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A WAY FORWARD FOR ENERGY PRICING AND MARKET REFORMS TO REDUCE EMISSIONS: THE CASE OF THE TOP 10 CARBON DIOXIDE–EMITTING COUNTRIES

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Abstract

The purpose of the current study was to assess energy, economic, and environmental efficiency based on the environmental reforms of the top 10 carbon dioxide (CO_2) emitter countries by using the Data Envelopment Analysis (DEA) model from 2013 to 2017 to assess energy pricing and market reforms from the perspective of emission reduction. The results revealed that the Russian Federation has the highest score for energy intensity while Saudi Arabia is effective in terms of CO_2 emissions. In the absence of market reforms, the level of non-fossil fuel technology development incentives will require a relatively low carbon price (about US$3.53/ton CO_2) by 2020. From 1995 to 2000, countries indexed the price of liquid petroleum products to the international market price. The energy sector will account for 52% of the total and the effect on CO_2 emissions will be about a 1.6% reduction in energy-related emissions in 2020 as a result of reducing subsidy spending, keeping fiscal deficits below 3%, and reducing the slowdown in economic growth. Research should revisit energy prices with subsidy reforms in favor of renewable energy and tax on fossil fuel.

Keywords: energy pricing reforms, economic–environmental efficiency, slack-based DEA, top 10 CO_2 emitters, environmental–economic reforms

JEL Classification: P28, Q4, Q20, Q40, Q56, Q48

Contents

1. INTRODUCTION

The influence of energy prices on carbon emissions cannot pass unnoticed as increasing energy prices can increase the price of carbon emissions (Chang, Mai, and McAleer 2019). Fossil fuels account for 70% of the total energy that transportation uses; this industry generates two-thirds of the world's carbon dioxide emissions. To maintain or even promote economic growth, energy efficiency policies are a key feature to reduce energy consumption. Achieving this objective needs a full understanding of the association between energy efficiency and energy price reforms. The literature regarding this line of research has aimed to connect the determinants of energy intensity, but few studies have discussed the relationship between energy intensity and energy pricing. A chance to reduce the energy demand is not likely to occur without policies that increase energy prices and reduce economic barriers to improve energy efficiency (Wen, Zhou, and Zhang 2018). Energy security and global warming have become increasing concerns for scholars and policymakers.

CO_2 constitutes a 70% share of greenhouse gas emissions and has become a global issue with economic and social consequences (Lin and Xu 2018; Tajudeen, Wossink, and Banerjee 2018). In accordance with the 2013 report of the Organisation for Economic Co-operation and Development (OECD), this report used the manufacturing value-added ratio to the production of large contaminants to calculate the level of environmental protection. In fact, to check the energy and economic consistency, the study performed a detailed analysis of environmental efficiency using the above three industrial pollutant emissions and the details of each country's industrial production volume (Tajudeen, Wossink, and Banerjee 2018). The International Energy Agency (IEA) (2016) reported that the characteristic of energy efficiency is more services for the same or fewer energy inputs. Due to rapid climatic changes, there is a link connecting economic development and energy security with energy efficiency (Mohsin et al. 2019). For the energy pricing reform process, energy efficiency is mandatory, and many developed and developing economies have set sudden targets to reduce carbon emissions and to improve energy efficiency to minimize climate change (Mohsin, Rasheed, and Saidur 2018).

To achieve the economic development goals, it is necessary to assess the energy efficiency conditions comprehensively and compare emission reductions (Guo et al. 2016), transport (Badjeck et al. 2010), and agriculture (Fei and Lin 2017). Accordingly, it is essential to measure and recognize the major portion of energy efficiency by conducting vertical comparisons within energy consumption sectors and horizontal comparisons between different ECSs in terms of emission reduction planning and energy efficiency (Mohsin et al. 2019). Energy efficiency has become a priority for the industrial sector due to sudden constraints, such as governments' implementation of stricter environmental regulations and accumulative pressure from local, national, and international communities (Martínez-Moya, Vazquez-Paja, and Gimenez Maldonado 2019). Due to the global climate change that greenhouse gas emissions have caused, people are paying increasing attention to energy use and CO_2 emissions. The list of the top CO_2 emitters is very complex as it mixes developed and developing economies, and seven developing economies and just three developed economies dominate it.

Recently published studies in this line of research, such as those of Charnes, Cooper, and Rhodes (1978); Zhou, Ang, and Poh (2008); and Sun et al. (2020), have measured the efficiency of the industrial sector by applying the DEA method and found that countries can achieve the best energy saving and emission efficiency by recycling and disposing of waste. Bi et al. (2014) employed DEA to measure the relationship between environmental regulation and fossil fuel consumption in the People's Republic of China (PRC). Geng et al. (2017) applied DAE to estimate environmental and energy efficiency during complex chemical processes in provincial industries and found that the potential for energy saving and carbon emission reduction increased due to the improvement in the inefficient decision-making units (DMUs). Jebali, Essid, and Khraief (2017) applied the DEA efficiency estimator to perform truncated regression on the efficiency score of DEA bias correction for environmental variables and concluded that the energy efficiency levels in Mediterranean countries are high but have declined over time. The study also found that the per capita gross national income, population density, and use of renewable energy can affect energy efficiency. Du et al. (2011) employed DEA to assess the CO_2 emission efficiency of service industries using the PRC's provincial data and stated that an increase in economic and carbon dioxide efficiency can lead to improved industrial services. Wang et al. (2016) proposed the DAE method to measure energy, economic, and environmental efficiency and found that developed countries (except the US, Japan, and Singapore) have high economic efficiency with low carbon dioxide emissions. They designed an environmental DEA to quantify the energy efficiency related to environmental–economic efficiency. Regarding the inputs and outputs, several studies considered capital investment, energy consumption, and labor as the key input factors and carbon dioxide emissions and GDP as the major outputs. They considered seven variables from the provincial point of view.

This study used the traditional output-oriented DEA model to assess the carbon emissions, energy consumption, and economic–environmental performance of the top 10 industrial countries during the period 2013–17. In addition, the study calculated the extent to which it is possible to reduce carbon dioxide emissions and primary energy use. Finally, the study's contribution includes the application of the DEA method to measure energy, economic, and environmental efficiency by taking the top 10 CO_2 emitting countries in the world as a case study to provide a way forward for energy pricing and market reforms from the perspective of emission reduction.

The remainder of the paper proceeds as follows: the following section describes the background, section 3 contains the methodology, section 4 explains the results and presents a discussion, and section 5 provides the conclusion and policy implications.

