Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 15	No. 4	pp. 1125-1132	2016

Original Research Paper

Trend and Factor Analysis of Beijing Areas' Economic Performance under Restrictions of Resource and Environment

Le Yang, Haiyan Wang† and Junkang Liu
School of Information Science and Technology, Beijing Forestry University, Beijing 100083, China
†Corresponding author: Haiyan Wang

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 29-09-2015
Accepted: 10-12-2015

Key Words:
Environmental efficiency
Total factor produtivity
Luenberger total factor productivity
Data envelope analyze model

ABSTRACT

Combining the feather of SBM directional distance function and Luenberger Index, and using the new method of productivity index's construction and decomposition, the paper studied the trend and factor analysis of Beijing area's economic performance under restrictions of resource and environment over the period of 2009-2013. Results showed that: (1) Energy consumption and pollution emissions mainly contributed to the inefficiency of Beijing's economy growth. And the regional environmental efficiency presented obvious differences from the city centre to the edge of the city, the central area with developed economy and the edge area with good environment. (2) During the 2009-2013, the trends of Beijing's Luenberger Total Factor Productivity (LTFP) was opposite to those of environmental efficiency, with the middle of the city highest. The development of suburban areas was relatively quick. (3) From a dynamic perspective, Beijing's economic performance was mainly influenced by changes in technical borders. Finally, the paper put forward relevant suggestions to enhance economic growth of Beijing and every area.

INTRODUCTION

As China's capital, Beijing's environmental conditions not only are the attention focus of people at home and abroad, but also directly affect the citizen's health and quality of life. Currently, the situations of Beijing's resource environment are not optimistic. Beijing's per capita water resources are 1/7 of the national average level, and only 1/28 of world level; more than 90% energy relies on outside; Beijing's population density is ten times as large as the national average level. At the same time, the total of Beijing's pollutants emissions is far beyond the scope of environmental accommodating. The country and Beijing municipal government issued a series of policies and regulatory regime about resource and environment. Under the high-intensity environment regulations, it's important for the sustainable development of Beijing to establish and improve the evaluation methods of environmental efficiency and Total Factor Productivity (TFP).

So far, a lot of scholars have been studying economy and environmental problems that the world need to solve, and have made certain achievements. Early in 1942, the concept of "efficient level" was first put forward. Soon after, Total Factor Productivity (TFP) was proposed. Then Shephard (1970) studied theory of cost and production functions. Caves et al. (1982) constructed Malmquist Index. Chung et al. (1997) presented Malmqusit-Luenberger (ML) productivity index. Reinhard et al. (2000) estimated environmental efficiency with multiple environmentally detrimental variables. Yan et al. (2004) measured the technical efficiency, technical progress and Malmquist productivity index of 30 Chinese provinces during 1978-2001. Using Stochastic Frontier Function, Li et al. (2008) estimated TFP of 34 Chinese industrial sectors. Wang et al. (2010) studied environmental efficiency and Environmental Total Factor Productivity growth in China's Regional Economies. Xie et al. (2010) researched utility Malmquist Index. Yang et al. (2010) did a research in evaluation and determinants of environmental efficiency of China. Liu et al. (2012) analysed Chinese economy based on a new method of productivity index. Tu et al. (2013) studied the China's industry based on the network data envelope analyze (DEA) model. Meng et al. (2013) measured environmental performance in China's industrial sectors with non-radial DEA. Bai et al. (2013) finished the research on regional environmental performance and its influential factors. Wang et al. (2013) measured energy and environmental efficiency of China regions in the period of 2000-2008 through the improved DEA model. Arabia et al. (2014) studied a new slacks-based model in Malmquist-Luenberger Index measurement. Jing et al. (2014) researched economic opening and China's industrial green technology progress. In overall, China's environmental TFP research is mainly focused on the industry and province.

Compared with existing researches, the study objects of the paper which included 16 Beijing counties were more specific, and the paper put environmental factors of counties into the overall analysis framework. According to SBM and Luenberger function and using a new method of productivity index's construction and decomposition, the paper analysed the impacts input and output factors made on TFP, thus providing practical advice for the development of Beijing and regions.

