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REGIONAL COOPERATION IN THE EU's BALTIC SEA REGION AND NON-BALTIC SEA REGION: ENVIRONMENT AND ENERGY

The EU's strategy with respect to the Baltic Sea Region (BSR) represents a serious effort to strengthen cooperation among the Baltic Sea littoral states as for environmental improvement and more efficient energy use. The EU's regional cooperation policy could be applied to other areas if its regional strategy in the BSR is successfully realized. This study compares the environmental and energy efficiencies between the BSR and non-BSR in the EU by using the data envelopment analysis (DEA) approach. The study's results indicate that environmental efficiency in the BSR surpassed that in the non-BSR in 2009, while energy efficiency in the BSR has gradually caught up with that in the non-BSR in 2009. In general, the non-BSR presents better environmental efficiency improvement given the same improvement degree of energy efficiency in these two regions.

Keywords: *BSR; EU; DEA; regional cooperation; efficient energy use.*

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РЕГІОНАЛЬНЕ СПІВРОБІТНИЦТВО У СФЕРІ ЕКОЛОГІЇ ТА ЕНЕРГЕТИКИ В ЄС: ПОРІВНЯННЯ БАЛТІЙСЬКОГО РЕГІОНУ З ІНШИМИ ЧЛЕНАМИ ЄС

У статті представлено стратегію, розроблену ЄС для країн Балтійського регіону з метою зміцнення співробітництва даних країн у сфері захисту навколишнього середовища та ефективного використання енергії. Якщо використання даної стратегії продемонструє свою успішність, вона буде застосована і до інших регіонів Європи. Для порівняння індикаторів захисту навколишнього середовища та використання енергії між країнами Балтії та іншими членами ЄС використано метод аналізу середовища функціонування. Результати показали, що екологічні показники Балтії випередили показники інших країн та регіонів ЄС у 2009 році. У тому ж 2009 р. показники Балтії щодо енергетики досягли загальноєвропейського рівня. У цілому, на фоні схожої динаміки розвитку енергетики країни без виходу до Балтійського моря демонструють більші успіхи щодо захисту навколишнього середовища.

Ключові слова: *країни Балтійського регіону; метод аналізу середовища функціонування; регіональне співробітництво; ефективне використання енергоресурсів.*
Форм. 4. Рис. 4. Табл. 5. Літ. 14.

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РЕГИОНАЛЬНОЕ СОТРУДНИЧЕСТВО В ВОПРОСАХ ЭКОЛОГИИ И ЭНЕРГЕТИКИ В ЕС: СРАВНЕНИЕ БАЛТИЙСКОГО РЕГИОНА С ДРУГИМИ СТРАНАМИ-ЧЛЕНАМИ ЕС

В статье представлена стратегия, разработанная ЕС для стран Балтийского региона с целью укрепления сотрудничества этих стран в сфере защиты окружающей среды и эффективного использования энергии. В случае, если применение данной стратегии окажется успешным, стратегия будет применена и к другим регионам Европы. Для сравнения индикаторов защиты окружающей среды и использования энергии между странами Балтики и другими членами ЕС использован метод анализа среды функционирования. Результаты показали, что экологические показатели Балтики превысили показатели других стран и регионов ЕС в 2009 году. И в том же 2009 г. показатели Балтики по энергетике достигли общеевропейского уровня. В целом, на фоне

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схожей динамики развития энергетики страны без выхода к Балтийскому морю демонстрируют большие успехи в вопросах защиты окружающей среды.
Ключевые слова: *страны Балтийского региона; ЕС; метод анализа среды функционирования; региональное сотрудничество; эффективное использование энергоресурсов.*

Introduction

The European Union (EU) is composed of 8 Baltic Sea states and 19 non-Baltic states (there are now 28 members. Croatia had been added a few days before this research was finalized. Since at the time of research it was not a member, Croatia is not included in the sample). The 8 Baltic Sea states are the members of the Baltic Sea Region Energy Cooperation (BASREC), established in 1999 having 5 working items as goals: bioenergy, climate change, electricity, energy efficiency and gas. BASREC can make policies and implement projects in the Baltic Sea Region (BSR), but it is clear from the BASREC mandate that the EU has actively participated in BASREC activities. The member states of the EU have to obey the 93/76/EC Directive on end-use energy efficiency and reduce the final energy consumption by 9% during the 9-year period until 2015. Similarly, the Baltic Sea states have applied the Energy Indicators for Sustainable Development initiated by IAEA, UNDESA, IEA, EEA, and EUROSTAT to monitor the energy sectors in the region. Following the 2004 enlargement of the EU, the Baltic Sea has become an internal sea of the EU, with the Baltic Sea states receiving about 55 bln EUR from Cohesion Funds during 2007–2013. The BSR is the first example of macroregional cooperation in the EU, and if this cooperation model is successfully realized, then it will be applied to other fields or areas.