2. BACKGROUND AND LITERATURE REVIEW

Historically, research has promoted the improvement of energy efficiency as an effective and economical way to decrease greenhouse gas emissions and the energy demand. Studies have considered the market structure of oligopoly as depending on the competition limited price. Fear of competitors' reactions to any individual organization's price fluctuations can act to constrain the latter, even though, obviously, the oligopolistic motivation for price tackiness is not reliant on the crucial assumptions of the demand curve model. The basic foundations of price inflexibility are not essentially challenging; actually, price intransigence might imitate the effect of economic activity in the market. The nexus between energy subsidies, energy taxes, and energy efficiency shows that the market is oligopolistic in nature as its construction involves extensive concern for the fairness of the price adjustments in the market. This has initiated concern among customers especially regarding the possible exploitation of market power, while this falls with considerable price changes. Therefore, the market is conditional on a substantial regulatory framework following the guidelines of a monopolistic market structure. These market reflections constrain the immediate and prompt reactions to the prices of the energy demand and demand changes that people suppose exist in a conservative market (Figus et al. 2020).

The energy, economic, and environmental scenario highlights a need for energy reforms. Subsidy reforms should revisit energy prices. A rise in price can be a good option but can be a complex procedure due to other economic and social indicators. The results of some studies have suggested that an increase in the energy price does not work alone, as in the case of Iran (Farzanegan and Raeisian Parvari 2014). The energy-intensive technologies in the industry along with the growth in the price of energy can be a suitable tool to improve energy efficiency. Here, subsidy reforms are necessary to achieve the goal of energy efficiency. If we save only 20% from subsidy reforms and reinvest it in an energy efficiency program and renewable energy projects, it may help to reduce the emission level by 1% worldwide. The task of the Conference of the Parties is to ensure the pre-industrial levels must remain within 2 degrees of the pre-industrial levels or that they must fall by this much. The Paris Agreement established under the Kyoto Protocol entered into force in 2005. During the last 20 years, the Chinese economy has experienced a growth rate of 9.5% annually on average. With this fast-paced economic development comes a set of environment-related concerns. During recent years, numerous Chinese cities have experienced persistent and serious fog, haze, and smog, especially in 2013, because of energy consumption and polluting discharge.

Figure 1: Top 10 CO_2 Emitting Countries

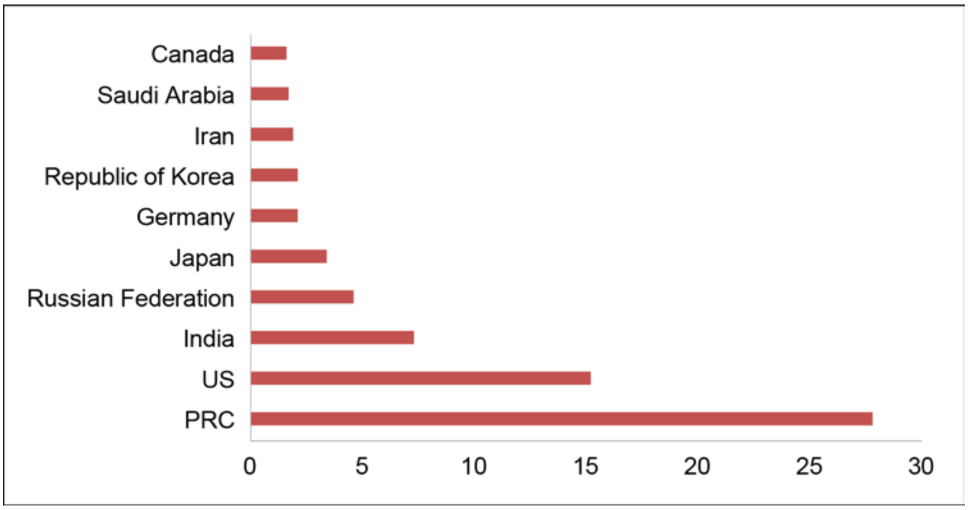


Figure 1 shows that the PRC is leading the list of world emissions with 27.8%. The US, India, and the Russian Federation are adding to the world emissions with 15.2%, 7.3%, and 4.6%, respectively (Sun et al. 2019a,b). Canada generates the smallest share of global emissions (1.6%). These 10 countries alone account for a 67.7% share of the total world emissions, which is very alarming. According to the British Petroleum (2019) "Statistical Review of World Energy," since the Kyoto Protocol, the annual global carbon dioxide emissions have increased by 20%. After 2005, the carbon dioxide emissions in the Asia and Pacific region increased by 50% while the emissions in the United States and the European Union declined.

Table 1: Top 10 CO_2 Emitting Countries in 2018

Country	CO_2 Emissions (BMT)	Change since the Kyoto Protocol

PRC	9.43	54.6
US	5.15	-12.1
India	2.48	105.8
Russian Federation	1.55	5.70
Japan	1.15	-10.1
Germany	0.73	-11.7
Republic of Korea	0.70	34.1
Iran	0.66	57.7
Saudi Arabia	0.57	59.9
Canada	0.55	1.60

Source: World Economic Forum.

The data on the CO_2 emissions after the Kyoto Protocol show that these top 10 emitters had a very poor response. The United States, Germany, and Japan all experienced double-digit declines. The rest of the countries increased their emissions after the Kyoto Protocol. India led this increase by accumulating 105.8%, while Saudi Arabia (59.9%), Iran (57.7%), and the PRC (54.6%) have added more than half of their total emissions since the Kyoto Protocol. Large changes in coal consumption are the main driving force for the PRC and India, which have significantly increased their coal use. The main driving force in the United States and Germany is the rapid growth in renewable energy use, which has reduced the demand for coal; however, in the United States, the boom in shale gas, which creates a large supply of inexpensive natural gas, is a greater driver of the reduced coal consumption.

Energy prices in terms of oil prices and annual shifts in the world GDP causes the sudden decrease in the world GDP growth causes a hike in the oil prices every time. A 4% reduction in GDP growth occurred as a result of the price increase due to the oil embargo in 1973. In two years, the world's GDP growth declined from 6% to 1%. As a result of the oil supply shortage in the 1979 Iranian Revolution, the oil prices increased by 100% and growth declined from 4% to 2% and later to less than 1%. In such a scenario, people have acknowledged that the laws are extremely strict as the organizer's optimization circumstances do not motivate stockpiling but the restriction completely encourages it, resulting in an ultimate level of reserves that are more than they will ever need during the extent of planning.