RESEARCH METHODS

Environmental technology and technical border: Viewing Beijing every county as a production decision-making unit (DMU), the article constructs Beijing's the best production borders of each period. According Fä re et al. (2007), we construct a production possibility set, namely environmental technology that includes "good" output and "bad" output. Assume K DMUs. And each DMU has three elements of input, desirable output and undesirable output. Assume N kinds of input, $x = (x_1,...,x_N) \in R_N^+$ M kinds of desirable output $y=(y_1,...,y_M) \in R_M^+$ and I kinds of undesirable output $b=(b_1,...,b_I) \in R_I^+$. In each period of t=1,...,T, kth (k=1,...,K) DMU's input and output values are (x_k^t, y_k^t, b_k^t). Under a series of assumptions that production possibility set is the closed set and bounded set, that desirable output and input can be freely disposed of, that it is the zero binding axiom and so on, environmental technology is expressed as:

$$P^t(x^t) = \{(y^t, b^t): \vec{\lambda}Y \geq y_{km}^t, \forall m; \vec{\lambda}B = b_{ki}^t, \forall i; \vec{\lambda}X \leq x_{kn}^t, \forall n; \vec{\lambda} \geq 0\} \quad ...(1)$$

Where $\vec{\lambda}$ is the weight vector, and,Y, B and X are the data of desirable output, undesirable output and input in process of constructing production border. If production technology is variable returns-to-scale (VRS), the formula need add the constraint of $\vec{\lambda}l = 1$, where l is a vector whose elements are all 1. Otherwise it is constant returns-to-scale (CRS).

SBM directional distance function: According to previous studies, the paper considers SBM directional distance function under restrictions of resource and environment. The SBM function is defined as (Eq. 2):

$$S_v^t(x_k^t, y_k^t, b_k^t, g^x, g^y, g^b) = \frac{1}{3}\max\left(\frac{1}{N}\sum_{n=1}^{N}\frac{s_n^x}{g_n^x} + \frac{1}{M}\sum_{m=1}^{M}\frac{s_m^y}{g_m^y} + \frac{1}{I}\sum_{i=1}^{I}\frac{s_i^b}{g_i^b}\right)$$
$$st.\ \vec{\lambda}Y - s_m^y = y_{km}^t, \forall m;\ \vec{\lambda}B + s_i^b = b_{ki}^t, \forall i;\ \vec{\lambda}X + s_n^x = x_{kn}^t, \forall n;$$
$$\vec{\lambda} \geq 0, \vec{\lambda}l = 1;\ s_n^x \geq 0, s_m^y \geq 0, s_i^b \geq 0 \quad ...(2)$$

Where (x_k^t, y_k^t, b_k^t) are k's vector of input and output, (g^x, g^y, g^b) are direction vector, and (s_n^x, s_m^y, s_i^b) that respectively represent excessive input, excessive pollution and inadequate output is the relaxation vector of input and output. By the equation, we can get k's inefficient value under considering environment in the period of t. To get specific sources of inefficiency, inefficiency is resolved into:

$$IE = S_v^t = IE_v^x + IE_v^y + IE_v^b \quad ...(3)$$

The inefficient values of IE^x (input), IE^y (desirable output) and IE^b (undesirable output) are expressed as:

$$IE^x = \frac{1}{3N}\sum_{n=1}^{N}\frac{s_n^x}{g_n^x};\quad IE^y = \frac{1}{3M}\sum_{m=1}^{M}\frac{s_m^y}{g_m^y};\quad IE^b = \frac{1}{3I}\sum_{i=1}^{I}\frac{s_i^b}{g_i^b} \quad ...(4)$$

Since the input includes energy, labour and capital, and undesirable output mainly includes PM_{10} density, SO_2 density, NO_2 density and amount of rubbish, the formula (3) is further decomposed as:

$$IE = IE_{energy} + IE_{labour} + IE_{capital} + IE_{GDP} + IE_{PM_{10}} + IE_{SO_2} + IE_{NO_2} + IE_{rubbish} \quad ...(5)$$

LTFP index: Chambers et al. (1996) developed a new method of productivity measurement, namely Luenberger Total Factor Productivity (LTFP). So between t and t+1, LTFP can be expressed as:

$$LTFP_t^{t+1} = \frac{1}{2}\left\{\begin{matrix}[IE_t(t) - IE_t(t+1)] + \\ [IE_{t+1}(t) - IE_{t+1}(t+1)]\end{matrix}\right\} \quad ...(6)$$

In the process of solving $IE_t(t+1)$、$IE_{t+1}(t)$

sample points taken do not participate in the establishment of technical borders, so there will be the case of no feasible solution. Referring to the ideas of Liu et al. (2012), the paper builds a new LTFP model.