Environment and energy are fundamentally alarming problems in the BSR. In order to improve energy efficiency and decouple economic development from energy use, the indicator of the overall energy productivity (total primary energy supply per GDP) developed by IAEA, UNDESA, IEA, EEA, and EUROSTAT was selected as the target indicator for monitoring energy intensity in the BSR. Since carbon dioxide emissions resulting from energy consumption cause global warming and climate change, the main environmental challenge in the BSR is climate change mitigation. In accordance with the Kyoto Protocol – an international treaty designed to mitigate global warming – all Baltic Sea countries are bound by their commitments and face different challenges in meeting their targets established by the protocol. The quantity indicator of CO2 emissions developed by IAEA, UNDESA, IEA, EEA, and EUROSTAT was selected to analyze the environmental impact of the energy sector in the BSR. The targets introducing the systems of tradable emission permits (TEPs) and tradable green certificates (TGCs) in the BSR are not only used as instruments of international cooperation, but also for the development of sustainable environment and energy sectors around the Baltic Sea. In an international cooperation framework Hindsberger et al. (2003) analyzed TEPs and TGCs in the BSR. Their study result shows that the price changes of TEPs and TGCs not only have important influences on the production and investment patterns in the electricity sector but will determine the international exchange of electricity and the international trade in TEPs and TGCs.

The traditional environment or energy efficiency index, which ignores other critical input factors such as capital and labor, only takes greenhouse gas emission or energy use into account as a single input to produce GDP output while greenhouse gas emission or energy use alone cannot produce just any output (Patterson, 1996; Hu and Wang, 2006). Therefore, for the correct estimation of environment or energy efficiency one should apply a multiple-input model. Boyd and Pang (2000) argued that energy efficiency improvement must rely on the total-factor productivity improvement. Following this line, Hu and Wang (2006) used the data envelopment analysis (DEA) approach under the total-factor framework to construct a new index of energy efficiency, named the total-factor energy efficiency (TFEE), to estimate energy efficiency in China. The concept of TFEE has also been applied in the estimation of environmental efficiency (Chang et al., 2009). According to the survey results in Google Scholar by Chang (2013), the TFEE index has been cited 183 times. Other relative articles include Hu and Kao (2007), Han et al. (2007), Honma and Hu (2008), Honma and Hu (2009), Chang and Hu (2010), Zhang et al. (2011), and Chang (2013).

Numerous articles have applied the concept of TFEE to estimate environment and/or energy efficiency but to our best knowledge, no study has employed the DEA method to measure environment and energy efficiencies in the BSR. This paper examines environment and energy efficiencies in the Baltic Sea countries by using the DEA approach under the total-factor framework. The main results conclude that environmental efficiency in the BSR surpassed that in the non-BSR in 2009, while energy efficiency in the BSR has become gradually close to and even in 2009 caught up with that in the non-BSR. Generally speaking, the improvement degree of environmental efficiency in the non-BSR is larger than that in the BSR.

The paper is organized as follows. Section 2 gives the methodology of the DEA. Section 3 presents the empirical results. Section 4 concludes.

Methodology

In the DEA model we simultaneously consider desirable output, undesirable output, energy input, and non-energy input to examine the environmental efficiency and energy efficiency of a given decision-making unit (DMU) labeled k. There are z DMUs, and each DMU uses m kinds of energy inputs and n kinds of non-energy inputs to produce p kinds of desirable outputs and q kinds of undesirable outputs.