In 2018, the United States' annual per capita emissions were 16 metric tons per person, while the PRC's per capita carbon dioxide emissions are slightly decreasing due to renewable energy. It is therefore clear that the United States is responsible for a share of the atmospheric carbon dioxide inventory. From 2012 to 2013, the top 10 emission sources cumulatively increased their emissions by 2.2%, while in the last decade the rise has been 2.4%. During the same period, the largest single-year percentage increases in greenhouse gas emissions were 4.3% and 1.4%, respectively. Even though the emissions of the largest emitters increased between 2012 and 2013, if we expand the time horizon, their total emissions remain unchanged over the past decade. During that time, the US emissions peaked in 2007 while Poland the EU's third-largest emitter was steadily decreasing its emissions. Over the past decade, other countries, including the Russian Federation and Canada, have also stabilized their emissions. The latest data, focusing only on energy-related carbon dioxide emissions, show that, even with global economic growth over the same period, such emissions remained unchanged globally from 2014 to 2016. This is an encouraging trend. We are waiting for further data to determine whether other types of greenhouse gases are increasing or decreasing and whether this trend will continue. As research has proven in 21 countries, CO_2 is decoupled.

Almost all of these countries are parties to the Kyoto Protocol, and their emission reduction targets are legally binding. Currently, the PRC (a developing economy) is the leading emitter with a 27.8% global share, while Canada (a developed economy) occupies the tenth position with a 1.7% global share in CO_2 emissions. Thus, the environment and climate change constitute a worldwide phenomenon and it is necessary to considered them as a global issue. Both developing and developed economies must contribute practically by reforming their environmental and economic management programs to overcome this problem during the sustainable development process (Asbahi et al. 2019; Iqbal et al. 2019; Mohsin et al. 2019a,b,c). During the past decade, a considerable amount of research work has investigated economic–environmental reforms and energy efficiency. It has highlighted these issues alone or in combination.

3. METHODOLOGY

This study adopted the slack-based methodology (SBM-DEA), which Tyteca (1996) and Zhou, Ang, and Poh (2006b) used, to assess the energy, economic, and CO_2 emission efficiency of the top 10 CO_2 emitter countries by taking the population and primary energy consumption as inputs and the GDP and CO_2 emissions as a desirable and an undesirable output, respectively (Rao et al. 2012; Wang et al. 2013; Wu et al. 2018). Let us consider the example of a manufacturing process that produces both desirable and undesirable outputs. $X = (x_1, x_2, \dots, x_n)$, $Y = (y_1,\ y_2, \dots, y_m)$, and $U = \left(u_1, u_2, \dots, u_j\right)$ are vectors of inputs and outputs as follows:

$$T = \{(X, Y, U): X can produced\ (Y, U)\} \tag{1}$$

The assumptions for *T*, which the study adopted from Faere et al. (1989), are:

(i) if $(X, Y, U) \in T$ and $0 \le \theta \le 1$, then $(X, \theta Y, \theta U) \in T$

(ii) if $(X, Y, U) \in T$ U = 0, then Y = 0

The supposition stated that (i) there are poorly disposable desirable and undesirable outputs, meaning that the reduction in undesirable outputs is not free and similarly that a relative reduction in undesirable and desirable outputs is possible (Emrouznejad and Yang 2016); and (ii) having manufactured the required outputs, certain undesirable outputs can also arise (Färe and Grosskopf 2004). It is possible to use (CRS) DEA environmental technologies as follows:

$$T = \{(x, y, u)\}: \sum_{k=1}^{K} z_k x_{nk} \le x_n \; n = 1,2, \dots, N$$

$$\textstyle\sum_{k=1}^{K} z_k y_{mk} \ge y_m \quad m = 1,2, \dots, M \tag{2}$$

$$\sum_{k=1}^{K} z_k u_{jk} = u_j, \qquad j = 1,2, \dots, J$$

$$z_k \ge 0, k = 1,2, \dots, K$$

Energy consumption is the basic pillar for economic development, and simultaneously a greater share of fossil fuel consumption causes environmental pollution and other harmful gases; consequently, it is essential to measure the efficiency of both CO_2 emissions and energy consumption (Zhou, Ang, and Poh 2006b).

$$PEI_1 = \theta_1^* = min\,\lambda \tag{3}$$

$$\text{s.t } \sum_{k=1}^{K} z_k x_{nk} + s_{nk}^- \leq x_{n0}, \quad n = 1,2,\dots,N \tag{3a}$$

$$\sum_{k=1}^{K} z_k e_k - s_{nk}^- \leq \theta e_0 \tag{3b}$$

$$\sum_{k=1}^{K} z_k y_{mk} \geq y_{m0},\ m = 1,\dots,M \tag{3c}$$

$$\sum_{k=1}^{K} z_k u_{jk} = u_{j0},\ \ j = 1,\dots,J \tag{3d}$$

$$z_k \geq 0, k = 1,\dots,K$$

whereas PEI_1 evaluates the consumption of primary energy for the proposed countries (DMUs).

$$PEI_2 = \theta_2^* = \min\theta \tag{4}$$

$$\text{s.t } \sum_{k=1}^{K} z_k x_{nk}(s_{nk}^+ - s_{nk}^-) \leq x_{n0},\ n = 1,2\dots,N \tag{4a}$$

$$\sum_{k=1}^{K} z_k y_{mk} \geq y_{m0},\ \ m = 1,\dots,M \tag{4b}$$

$$\sum_{k=1}^{K} z_k c_k = \theta c_0, \tag{4c}$$

$$\sum_{k=1}^{K} z_k u_{jk} = u_{j0},\ \ j = 1,\dots,J \tag{4d}$$

$$z_k \geq 0, k = 1,\dots,K$$

The DEA method has advantages in dealing with multiple inputs and multiple outputs and does not need the presupposition of a functional relationship in the evaluation, which greatly reduces the subjective controversy of the study and can overcome the deviation that the radial and angle cause in the traditional model, gradually evolving into the mainstream model of agro-ecological efficiency evaluation, as DEA theory suggests (Bian, He, and Xu 2013). For ineffective economies:

$$PES_k = (1 - \theta_{1k}^*)\ \times e_k \tag{5}$$

$$PCR_k = 1 - \theta_{2k}^*\ \times u_k \tag{6}$$

Economic production plays a role between energy consumption and environmental degradation; for example, research has considered energy consumption to be a major contributor to environmental pollution at the same time as the major percentage of fossil fuel consumption affects environmentally harmful gases and therefore the efficiency assessment performance.