According to the formula (2), GIE and CIE, which are under two different technical borders, are expressed as:

$$GIE_c(t) = CIE_c(t) + TG_c(t) \quad ...(7)$$

Where GIE represents the environmental inefficiency value under unified border (intertemporal DEA), CIE shows the environmental inefficiency value under current border (current DEA), the "c" indicates CRS, and TG is technical gap which expresses the object's efficient gap under different technical borders. Different from the equation (6), LTFP is obtained by the formula (7). It is:

$$LTFP_t^{t+1} = GIE_c(t) - GIE_c(t+1) \quad ..(8)$$

If the production DMU's efficiency in the period of t+1 is higher than that in the period of t under the unified border, the corresponding $GIE_c(t+1)$ will be less than $GIE_c(t)$. And $LTFP_t^{t+1}$ is positive, otherwise negative. Similarly, LTFP can be further decomposed into efficient change (LEC) and technical progress (LTP). They are:

$$LEC_t^{t+1} = CIE_c(t) - CIE_c(t+1) \quad ...(9)$$

$$LTP_t^{t+1} = TG_c(t) - TG_c(t+1) \quad ...(10)$$

The formula (8), (9) and (10) have similar meaning. We will not explain the formula (9) and (10) in detail. Here, the equation (7) is further deduced. The result is (Eq. 11).

Where $LTFP_t^{t+1}$ is broken down into, $LTFP^x$, $LTFP^y$ *and* $LTFP^b$ that respectively represent input's, desirable output's and undesirable output's influences on LTFP. Be seen from the above, LTFP is decomposed into LEC and LTP that are also expressed by the above formula. The detail is not listed here.

EMPIRICAL RESEARCH ON ENVIRONMENTAL EFFICIENCY AND LTFP

Beijing Municipal Development and Reform Commission issued a plan that was about Beijing functional areas' development in the 11th 5-year period, on December 6th, 2006. The planning pointed out that Beijing would build 4 major functional areas, including Capital functional core area, Urban functional expansion area, Urban development new area and Ecological conservation development area. In the paper, 2009-2013 year is a study interval, and 16 Beijing counties and 4 functional areas are basic research units. The data of input, desirable output and undesirable output are mainly from Beijing Statistical Yearbook, Beijing Regional Statistical Yearbook, the counties' statistical yearbooks and so on. Input includes labour, capital and energy. Desirable output is measured with the counties' GDP. The undesirable output consists of PM_{10} density, SO_2 density, NO_2 density and amount of rubbish.

The results and decomposition of environmental efficiency: Using the intertemporal DEA and the current DEA, the paper makes use of Beijing counties' sample data during 2009-2013, and structures Beijing's best border under restrictions of resource and environment. Because intertemporal DEA uses sample data to build a unified technical border, the results are bigger than those of current DEA. To accurately compare efficiency, the paper is mainly based on the results of intertemporal DEA. The paper calculates the environmental inefficiency value under two assumptions of CRS and VRS. Table 1 lists the functional areas' environmental inefficiency averages and source decomposition of inefficiency based on the assumption of VRS.

The data showed that the average of Beijing's environmental inefficiency was 0.1872 during 2009-2013. Of input, output, and pollution, output-related inefficiency was the lowest and only 0.0503, which indicated inadequate output was not the main reason for Beijing environmental inefficiency. Compared with the output, input of which the relevant inefficiency was 0.0612 made bigger impact on Beijing's environmental efficiency. Pollution inefficiency was 0.0757, and it accounted for 40.44% of the total environmental inefficiency that was the highest. Among the pollution factors, PM_{10} density had the largest effects on environmental inefficiency followed by SO_2 density. The combined inefficiency of energy and pollution was 0.1017 and 54.33% of environmental inefficiency, which showed it is quite important for sustainable development of Beijing's economy to save energy and reduce emissions.

The orientation of Beijing's each functional area was different, so their values of environmental inefficiency quite

$$LTFP_t^{t+1} = \underbrace{GIE_c^x(t) - GIE_c^x(t+1)}_{LTFP^x} + \underbrace{GIE_c^y(t) - GIE_c^y(t+1)}_{LTFP^y} + \underbrace{GIE_c^b(t) - GIE_c^b(t+1)}_{LTFP^b} \quad ...(11)$$

Table 1: Environmental inefficiency and source decomposition of Beijing and each functional area 2009-2013 (VRS).

