reduction: If the slack variables of input indexes are not equal to 0, then the input elements are all fully used in the year. Table 3 shows that the slack variables of the input indexes were not 0 in 2006 and 2007. X1, X3, and X4 in 2006 were underused, which should be adjusted and strengthened to make full use of capitals. All five input indexes were underused in 2007, which may be influenced by the invalid environmental management of the previous year, thus resulting in decision making error of environmental resource investment of the year.

Similarly, if the slack variables of the output indexes are not equal to 0, then the output indexes are inadequate, thereby indicating that it does not realize the effective output. Table 4 shows that the slack variables of the output indexes in 2006 and 2007 were not 0. Y1 did not reach the effective output in 2006, while Y1 and Y3 did not reach the effective output in 2007. These results are mainly due to poor matching of industrial pollution investment and number of projects with industrial pollutant emission, thus resulting in unsatisfactory pollution control of high-emission and high energy-consuming industries, as well as inadequate capitals and scientific strength for industrial pollution reduction.

SPECIFIC ENERGY SAVING AND EMISSION REDUCTION MEASURES

Accelerating the adjustment of industrial structure and development of energy saving and emission reduction technologies: The industrial development in one country or region is an important factor that influences energy utilization and cleanliness of pollution emission, and is the core of an energy saving and emission reduction policy system. Controlling existing industrial development and facilitating the development of emerging industries should achieve a balance between economic growth and structural adjustment. This measure accelerates the adjustment of the industrial structure, vigorously promotes the development of high and new technology industries, facilitates independent innovation, releases policies on high-tech industrialization development, searches advantageous high-tech industries in this region according to regional development level, and achieves breakthroughs in electronics, information technology, biological technology, and new materials. In addition, the proportion of modern service industries in the economy is expected to increase. As an important environmental-friendly smokeless industry, the modern service industry is the key concern in structural adjustment and is the scientific structural adjustment method in finance, tourism, business, and logistics. With respect to economic growth, existing industries should be updated and optimized continuously through various efforts, such as restricting the development of thermal power, facilitating the development of new energy sources (wind and solar energy), increasing the transformation and upgrading of production technologies of industrial enterprises, developing environment-friendly building materials, restricting the development of heavy industries (steel, coal, and chemical engineering), and using advanced energy saving and emission reduction technologies. Management of non-point source agricultural pollution should be strengthened, and high-quality modern agriculture should be developed.

Releasing emission reduction policies and paying attention to the market orientation: China's government at all levels needs to pay attention to the balance of different economic regulation policies. When releasing punitive taxes

Table 2: Estimated results of industrial pollution reduction efficiency in Henan Province from 2000-2014.

Year efficiency value	Comprehensive efficiency value	Pure technical efficiency	Scale efficiency
2000	0.901	1	0.901
2001	0.865	1	0.865
2002	1	1	1
2003	1	1	1
2004	1	1	1
2005	1	1	1
2006	0.838	0.869	0.964
2007	1	1	1
2008	1	1	1
2009	1	1	1
2010	1	1	1
2011	0.773	0.945	0.818
2012	1	1	1
2013	1	1	1
2014	1	1	1

Table 3: Slack variables of input indexes in DEA evaluation of industrial pollution reduction efficiency in Henan Province, China.

Year/ Input indexes	X1	X2	X3	X4	X5
2000	0.000	0.000	0.000	0.000	0.000
2001	0.000	0.000	0.000	0.000	0.000
2002	0.000	0.000	0.000	0.000	0.000
2003	0.000	0.000	0.000	0.000	0.000
2004	0.000	0.000	0.000	0.000	0.000
2005	0.000	0.000	0.000	0.000	0.000
2006	78950.459	0.000	12475.014	8412.542	0.000
2007	0.000	0.000	0.000	0.000	0.000
2008	0.000	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000	0.000
2011	298745 .547	1254 .653	20187 .654	15472 .654	102 .352
2012	0.000	0.000	0.000	0.000	0.000
2013	0.000	0.000	0.000	0.000	0.000
2014	0.000	0.000	0.000	0.000	0.000