$$PEI_3 = \theta_3^* = \min\theta \tag{7}$$

$$\text{s.t } \sum_{k=1}^{K} z_k x_{nk} + s_{nk}^- \leq x_{n0},\ n = 1,2,\dots,N \tag{7a}$$

$$\sum_{k=1}^{K} z_k y_{mk} + s_{nk}^{-} \geq y_{m0}, \quad m = 1,2 \ldots, M \tag{7b}$$

$$\sum_{k=1}^{K} z_k u_{jk} \times (s_{nk}^{+} - s_{nk}^{-}) = \theta u_{j0}, \quad j = 1,2, \ldots, J \tag{7c}$$

$$z_k \geq 0 \quad \text{and} \quad k = 1, 2 \ldots, K$$

The study used the method that Stone and Cooper (2001) proposed. Zhou, Ang, and Poh (2006a) improved it, providing the extension of the SBM model to measure an economic–environmental performance:

$$\theta^{*} = \min \frac{1 - \frac{1}{N}\sum_{n=1}^{N} s_n^{-}/s_{n0}}{1 + \frac{1}{M}\left(\sum_{m=1}^{M} \frac{s_m^{+}}{y_{m0}} + \frac{s_{uk}^{-}}{\theta_3^{*} u_0}\right)} \tag{8}$$

$$\text{s.t} \quad \sum_{k=1}^{K} z_k x_{nk} + s_{nk}^{-} = x_{n0}, \quad n = 1, 2 \ldots, N \tag{8a}$$

$$\sum_{k=1}^{K} z_k y_{mk} - s_{mk}^{+} = y_{m0}, \quad m = 1, \ldots, M \tag{8b}$$

$$\sum_{k=1}^{K} z_k u_{jk} + s_{uk}^{-} = \theta_3^{*} u_{j0}, \quad j = 1, \ldots, J \tag{8d}$$

$$z_k \geq 0, k = 1, \ldots, K \qquad s_n^{-}, s_n^{+} \geq 0$$

Further reviewing the literature, the study found that, in the process of applying the DEA-SBM model, there are great differences in the selection indicators of unexpected output among different scholars in the research on efficiency measurement using the DEA model. θ^{*} shows the measurement of slack-based economic performance (Zhou et al. 2006b).

4. RESULTS AND DISCUSSION

In the past half century, the global economy has developed rapidly. In the meantime, environmental issues resulting from human activities, particularly the greenhouse effect, have become progressively more prominent. To mitigate the greenhouse effect, many economies have set individual carbon dioxide reduction objectives and are working to cut their carbon dioxide emissions. Scientists are extremely convinced that humans are the main producers of global warming due to rising greenhouse gases (GHG), and the biggest drivers of global warming CO_2 emissions are fossil fuel combustion, cement production, and land use change (such as deforestation). Researchers, scientists, and policymakers agree that undue greenhouse gas emissions from production activities cause global warming and that this will harm the sustainable development of human society (Lin and Du 2015). Thus, they have reached a consensus on reforms for a low-carbon economy.

The energy consumption growth rate values vary from –1.40 to 5.30, while the CO_2 growth values vary from –1.05 to 4.98. India has the highest values while the US has the lowest values of the CO_2 emission growth rate. During the study period, India's energy consumption growth rate was the highest at 5.30% and, in terms of carbon dioxide emissions, the PRC's growth rate was the highest at 4.10%. In the United States, the energy consumption was the highest at 2,231 (Mtoe). During the study period, India's GDP growth rate was the highest at 7.33%; India's carbon dioxide emissions growth rate ranked second.

Table 2: Values of Descriptive Statistics

	Energy Use		CO_2		GDP		Population		
	Avg	**GR** (%)	**Avg**	**GR** (%)	**Avg**	**GR** (%)	**Avg**	**GR** (%)	**GDPPC**
Iran	25.67	3.50%	284.44	2.40%	1,423.03	2.78%	46.52	–0.02	27,879
Canada	334.00	0.70%	540.00	1.44%	1,806.79	2.08%	35.88	1.99	46,791
PRC	3,013.94	4.10%	9,184.02	0.07%	8,934.85	6.94%	1,371.86	0.165	7,954
Germany	326.9	0.21%	765.44	–0.95%	3,716.02	1.95%	81.168	0.62	44,519
Republic of Korea	285.8	1.30%	658.26	1.26%	1,269.89	3.03%	50.48	0.51	27,631
Russian Federation	687.64	2.56%	1,517.80	0.02%	1,678.59	–0.19%	144.22	0.17	11,796
India	690.66	5.30%	2,151.40	4.98%	2,302.06	7.33%	1,308.65	1.16	1,658
US	2,231.44	0.74%	5,220.16	–1.05%	16,581.96	2.29%	321.46	0.74	56,208
Japan	457.72	–1.40%	1,212.08	–1.97%	6,003.19	1.09%	127.86	–0.12	38,106
Saudi Arabia	255.22	4.50%	575.46	2.74%	666.77	2.14%	31.45	2.41	22,214

GR stands for growth rate. The existing literature has studied the assessment of economic and energy efficiency and its influencing factors in depth, but there are still areas that require further investigation. Firstly, in the technology and environmental context, the mutual effect of energy, economic, and environmental efficiency provides empirical evidence for formulating or adjusting the development strategy of the green energy roadmap; on the other hand, the existing research on energy, economic, and environmental efficiency development has mainly focused on the popularization of the technology, which cannot truly reflect the regional energy and environment levels. Secondly, there is a lack of evaluation of the coupling coordination between energy, economic, and environmental efficiency development. The outcomes revealed that the PRC, Japan, and Saudi Arabia were the most efficient from 2013 to 2017 and the Russian Federation was the least efficient among the 10 highest emitting countries. Canada and Iran showed significant improvements during these 5 years. Our study raised the question of whether the sum of the costs characterizes the price. In a perfectly competitive market, it does. However, the primary energy market does not constantly behave like a perfectly competitive market because perfect competition needs all the producers to have the same cost curves. Furthermore, certain categories of fundamental energy, such as wood or lignite, have relatively high transportation costs concerning the ex-works price of the product; hence, the market cannot be perfectly competitive. The market is also usually distorted by special subsidies, taxes, price agreements, and cartels. Consequently, the cost may not be easily recognizable while the taxes, rents, and subsidies could be inseparable from the final product price. The major assumptions of Center of Enterprise Risk Management show that energy characterizes all the production factors except land or that it is possible to express them in energy equivalents. Land is the source of crops, wood, raw materials, cattle, and so on, even though, without human work, machinery, and energy, that source would be unexploited.