Area	Total	Input	Contents			Output	Pollution	Contents			
			Energy	Labour	Capital			PM_{10}	SO_2	NO_2	Rubbish
Beijing	0.1872	0.0612	0.0260	0.0002	0.0350	0.0503	0.0757	0.0253	0.0199	0.0156	0.0148
Capital functional core area	0.0699	0.0176	0.0021	0.0017	0.0138	0.0000	0.0523	0.0174	0.0134	0.0115	0.0099
Urban functional expansion area	0.2530	0.0644	0.0288	0.0000	0.0356	0.1137	0.0749	0.0280	0.0171	0.0132	0.0168
Urban development new area	0.2547	0.1028	0.0476	0.0000	0.0552	0.0427	0.1093	0.0332	0.0292	0.0251	0.0218
Ecological conservation development area	0.1138	0.0345	0.0118	0.0000	0.0227	0.0273	0.0520	0.0184	0.0155	0.0098	0.0082

varied. The Table 1 showed the environmental inefficiency first increased and then decreased from the city centre to the edge of the city, which was due to economic level's decline from the city centre to the middle of the city and environmental quality's rise from the middle of the city to the edge of the city. From the perspective of areas, the average inefficiency of Capital functional core area was 0.0699, with environmental pollution being a major source of inefficiency. Though Ecological conservation development area had good ecological quality, its industrial base was weak. And the area's environmental inefficiency that was mainly influenced by pollution was 0.1138. Urban functional expansion area was a high-tech base of the nation, and its environmental inefficiency was 0.2530 with insufficient output being the main source of inefficiency. Urban development new area that was the main carrier of Beijing high-tech industries, modern manufacturing and modern agriculture had great potential to develop. The area's environmental inefficiency whose major sources were input-related and output-related inefficiency was 0.2547. The area should pay attention to reduce input, increase output and control pollution emissions. To sum up, environmental pollution was a common problem faced by each area.

The results and decomposition of LTFP: Luenberger Total Factor Productivity (LTFP) can effectively analyze functional areas' efficient change and technical progress. The paper uses the Ruixiang and Tongliang's (2012) Environmental TFP construction method to calculate LTFP. Then the index is broken down into efficient change (LEC) and technical progress (LTP). During the 2009-2013, LTFP's relative results of Beijing and each functional area are shown in Table 2.

According to Table 2, the average of Beijing's LTFP, where LEC was 0 and LTP was 0.77%, was 0.77%, which showed technical progress promoted productivity's rising. Meanwhile, each functional area's LTFP was obviously different. Urban functional expansion area's LTFP whose growth speed was very fast was 1.83%, reaching the highest value in 4 areas. Secondly, it is Urban development new area whose LTFP was 0.98%. The area's LEC was the main reason for productivity growing, accounting for 59%. Capital functional core area's LTFP was 0.59%, with LTP accounting for 97% of LTFP. Ecological conservation development area's environmental efficiency was high, but its LTFP that was -0.22% was far lower than the city's level. And the area's efficiency relatively worsen, which might be related to the area's functional orientation.

In the Fig. 1, LTFP's sources were decomposed during 2009-2013. As it could be seen from the figure, Beijing's LTFP rose in 2010, which was mainly due to LTFP's increase of Urban development new area, while efficiency and technology decline of Capital functional core area slowed the increase of Beijing's LTFP in 2010. In 2011, Beijing's LTFP was positive, mainly fuelled by LTP, and efficiency generally worsened. Urban functional expansion area's technology had the biggest advance. Capital functional core area's efficiency the most seriously worsened. Efficiency and technology simultaneously decreased in Urban development new area, thus leading to the area's negative LTFP. In 2012, a sharp decline in LTFP, with most areas' LTFP negative, mainly was owing to efficient reduction. Then efficiency was the worst in Urban development new area and areas' technical progress was commonly not obvious. In 2013, each area's development kept imbalanced. The LTFP got enhanced in Urban development new area and Capital functional, which was mainly due to efficient improvement. However, efficient deterioration of other functional areas led to LTFP's decrease.

Table 2: LTFP's, LEC's and LTP's average growth rate of Beijing and each functional area (%).