We define e_{ri} as the rth energy input for the ith DMU, x_{si} is the sth non-energy input for the ith DMU, g_{ti} is the tth desirable output for the ith DMU, and b_{ui} is the uth undesirable output for the ith DMU, where $i = 1,..., z$, $r = 1,..., m$, $s = 1,..., n$, $t = 1,..., p$, and $u = 1,..., q$. We specify the input-oriented DEA model as follows:

$$\begin{gathered} Min\,\phi_k \\ \text{s.t.} \\ \sum_{i=1}^{z} v_i e_{ri} \le \phi e_{rk}, \sum_{i=1}^{z} v_i x_{si} \le \phi x_{sk}, \sum_{i=1}^{z} v_i g_{ti} \le g_{tk}, \sum_{i=1}^{z} v_i b_{ui} \le \phi b_{uk} \\ v_i \ge 0, \phi \ge 0, \end{gathered} \tag{1}$$

where v_i is the weight of the ith DMU used for connecting the energy input, the non-energy input, the desirable output, and the undesirable output by a linear combination of each DMU. The undesirable output in (1) can be treated as input factors (Seiford and Zhu, 2002).

The model in (1) uses a directional distance function approach to solve the overall efficiency value ϕ_k, which stands for the distance from the location of the kth DMU, i.e., $(e_{rk}, x_{sk}, g_{tk}, b_{uk})$ to the production efficiency frontier, where $0 < \phi_k < 1$. Here, $\phi_k = 1$ means production efficiency, and $\phi_k < 1$ means production inefficiency. According to Figure 1, we can depict the overall efficiency value of DMU k as follows:

$$\phi_k = k^* / k^O = \text{Target Input Amount} / \text{Real Input Amount} = v_k x_k^* + v_k e_k^* + v_k b_k^* / v_k x_k + v_k e_k + v_k b_k < 1. \quad (2)$$

Similarly, we define the scores of environmental efficiency and energy efficiency for DMU k respectively as follows:

$$\phi_k^{ET} = k^* / k^{ET} = \text{Target Input Amount} / \text{Real Input Amount} = b_k^* / b_k, \quad (3)$$

$$\phi_k^{EY} = k^* / k^{EY} = \text{Target Input Amount} / \text{Real Input Amount} = e_k^* / e_k. \quad (4)$$

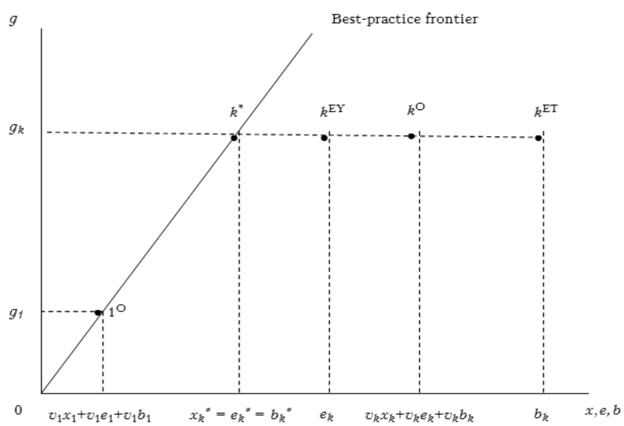


Figure 1. **Input-oriented DEA model**

Variables and data

We now employ the model introduced in Section 2 to evaluate the environmental and energy efficiency performances in the Baltic Sea and non-Baltic Sea states from 1995 to 2009. In Section 3.1 we describe the sample data. Sections 3.2 and 3.3 respectively present the results of environmental and energy efficiency performances in the Baltic and non-Baltic states.

The dataset in this study includes one desirable output (i.e., real GDP based on the price level in 2005), and one undesirable output (i.e., CO2 emission with the calculation unit as kilotons, kt). There are two non-energy inputs (i.e., real capital and labor employment) and one energy input (i.e., energy use with the calculation unit as kt of oil equivalent). All the data are from the World Bank website, and the time span is from 1995 to 2009. Table 1 shows the descriptive statistics of 3 inputs and 2 outputs for the EU, non-BSR, and BSR. The BSR has higher GDP but lower capital stock, a higher amount of labor and energy consumption than those in the non-BSR. Moreover, the standard deviations for all output and input variables in the BSR are larger than those in the non-BSR. This result implies there is a large difference in economic development among Baltic Sea states.

Table 1. **Descriptive statistics of inputs and output by area**

		EU	Non-BSR	BSR
Output				
Real GDP (mln USD)	Mean	461,392	461,307	461,595
	Std. Dev.	713,612	651,423	846,236
CO2 (kt)	Mean	146,920	137,872	168,410
	Std. Dev.	196,623	156,817	268,143
Inputs				
Real capital stock (bln USD)	Mean	9,475,662	9,620,628	9,131,367
	Std. Dev.	14,033,955	12,874,606	16,519,353
Labor (1,000 persons)	Mean	933,503	919,041	967,850
	Std. Dev.	1,156,722	1,038,170	1,403,055
Energy consumption (kt of oil equivalent)	Mean	63,588	61,150	69,377
	Std. Dev.	84,921	74,350	106,028

Notes: The monetary value is based on the 2005 prices.
Source: Developed by the author.