The results show that energy prices play an important role in energy consumption patterns, which eventually affect the greenhouse gas emissions that energy consumption generates. Therefore, increasing energy prices can be an effective way to suppress carbon dioxide emissions. Neoclassical economic theory also supports this line of action: with a “rise of relative price of a commodity with respect to its substitute, demand for that commodity will fall.” For this study, even in the PRC, where the market is still inefficient, it was possible to consider energy as a resource commodity. Thus, producers in the PRC can replace energy consumption with other factors of production, like a change in labor, the application of new technologies, or employing extra workers with energy-saving technologies. These kinds of effort will help to reduce the carbon dioxide emissions from energy consumption. Therefore, accelerating market-oriented reforms in the energy market and reducing strict government control may reshape the energy consumption patterns of the energy industry, and this may also lead to a decrease in greenhouse gas emissions. To promote a united national concept of open markets with fewer trade barriers, the role of the energy market in decreasing the CO_2 emissions resulting from energy consumption may be critical to enhance the positive spillover effects of energy market factors. This model may compensate for the lack of strict environmental regulations that leads to unsustainable economic growth.

Table 3: Energy Efficiency of the Top 10 CO_2 Emitting Countries

Country	2013	2014	2015	2016	2017
Iran	0.53	0.52	0.51	0.52	0.53
Canada	0.47	0.46	0.45	0.47	0.47
PRC	1.00	1.00	1.00	1.00	1.00
Germany	1.00	1.00	1.00	0.56	1.00
India	0.40	0.48	0.47	0.50	0.50
Saudi Arabia	0.61	0.62	0.61	1.00	1.00
Republic of Korea	0.53	0.53	0.52	0.53	0.55
United States	0.55	0.56	0.54	0.56	0.55
Japan	1.00	1.00	1.00	1.00	1.00
Russian Federation	0.48	0.48	0.48	0.49	0.48

Table 3 shows the energy efficiency of the top 10 CO_2 emitting countries. Due to the availability of many substitutes in the energy sector, an increase in the price of one source, for example crude oil, may lead to an increase in the demand for coal. To avoid such kinds of substitution, it is necessary to increase the price level of all nonrenewable sources by the same proportion and encourage consumers by subsidizing or motivating them to adopt renewable sources with improved technologies. It was observed that the PRC, Japan, and Saudi Arabia are the most efficient economies while India ranked sixth among the top 10 CO_2 emitting countries. Similarly, the Russian Federation is the country with the highest energy intensity with an efficiency score of primary energy consumption of 0.449. The positive trend of the time coefficient indicates that technological growth will increase energy intensity. Thus, policies regarding increased energy prices can be helpful in reducing the intensity energy. The reason for companies and factories' failure to invest properly in energy efficiency or energy-efficient technologies is the low price of energy.

Figure 2 shows a graphical representation of the energy efficiency score. The technological gap between the industries in developing and developed countries has increased due to the companies' investment in such technologies. Our results show that, ceteris paribus, changing oil prices can affect energy efficiency. In 2018 alone, reforms in energy prices prompted protests in various countries, such as Haiti, France, Belgium, Burkina Faso, Bulgaria, India, and Sierra Leone (Timilsina and Pargal 2020).

Figure 2: Energy Efficiency Score

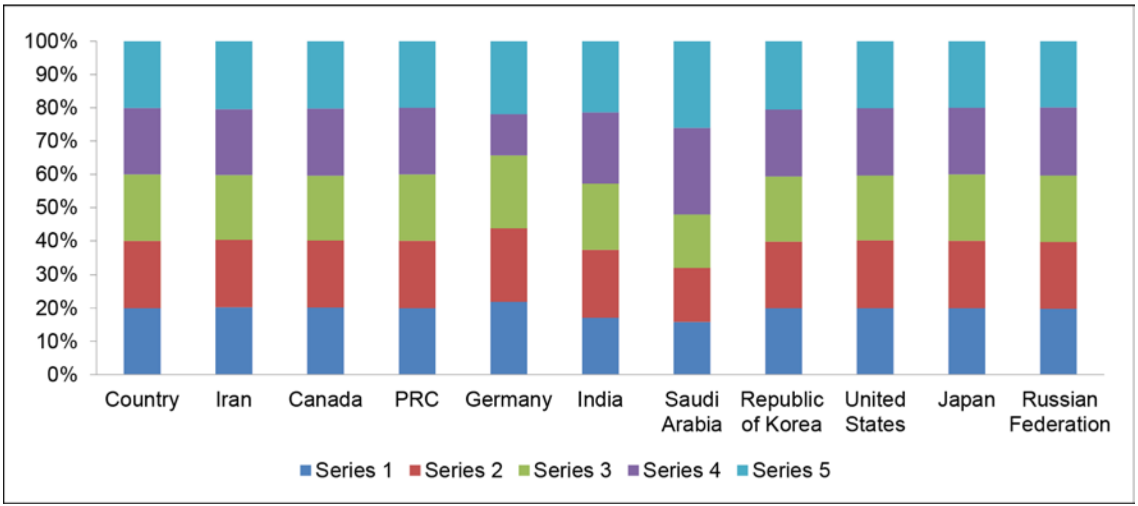


Table 4: Ranking Score of the Top 10 Countries

Sr. No	Country	Rank
1	Japan	1
2	Saudi Arabia	1
3	Germany	1
4	PRC	1
5	United States	0.55
6	Republic of Korea	0.55
7	Iran	0.53
8	India	0.50
9	Russian Federation	0.48
10	Canada	0.47

Table 4 shows the ranking of the top 10 CO_2 emitting economies.