Area	LTFP	LEC	LTP
Beijing	0.77	0.00	0.77
Capital functional core area	0.59	0.01	0.57
Urban functional expansion area	1.83	-0.13	1.95
Urban development new area	0.98	0.58	0.40
Ecological conservation development area	-0.22	-0.49	0.27

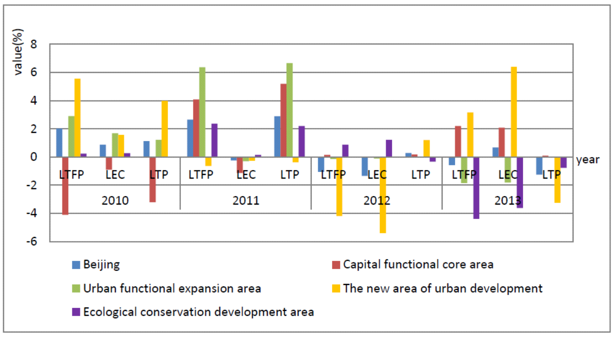

Fig. 1: LTFP, LEC and LTP of Beijing and each functional area 2009-2013.

FACTOR ANALYSIS OF BEIJING AREAS' ECONOMIC PERFORMANCE UNDER RESTRICTIONS OF RESOURCE AND ENVIRONMENT

Static factors analysis of LTFP: Table 3 shows partial decomposition results of LTFP average during the 2009-2013. In the table, the impact of pollution on Beijing's LTFP was the largest, with relevant pollution LTFP being 0.66%. In PM_{10}, SO_2, NO_2 and rubbish, the impact of PM_{10} density on LTFP was the most significant. Input's impact on LTFP was a little smaller than pollution's. In input factors, capital had the larger influences on LTFP, with is being 0.13% and relative LTFP of energy being 0.1%. The relevant LTFP of combining energy and pollution was about 0.79%, which showed Beijing environmental inefficiency was caused mainly by high energy consumption and heavy pollution. So saving energy and reducing emissions were the main way to improve Beijing's economic performance.

From the aspect of areas, the LTFP of Beijing's functional areas had different influence factors. For Urban functional expansion area, the pollution-related LTFP was 1.1%, which was the highest in the input, output and pollution. It indicated effective environmental management was the main way to improve the area's economic performance. Capital functional core area's economy was relatively developed, but output-related LTFP was 0, and the pollution-related LTFP was as high as 1.02%. The reason for above situation was possibly that the area's economy was developed and that its output inefficiency was so very low that it is difficult to increase output inefficiency. Therefore, managing pollution became a major source of the area's economic growth. In contrast with Capital functional core area, output-related LTFP of Urban development new area was 0.76%, while pollution-related LTFP was only 0.11%. This indicated that economic growth in the area was mainly dependent on the economic fast development and that environmental management and input efficiency had relatively small influences. For Ecological conservation development area, average LTFP was negative and productivity declined year by year.

Dynamic trend analysis of LTFP: The above finished LTFP's static decomposition based on input-output factors. Meanwhile, the paper also needs to analyze dynamic trends of LTFP. Because LTFP, LEC and LTP can be respectively obtained by GIE's, CIE's and TG's difference in adjacent period. Then the paper would study changes of the above 3 variables to give a reasonable explanation for economic growth, technical advances and efficient improvements in Beijing and each functional areas.

1. GIE's change path under the unified border: Fig. 2 shows the trends of GIE and related components in Beijing and functional area during the 2009-2013. According to the formula (8), the paper explained LTFP's changes by means of GIE's trends. The figure showed that Beijing GIE's value in 2011 was a node, first declining and after slowly rising, which was a direct reason for LTFP's declining during the 2011-2013. Overall, LTFP's change trends in Beijing were relatively stable in the period of analysis. Besides, pollution-related GIE had the largest influences.

For functional areas, the reasons for impact on their economic performance were different. At the aspect of input, output or pollution efficiency, Capital functional core area reached to the highest level in Beijing. Because of developed economy, the area's output-related inefficiency was on the best technical border. As Input-related inefficiency had been increasing year by year, its proportion was small. And pollution-related inefficiency was a major source of environmental inefficiency. Environmental inefficiency trends in Urban functional expansion area were close to those in Beijing. And environmental inefficiency of the area was higher than the overall level of Beijing, mainly due to output-related inefficiency increasing year by year. Environmental inefficiency in Urban development new area first decreased, then increased, and finally decreased during the 2009-2013. Excessive input and pollution mainly contributed to the area's high environmental inefficiency. So it is necessary to save energy and reduce emissions. Ecological conservation development area's environmental inefficiency

Table 3: LTFP decomposition based on the different input-output elements of Beijing 2009-2013(%).