to high-polluting industries, special financial support to environmental protection industries needs to be increased to ensure economic structural adjustment during energy saving and emission reduction by economic means; such a measure maintains pollution control and protects economic development. The goal of increasing energy utilization and reducing pollution emission could be realized by creating and implementing energy saving and emission reduction policies, such as market regulation mechanism, management of contracting energy sources, market auditing of emission trading, and carbon emission trading. Measures that encourage trades should be implemented among energy saving and emission reduction industries to facilitate the economic growth of these industries and accelerate the applications and promotions of energy saving and emission reduction technologies. Such measures include formulating corresponding policies, encouraging the development of scientific technologies, innovating new energy saving and emission reduction technologies, and promoting scaled and industrialized development through reward and favourable measures. Industrial development of new energy saving and emission reduction technologies will not only increase production and economic efficiency, but also decrease energy consumption and pollution emission, thus facilitating energy saving and emission reduction comprehensively and evenly.

Determining the cyclic economic development way by depending on whole society participation in energy saving and emission reduction: The participation of the entire society should not be neglected when formulating energy saving and emission reduction policies. According to foreign experiences, effective promotion of energy saving and emission reduction is closely related with participation of the public. Different energy saving and emission reduction activities need to be implemented in enterprises and public institutions. Furthermore, education and promotion of related issues among the public should be increased to make them comprehend the importance of energy saving and emission reduction in their daily life; this step in particular will ensure that they will not formulate empty opinions about the matter. In cyclic economic development, governments at all levels can achieve energy saving and emission reduction by increasing the technological level, establishing a resource recycle system in economic development through corresponding energy saving and emission reduction policies, and forming a closed loop of different resources from the perspective of input, production, and consumption, thus realizing harmonious development between the economy and the natural environment. This approach covers comprehensive utilization of resources, industrial utilization of renewable resources, recycling of garbage, and utilization of water resources.

Perfecting laws and regulations on energy saving and emission reduction, and strengthening administrative supervision: Standards of pollution reduction catalogue, energy consumption, market access, water resource consumption, and pollution emission that conform to actual industrial production, energy demands, and pollution reduction status in Henan Province need to be developed as soon as possible. Suggested approaches include strengthening the construction and organization of pollution reduction supervision teams and their capabilities, enhancing the super-

Table 4: Slack variables of output indexes in DEA evaluation of industrial pollution reduction efficiency in Henan Province, China.

Year/ Output index	Y1	Y2	Y3	Y4
2000	0.000	0.000	0.000	0.000
2001	0.000	0.000	0.000	0.000
2002	0.000	0.000	0.000	0.000
2003	0.000	0.000	0.000	0.000
2004	0.000	0.000	0.000	0.000
2005	0.000	0.000	0.000	0.000
2006	598.457	0.000	0.000	0.000
2007	0.000	0.000	0.000	0.000
2008	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000
2011	468.654	0.000	2.987	0.000
2012	0.000	0.000	0.000	0.000
2013	0.000	0.000	0.000	0.000
2014	0.000	0.000	0.000	0.000

vision of key energy consumption units and pollution sources, and strictly controlling illegal activities to reduce pollution in Henan Province. Other methods include setting the basic goal of energy saving and emission reduction and formulating main incentive measures; making full use of the media to promote policies, measures, and examples; regularly publishing related data (e.g., responsible organization, goal, and time limit) to the public; supervising society and monitoring public opinions; perfecting the energy saving supervision system; strengthening personnel training; and perfecting an industrial pollution reduction system that integrates the management, supervision, and service of the entire province. Important posts in key energy-consuming enterprises must include managers of industrial pollution reduction. Moreover, the construction of an energy management centre needs to be accelerated, and an enterprise supporting system that involves energy saving decision making, management, and technologies, especially in steel, petrifaction, and building material industries, must be perfected.