Figure 3: Ranking Based on the Energy Efficiency Score

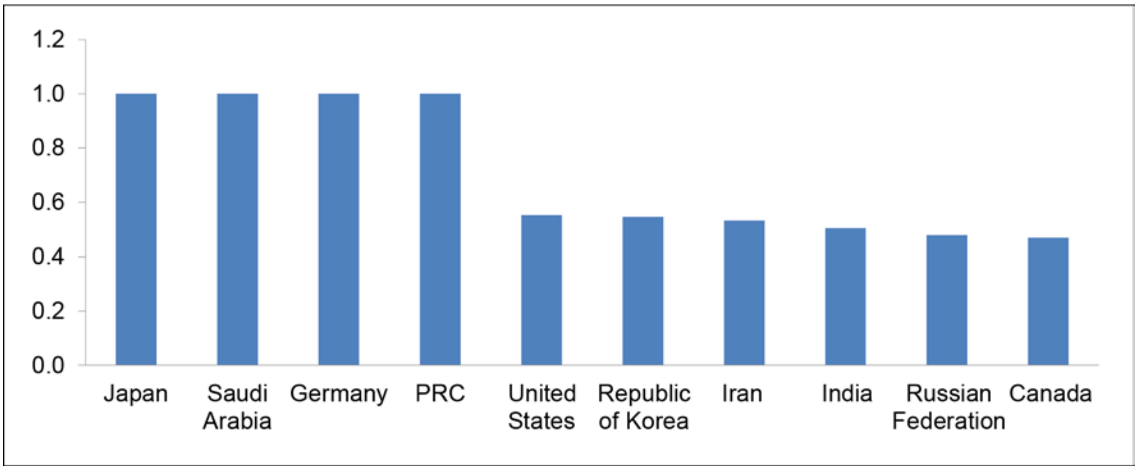


Figure 3 shows the ranking based on the energy efficiency score.

Table 5: Descriptive Statistics

	Population	Energy Use	GDP	CO_2
Max.	138,6395,000	3,051	1.94854E+13	9,838,754,028
Min.	18,037,776	212	162,390	572,782,585.8
Average	346,899,424.5	870.3	4.71659E+12	2,376,848,085
SD	515,133,085.7	919.6204	5.95477E+12	2,840,413,837
Kurt.	1.154077966	2.146592	2.485672997	4.396359334
Skew.	1.803495758	1.814325	1.860878466	2.210077835

Table 5 shows the descriptive statistics of the data. It is possible to reinvest a fixed share of the revenue generated from corporate tax in carbon reduction and energy efficiency technologies or to offer tax burden relaxation to facilitate R&D for these technologies. This can partly address the obstacles to tax implementation—at least in sectors in which the extra cost of low-carbon technology choices is comparable to tax revenues. However, given that technology investment happens in advance, to be effective, host governments need to make advance payments. Equation 5 calculates the potential energy savings (PES) of the less efficient countries. The results show that the United Kingdom has the lowest PES value of 40.2. Although its main energy use efficiency score is 0.874, the general energy use of the United States remains greater than that in all the top 10 CO_2 emitting economies. Consequently, for those economies that use a greater amount of energy, even a slight increase in their energy efficiency can save a lot of energy. An energy efficiency analysis of energy consumption (McGlade and Ekins 2015) identified the atmospheric carbon dioxide concentration.

Figure 4: CO_2 Emissions

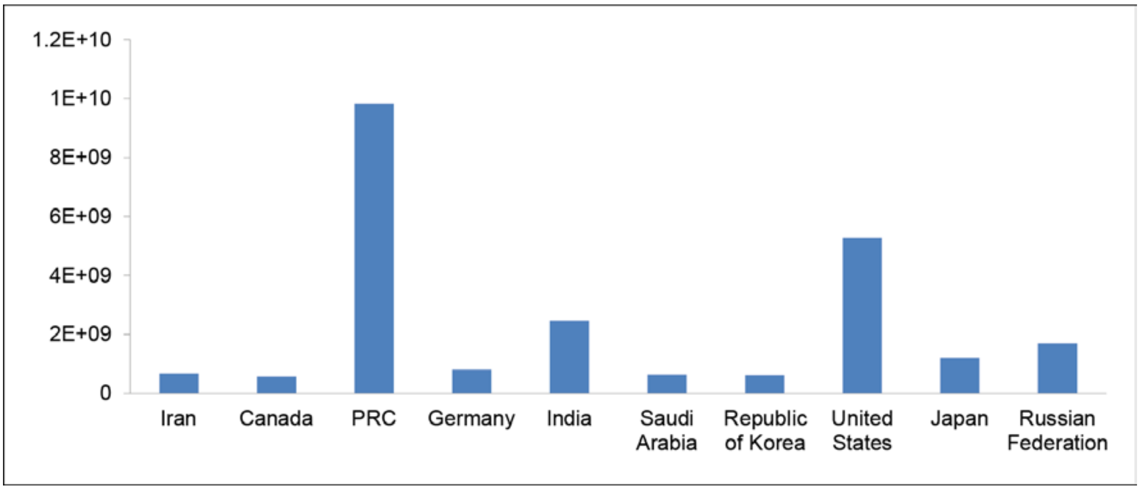


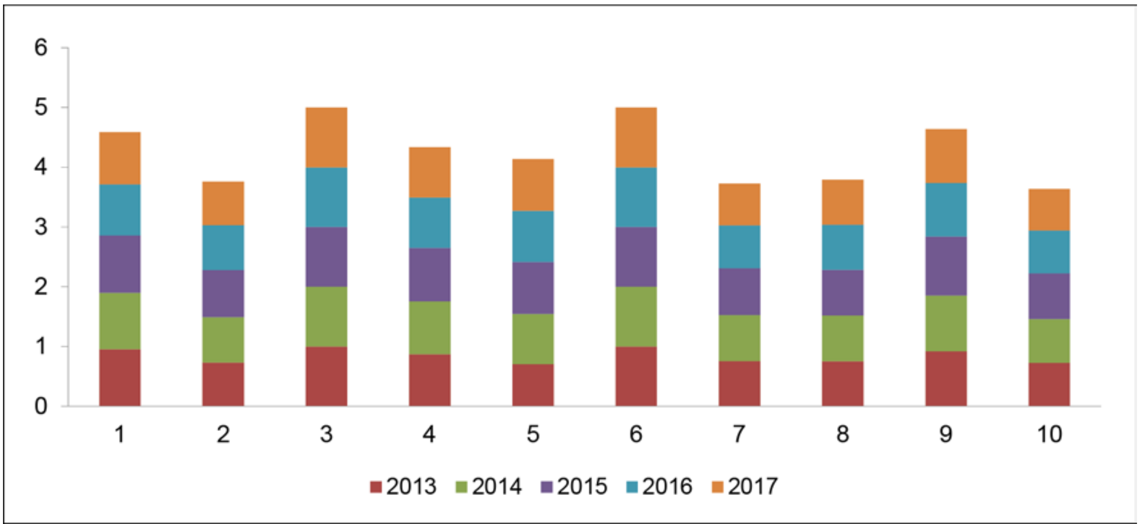
Figure 4 shows the CO_2 emissions. Among the top 10 CO_2 emitting countries, Saudi Arabia appears for 5 consecutive years after 2005, in 2013 to 2017. Canada was efficient, while the relative rankings show that the UK and the Republic of Korea have experienced significant improvements in efficiency. Other market factors can prejudice energy efficiency, for example a country's growth and variations in its GDP, global economic trends, demographics, and climate patterns (Antonietti and Fontini 2019). Globally, the improvement of energy efficiency is a major factor in sustainability policies; for example, the European Union has established energy intensity as a driving force of its climate change strategy. Likewise, organizations or countries implement energy intensity reduction targets at the national and international levels.