Area	Total	Input	Contents			Output	Pollution	Contents			
			Energy	Labour	Capital			PM_{10}	SO_2	NO_2	Rubbish
Beijing	0.77	0.21	0.10	-0.02	0.13	-0.10	0.66	0.32	0.25	-0.09	0.19
Capital functional core area	0.59	-0.43	-0.15	-0.22	-0.06	0.00	1.02	0.62	0.36	-0.01	0.05
Urban functional expansion area	1.83	0.80	0.30	0.00	0.50	-0.07	1.10	0.35	0.36	-0.02	0.41
Urban development new area	0.98	0.11	0.06	0.02	0.02	0.76	0.11	0.14	0.15	-0.11	-0.07
Ecological conservation development area	-0.22	0.09	0.10	0.00	-0.01	-1.33	0.81	0.20	0.22	0.10	0.30

trends were relatively stable during the study. The rise of the area's environmental inefficiency during the 2012-2013 led to LTFP's decline, which was mainly due to lack of output. During the study, pollution-related inefficiency and input-related inefficiency declined gradually. These showed the area should speed up industrial restructuring and keep ecological conservation and economic development balanced.

2. CIE's change path under the current border: CIE's trends of Beijing and each functional area during the 2009-2013 are shown in Fig. 3. According to the formula (9), the paper explained efficient changes based on CIE's trends. For the whole Beijing, CIE remained basically stable during the analysis. In the 2012, inefficient value rose slightly, which was mainly owing to the rising of input-related inefficiency. If we analyze separately input-output factors, labour mainly resulted in efficient decrease. Moreover, NO_2 made a greater impact on the environmental inefficiency in various pollution-related factors.

As it is shown in Fig. 3, Environmental inefficiency of Capital functional core area in 2011 was a node, first rising and then declining. During the analysis, pollution-related inefficiency was the most important source of Beijing's environmental inefficiency, and output-related inefficiency was on the technical border. Urban functional expansion area's inefficiency maintained steady during the 2009-2011, and then rose during the 2011-2013 with output-related and pollution-related inefficiency upward. The main reason for the area's environmental inefficiency was output-related inefficiency. Environmental inefficiency, input-related inefficiency and pollution-related inefficiency in Urban development new area reached maximum in 2012, mainly due to the increase of input-related inefficiency and pollution-related inefficiency, and recovered once again in 2013. The area's major effect factor was pollution-related inefficiency in the period of analysis. For Ecological conservation development area, environmental inefficiency was rising in 2012-2013, mainly due to increase of output-related inefficiency, which indicated that there was a big gap between the best technical border and the area, and that the area's economy had great room to improve.

3. TG's change path: Fig. 4 shows the trends of TG and related factors in Beijing and each functional area during the 2009-2013. According to the formula (10), the paper gave an explanation for technical progress based on TG's changes. In Fig. 4, Beijing's TG in 2012 was a node, first declining and then rising. And CIE's changes were relatively stable during the analysis (Fig. 3), which indicated LTP rather than LEC was the main reason for affecting LTFP for Beijing. In Fig. 4, TG values of Beijing and each functional area tended to 0 in 2012, and gradually dispersed in 2013, which indicated the current technical border is close to the unified technical border in 2012.

In Fig. 4, there were different sources for technical progress in functional areas. Pollution-related TG in Capital functional core area decreased most rapidly. While input-related TG rose during 2011-2013, which led to technical setbacks. For Urban functional expansion area, input and pollution emissions played similar role in technical progress. In the area, pollution-related TG's effect on TG was the greatest, and output-related TG's effect was the least. The area's TG rose during the 2012-2013, which resulted in contraction of technical border. Different from other areas, Ecological conservation development area's TG had a sharp increase in 2011-2013, which was mainly due to the increase of output-related TG. While pollution-related TG kept downward in 2011-2013, which indicated economic factors seriously affected technical progress in the area. Obviously, the sources of technical advances in each functional area were different, which is related to their respective stages