CONCLUSIONS

Henan Province in China, suffers from serious industrial pollution. The high emissions of atmospheric pollution, water pollution, and solid wastes have exceeded the environmental capacity. Pollution reduction has become a commonly used environmental management measure throughout the world. It improves environmental quality mainly by reducing and limiting pollutants' emissions, and has achieved remarkable results in improving the atmospheric and water environments. Based on statistical data of environmental pollutants in Henan Province from 2000 to 2014, the industrial pollution status and problems in Henan Province are analysed, and the evaluation index system of industrial pollution reduction efficiency in Henan Province is established. Slack variables of input and output indexes of industrial pollution reduction efficiency are estimated in the DEA-CCR model. Research results demonstrate that industrial exhaust and wastewater emissions in Henan Province increase with fluctuations, whereas industrial dust and smoke emissions reduce significantly. The comprehensive efficiency in the DEA-CCR model reached DEA efficiency in 11 years. However, the comprehensive efficiency in 2000 and 2001 is unsatisfactory due to poor scale efficiency. The industrial pollution reduction efficiency did not reach technical and scale efficiencies in 2006 and 2011. With respect to input indexes, investments in the management of exhaust, wastewater, and other pollutants in 2006 were underused. All five input indexes were underused in 2007. For output indexes, exhaust emission did not reach the effective output in 2006, and the exhaust and wastewater emissions failed to reach the effective output in 2007. Given that this paper focuses on pollution reduction efficiency and control measures in Henan Province from 2000-2014, further studies are recommended to introduce new monitoring and evaluation methods, perfect the collection of key data related to industrial energy saving and emission reduction, and cover different industries in different provinces. Other evaluation methods and DEA evaluation method could be combined and used to evaluate energy saving and emission reduction efficiency so as to provide more scientific and reasonable evaluation methods for associated studies.

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REFERENCES

Bian, Y. and Yang, F. 2010. Resource and environment efficiency analysis of provinces in China: A DEA approach based on Shannon's entropy. Energy Policy, 38(4): 1909-1917.

Ciampe, F. 2004. Third party financing and energy performance contracting-An integrated financing and managing technique born from and for energy efficient projects. Energy Engineering, 24(1): 13-16.

Fisher-Vanden, K., Jefferson, G. H. and Jingkui, M. et al. 2006. Technology development and energy productivity in China. Energy Economics, 28(5): 690-705.

Gillenwater, M. and Breidenich, C. 2009. Internalizing carbon costs in electricity markets: Using certificates in a load-based emissions trading scheme. Energy Policy, 37(1): 290-299.

Hu, J. L. and Wang, S. C. 2006. Total-factor energy efficiency of regions in China. Energy Policy, 34(17): 3206-3217.

Knutsson, D., Werner, S. and Ahlgren, E.O. 2006. Short-term impact of green certificates and CO_2 emissions trading in the Swedish district heating sector. Applied Energy, 83(12): 1368-1383.

Levin, T., Thomas, V. M. and Lee, A.J. 2011. State-scale evaluation of renewable electricity policy: The role of renewable electricity credits and carbon taxes. Energy Policy, 39(2): 950-960.

Mayor, K. and Tol, R.S.J. 2007. The impact of the UK aviation tax on carbon dioxide emissions and visitor numbers. Transport Policy, 14(6): 507-513.

Michel, R. 2004. Government Support for Energy Saving Projects. Lecture Notes in Computer Science, 3183(6): 97-101.

Miranda, M.L. and Hale, B. W. 2002. A taxing environment: Evaluating the multiple objectives of environmental taxes. Environmental Science & Technology, 36(24): 5289-5295.

Nwaobi, G.C. 2004. Emission policies and the Nigerian economy: simulations from a dynamic applied general equilibrium model. Energy Economics, 26(5): 921-936.

Park, C.W., Kwon, K.S. and Kim, W.B. et al. 2009. Energy consumption reduction technology in manufacturing-A selective review of policies, standards, and research. International Journal of Precision Engineering and Manufacturing, 10(5): 151-173.

Rogge, K.S., Schneider, M. and Hoffmann, V.H. 2011. The innovation impact of the EU emission trading system-Findings of company case studies in the German power sector. Ecological Economics, 70(3): 513-523.

Shi, G.M., Bi, J. and Wang, J.N. 2010. Chinese regional industrial energy efficiency evaluation based on a DEA model of fixing non-energy inputs. Energy Policy, 38(10): 6172-6179.

Xie, B.C., Shang, L. F. and Yang, S.B. et al. 2014. Dynamic environmental efficiency evaluation of electric power industries: Evidence from OECD (Organization for Economic Cooperation and Development) and BRIC (Brazil, Russia, India and China) countries. Energy, 74(5): 147-157.

Zhou, P. and Ang, B.W. 2008. 2008. Linear programming models for measuring economy-wide energy efficiency performance. Energy Policy, 36(8): 2911-2916.