Table 6: Efficiency of CO_2 Emissions for the Top 10 CO_2 Emitting Countries

No.	Country	2013	2014	2015	2016	2017
1	Iran	0.95	0.95	0.96	0.85	0.88
2	Canada	0.73	0.76	0.79	0.75	0.73
3	PRC	1.00	1.00	1.00	1.00	1.00
4	Germany	0.87	0.88	0.90	0.84	0.84
5	India	0.71	0.84	0.87	0.86	0.87
6	Saudi Arabia	1.00	1.00	1.00	1.00	1.00
7	Republic of Korea	0.76	0.77	0.78	0.72	0.70
8	United States	0.75	0.76	0.77	0.75	0.75
9	Japan	0.92	0.94	0.98	0.90	0.90
10	Russian Federation	0.73	0.73	0.76	0.72	0.70

Table 6 shows the efficiency of CO_2 emissions for the top 10 CO_2 emitting countries. The energy demand (globally) in 2011 was 13326 million metric tons of oil equivalent (MMT), which grew by 1.82% and passed 13569 MMT in 2012. There was a small decrease (0.41%) in the demand for energy in the next year, 2013, but, after this slight decrease, the data of the following years show an increase in the energy demand with increasing trends (Figure 5).

Figure 5: Efficiency of CO_2 Emissions



Energy subsidies produce economic losses for governments, which ultimately cause inefficiency in energy consumption and enforce the increasing environmental costs. Even though subsidies aim to provide financial assistance for poor households, they are frequently unable to achieve economic benefits, which accumulate to rich families. Various countries have eliminated energy subsidies or implemented energy price reforms, with many failures and some successes. The magnitude (level) of energy efficiency assists policymakers in comprehending and forecasting the significance of energy subsidy reforms with the help of rigorous empirical analysis. Therefore, the current study proposed the relationship between energy efficiency and energy subsidies to understand the mechanism of energy prices in the region. An example is Haiti's endeavored energy subsidy of up to 2.2% of its GDP in 2018, which kindled disturbances, causing deaths and political instability.

The same fluctuating pattern of global CO_2 emissions is apparent; for example, it was 33,049 MMT in 2011, 33,579 MMT (1.6% growth) in 2012, and 33,049 MMT (1.72% decrease) in 2013 (Iftikhar et al. 2018). Table 7 lists the efficiency of the average CO_2 emissions of the top 10 CO_2 emitting countries during the period 2013–17. The results indicate that the CO_2 emission intensity is between 0.637 and 0.0619. Among the top 10 CO_2 emitting countries, India has the highest CO_2 emission intensity score. In addition, Saudi Arabia's efficiency score is the highest, but it has a score of 0.462 for the carbon dioxide emission intensity, ranking 10th.

Table 7: Ranking Based on the Efficiency of CO_2 Emissions

Country	CO_2 Efficiency Score	Ranking
Saudi Arabia	1.00	1
PRC	1.00	2
Japan	0.90	3
Iran	0.88	4
India	0.87	5
Germany	0.84	6
United States	0.75	7
Canada	0.73	8
Republic of Korea	0.70	9
Russian Federation	0.70	10

Table 7 shows the ranking of the top 10 CO_2 emitting countries based on the efficiency of CO_2 emissions. The results in Figure 6 show the potential reductions in CO_2 emissions in 2017 for low-efficiency countries, although the country with the lowest potential CO_2 emission reduction is the United States, which is the main CO_2 emitter. Any improvement in the efficiency of CO_2 emissions could bring considerable benefits, including reduced carbon dioxide.

Figure 6: Economic Efficiency Score

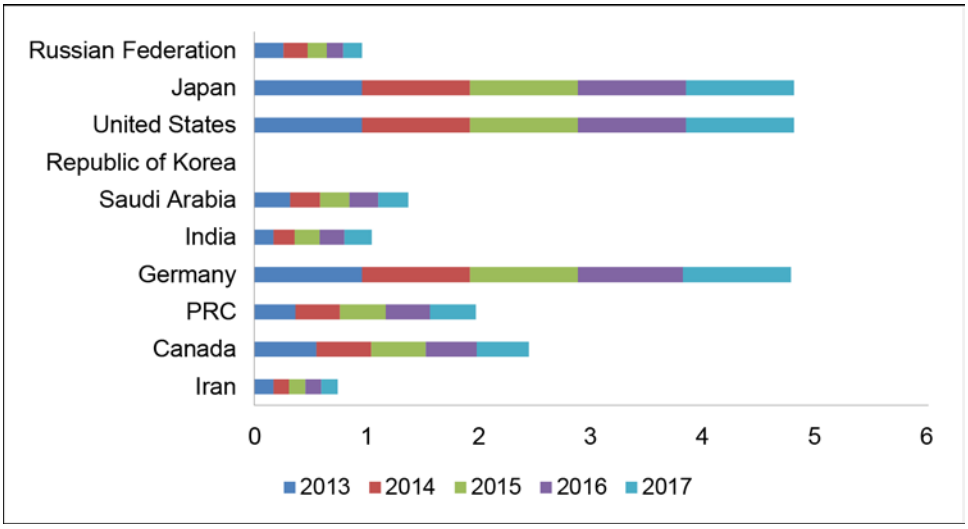


Figure 6 shows the economic efficiency score. The US and Japan were the best-performing countries, while the Russian Federation and India ranked in the last five during the study period.