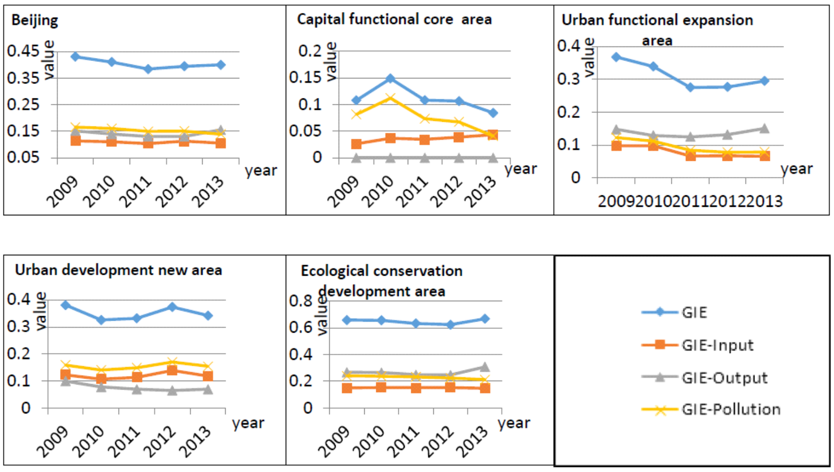

Fig. 2: The trends in GIE and its factors of Beijing and each functional area 2009-2013.

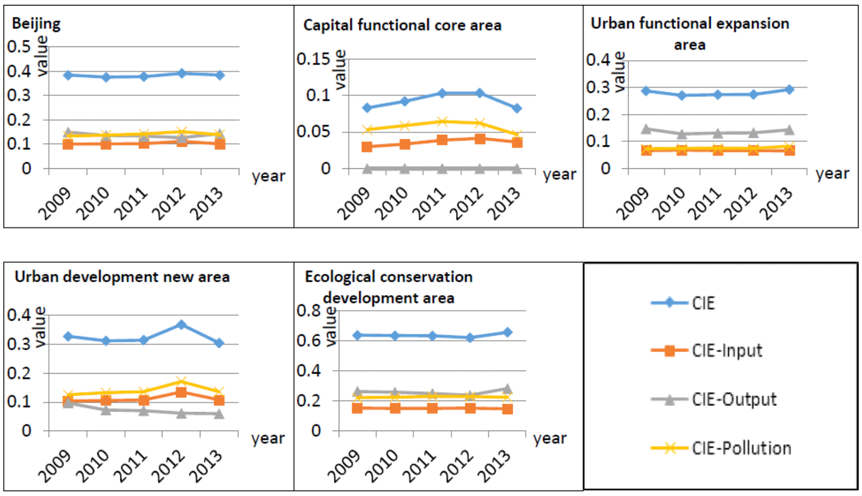

Fig. 3: The trends in CIE and its factors of Beijing and each functional area 2009-2013.

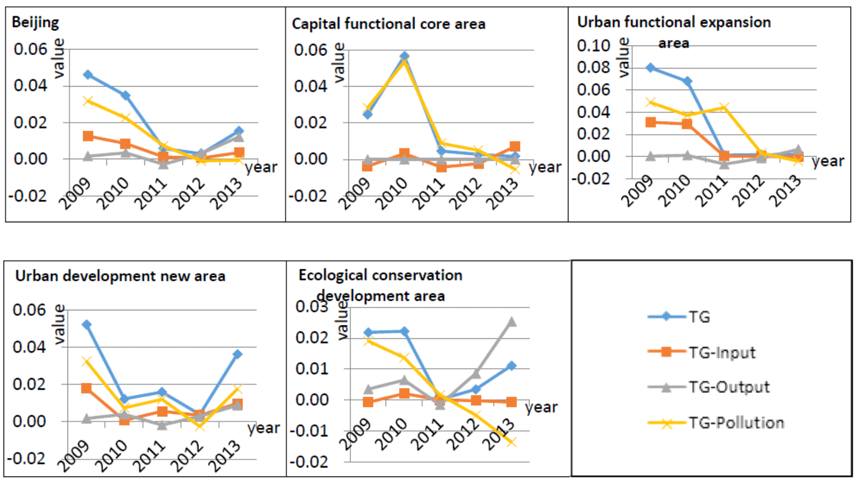

Fig. 4: The trends in TG and its factors of Beijing and each functional area 2009-2013.

of development.

CONCLUSIONS

Combining SBM directional distance function and Luenberger Index, and using the new method of productivity index's construction and decomposition, the paper measured Beijing areas' environmental efficiency and LTFP during 2009-2013. Results showed that: (1) Energy consumption and pollution emissions was the main reason for environmental inefficiency of Beijing. Environmental efficiency of each area was obviously different, ranging from the city centre to the edge of the city. Then LTFP of the middle of the city area was higher than that of the city centre which was higher than that of the edge of the city. (2) Statically, factors were pollution, input and desirable output in order of impact on Beijing's LTFP decreasing during 2009-2013, which indicated pollution situation was still serious. (3) Dynamically, Beijing's economic performance was mainly influenced by change in technical borders.

Finally, according to the analysis results, Beijing and each area should pay attention to save energy and reduce emissions to achieve sustainable development. Besides, improve economic performance through efficient changes rather than technical advances. And the areas should make practical and feasible development programs based on their development orientation.

ACKNOWLEDGEMENTS

This study was financially supposed by the Fundamental Research Funds for the Central Universities (Grant No. TD2014-02), Beijing Excellent Talents Training Project (Grant No.2013D009046000006) and Development Research Centre of Beijing New Modern Industrial Area (Grant No. JD2014004). The authors also gratefully acknowledged the helpful comments and suggestions of the reviewers, which had improved the presentation.

REFERENCES

Arabia, B., Munisamyb, S., Emrouznejadc, A. and Shadman, F. 2014. Power industry restructuring and eco-efficiency changes: A new slacks-based model in Malmquist-Luenberger Index measurement. Energy. Policy, 68: 132-145.

Bai, Y.P., Zhang, X.Z., Hao, Y.P. and Song, X.W. 2013. Research on regional environmental performance and its influential factors based on SBM-Malmquist-Tobit Model. Areal Research and Development, 32(2): 90-95.

Caves, D.W., Christensen, L.R. and Diewert, W.E. 1982. The Economic theory of index numbers and the measurement of input, output and productivity. Econometrica, 50(6): 1393-1414.

Chambers, R.G., Fare, R. and Grosskopf, S. 1996. Productivity growth in APEC countries. Pacific Economic Review, 1: 181-190.

Chung, Y. H., Fare, R. and Grosskopf, S. 1997. Productivity and Undesirable Outputs: A directional distance function approach. Journal of Environmental Management, 51(3): 229-240.

Fä re, R., Grosskopf, S. and Pasurka Jr., C.A. 2007. Environmental production functions and environmental directinal distance functions. Energy, 32(7): 1055-1066.

Jing, W.M. and Zhang, L. 2014. Environmental regulation, economic opening and China's industrial green technology progress. Economic Research Journal, 9: 34-47.

Li, S.W. and Li, D.S. 2008. China's industrial total factor productivity fluctuations: 1986-2005. The Journal of Quantitative & Technical Economics, 5: 43-54.

Liu, R.X. and An, T.L. 2012. Trend and factor analysis of Chinese economic growth performance under restrictions of resource and environment - A research based on a new method of productivity index's. Economic Research Journal, 11: 34-46.

Meng, F.Y., Fan, L.W., Zhou, P. and Zhou, D.Q. 2013. Measuring environmental performance in China's industrial sectors with non-radial DEA. Mathematical and Computer Modelling, 58(5): 1047-1056.

Reinhard, S., Lovell, C.A.K. and Thijssen, G.J. 2000. Environmental efficiency with multiple environmentally detrimental variables; estimated with SFA and DEA. European Journal of Operational Research, 121(2): 287-303.

Shephard, R.W. 1970. Theory of Cost and Production Functions. New York: Princeton University Press.

Tu, Z.G. and Shen, R.J. 2013. Does environment technology efficiency measured by traditional method underestimate environment governance efficiency? From the evidence of China's industrial provincial panel data using environmental directional distance function based on the network DEA model. Economic Review, 5: 89-99.

Wang, B., Wu, Y.R. and Yan, P.F. 2010. Environmental efficiency and environmental total factor productivity growth in China's regional economies. Economic Research Journal, 5: 95-109.

Wang, K., Yu, S.W. and Zhang, W. 2013. China's regional energy and environmental efficiency: a DEA window analysis based dynamic evaluation. Mathematical and Computer Modelling, 58(5): 1117-1127.

Xie, B.C. and Du, G. 2010. Utility Malmquist Index and listed thermal power Corporations empirical analysis. Chinese Journal of Management Science, 1: 46-51.

Yan, P.F. and Wang B. 2004. Technical efficiency, technical progress and productivity growth: An empirical analysis based on DEA. Economic Research Journal, 12: 55-65.

Yang, J., Shao, H.H. and Hu, J. 2010. Empirical study on evaluation and determinants of environmental efficiency of China. China Population Resources and Environment, 20(2): 49-55.