Table 8: Economic Efficiency Score

Country	2013	2014	2015	2016	2017
Iran	0.18	0.14	0.15	0.15	0.15
Canada	0.58	0.51	0.51	0.47	0.48
PRC	0.38	0.41	0.42	0.41	0.43
Germany	1.00	1.00	1.00	0.97	1.00
India	0.18	0.19	0.23	0.23	0.25
Saudi Arabia	0.33	0.28	0.27	0.27	0.28
Republic of Korea	0.00	0.00	0.00	0.00	0.00
United States	1.00	1.00	1.00	1.00	1.00
Japan	1.00	1.00	1.00	1.00	1.00
Russian Federation	0.27	0.22	0.18	0.15	0.17

Sectoral Effects of Subsidy Removal and Energy Prices

Sectoral effects are sensitive to the intensity of the consumption of gas, though there is a decrease in power production because of the elimination of the subsidy for gas, below 10%, since a new source of energy, for instance oil, would replace the gas for power generation. The gas sector output decreases by 15%–17% relying on the scheme of revenue recycling because of the deterioration (Wear and Harrington 2002; MacGill, Outhred, and Nolles 2004). Energy subsidies are general steps to benefit low-income households in industrialized and emerging economies; while after-tax subsidies were responsible for about $5.3 trillion, or ~6.5%, of the worldwide GDP in 2015, it might have been around 14%–18% of the GDP in emerging economies in Northern Africa (MENA), the Middle East, and other regions (Coady et al. 2015). Such energy subsidies express the fossil fuel subsidies that target the power prices, causing decreases in the costs of energy for the end users while increasing the revenue for energy suppliers. In this situation, researchers have suggested the privileged management of energy producers (Rentschler and Bazilian 2017). The MENA constituency contains the greatest share of worldwide pre-tax energy subsidies, about $237 trillion (48%) of the worldwide subsidies in 2012–14, which is about 9% of the GDP of the constituency (El-Katiri and Fattouh 2017; Griffiths 2017).

The subsidies' removal causes the transfer of the increased revenues or extra acquired budget within the economy, producing economic development and correcting the prevailing distortions due to the remaining subsidies. GDP increases and positive economic outcomes rely on the way in which the economy incorporates the investments or augmented income. If the extra collected revenues and savings (due to the subsidy removal) were cast off to finance investment in energy, they would yield constructive monetary effects. Channeling the new collected revenue and the savings to households may yield the lowest economic welfare and government spending among the four revenue reprocessing schemes. These findings are consistent with the studies that Khalid and Salman (2020) and Timilsina and Pargal (2020) conducted, even though the major emphasis of the existing studies has been on the tax scheme of carbon emissions.

The major strategy understanding is that rearrangement and investment through the capital that subsidy removal produces are important to make the best use of monetary welfare from the removal of energy subsidies while tax cuts or investment are better than other options to assign the savings from an efficiency viewpoint. The economic welfare increases due to a decrease in the excise tax or personal income tax. This is due to poor households paying excise taxes that are proportionate to their lower income, and cutting taxes does not assist them economically. Various subdivisions interrupt the energy price effects; especially in the manufacturing sector, the output decreases by 10%–11%, nourishment and other substances decrease by ~7%, and crude oil falls by ~5%.

The scheme of emission mitigation does not have a tendency to eradicate energy subsidies; it removes or decreases them conditional on the sector and the targeted households that benefit from them. Iran started by removing and keeping particular energy subsidies while decreasing the recipients in specific households. Meanwhile, it assists particular types of manufacturing that rely heavily on economic survival and maintain global antagonism, for instance Saudi Arabia's oil production. They largely consume fuels among underprivileged households or energy sources that are comparatively cleaner than other energy sources. Jordan, for example, reformed the energy subsidy reserved for LPG to ensure low carbon emissions (Sarrakh et al. 2020).

5. CONCLUSION AND POLICY IMPLICATIONS

The study used the DEA method to measure energy, economic, and environmental efficiency by taking the top 10 CO_2 emitting countries in the world as a case study to provide a way forward for energy pricing and market reforms from the perspective of emission reduction. The PRC, Japan, and Saudi Arabia are efficient countries regarding energy, while the study identified the Russian Federation as the least efficient of all the top 10 CO_2 emitting countries from 2013 to 2017. In terms of energy intensity, the Russian Federation achieved the maximum score of 0.409. In comparing energy intensity and energy efficiency, using energy intensity to measure a country's energy efficiency may not be appropriate. In terms of carbon dioxide emissions' efficiency, the US and Saudi Arabia are effective countries among the top 10 CO_2 emitting countries, while eight countries scored less than 0.5, with efficiency scores of 0.408, respectively. Saudi Arabia has been leading for 5 consecutive years. Canada was efficient in terms of relative rankings, whereas the UK and the Republic of Korea made significant improvements in energy efficiency. The results revealed that the CO_2 emission intensity is between 0.637 and 0.0619 and that India had the highest CO_2 emission intensity score while Saudi Arabia had a score of 0.462 for carbon dioxide emission intensity. It is possible to decrease the CO_2 emissions even though these countries have the lowest potential CO_2 emission reductions, while an improvement in the efficiency of CO_2 emissions could bring a considerable reduction in carbon dioxide emissions.

A government opens up its energy market, then the intervention of the energy policy can increase the share of non-fossil fuel power generation to 34%, which is consistent with the national target of non-fossil fuels by 2020. In the absence of market reforms, the level of non-fossil fuel technology development incentives will require a relatively low carbon price (about US$4.52/ton CO_2) by 2025. The Kingdom of Saudi Arabia has given priority to increasing the domestic energy, such as renewable energy, domestic oil, and gas. International prices have experienced several rapid increases, which have had a profound impact on energy policies. Subsidies for petroleum products used as fuel mainly affect the power sector. Estimations have indicated that the energy sector will account for 52% of the total, while the other effects on CO_2 emissions will account for about a 1.6% reduction in energy-related emissions in 2020. Energy-intensive industries are usually the most concerned about keeping prices low. Industries that strive to remain competitive globally may also face particular pressure to reduce their operating costs. Economists generally believe that high subsidies cause wasteful consumption and distort the energy market. However, the needs to protect vulnerable groups, maintain political stability, and lobby for special interests may constitute an insurmountable obstacle to reform. It is necessary to reduce subsidy spending, keep fiscal deficits below 3%, and reduce the slowdown in economic growth.

Based on the above conclusions, we present the policy implications, which can provide reference for relevant departments to formulate strategies for the development of efficiency measurement against the background of energy, economic, and environmental efficiency.

1) Regional energy, economic, and environmental efficiency development are an organic system, and the degree of matching between the energy consumption and CO_2 emissions and the development mode should be an important reference standard for the development of green energy sources.

2) While continuing to promote the construction of a regional renewable energy plan, a government should improve the channels for information dissemination and optimize the integration of renewable energy to enhance the income-increasing effect of renewable energy, which will create jobs.

3) Under the guidance of the supply-side energy reform policy and the current supply and demand situation, countries can develop and implement high taxes for fossil fuel to avoid increasing its demand.

4) Countries should improve the factor allocation ability of farmers and promote the reform of the traditional agricultural production mode with petrochemical agriculture as the main part.

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