The correlation coefficients between the input and output variables in Table 2 are positive, which means that the input and output variables satisfy the principle of isotonicity in the DEA approach.

Table 2. **Correlation coefficient matrix**

	Real GDP	CO2 emission	Real capital	Labor	Energy usage
Real GDP	1	–	–	–	–
CO2 emission	0.922***	1	–	–	–
Real capital	0.986***	0.914***	1	–	–
Labor	0.943***	0.975***	0.933***	1	–
Energy usage	0.958***	0.967***	0.945***	0.978***	1

*** Correlation is significant at the 1% level.
Source: Developed by the author.

Empirical results — Environmental efficiency

Table 3 displays the results of environmental efficiency for 27 Baltic and non-Baltic states, showing that the average environmental efficiency scores in those 2 regions are respectively 0.643 and 0.692. This implies that Baltic and non-Baltic states need to reduce CO2 emissions by 35.7% and 30.8% respectively in order to remove environmental inefficiency. In Baltic Sea states, Sweden registers the highest average environmental efficiency score (0.994), while Estonia has the lowest one (0.233). In non-Baltic states, Luxembourg has the highest environmental efficiency score (0.953), while Bulgaria, Czech Republic, and Slovak Republic have the worst environmental efficiencies with the scores below 0.5.

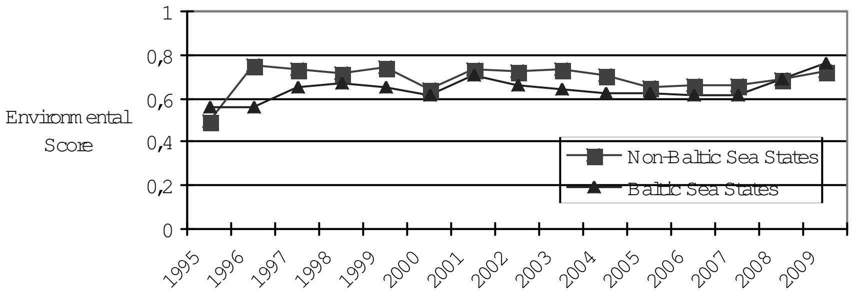


Figure 2. **Trend of environmental efficiency**

Table 3. **Environmental efficiencies of Baltic Sea and non-Baltic Sea states during 1995–2009**

Category	Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average
Baltic Sea States	Denmark	0.536	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.969
	Estonia	0.200	0.121	0.254	0.299	0.289	0.149	0.277	0.247	0.272	0.256	0.188	0.215	0.194	0.225	0.305	0.233
	Finland	0.446	0.786	0.471	0.522	0.471	0.858	0.824	0.732	0.451	0.494	0.853	0.740	0.753	0.869	0.824	0.673
	Germany	0.422	0.890	0.802	0.813	0.666	0.850	0.839	0.808	0.734	0.668	0.812	0.800	0.796	0.922	0.887	0.781
	Latvia	1.000	0.270	0.766	0.718	0.713	0.524	0.644	0.584	0.572	0.495	0.496	0.453	0.483	0.583	0.691	0.599
	Lithuania	0.598	0.205	0.621	0.684	0.630	0.335	0.610	0.549	0.713	0.676	0.438	0.459	0.461	0.549	1.000	0.569
	Poland	0.362	0.240	0.322	0.330	0.409	0.223	0.430	0.355	0.358	0.375	0.236	0.239	0.255	0.332	0.385	0.323
	Sweden	0.909	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.994
	Average	0.559	0.564	0.655	0.671	0.647	0.617	0.703	0.659	0.638	0.621	0.628	0.613	0.618	0.685	0.762	0.643
Non-Baltic Sea States	Austria	0.554	0.977	0.987	0.970	0.926	0.878	0.885	0.892	0.871	0.866	0.861	0.893	0.890	0.907	0.883	0.883
	Belgium	0.375	0.855	0.654	0.597	0.556	0.783	0.810	0.844	0.605	0.689	0.874	0.840	0.849	0.833	0.806	0.731
	Bulgaria	1.000	1.000	1.000	1.000	0.321	0.132	0.227	0.204	0.232	0.251	0.142	0.143	0.134	0.167	0.292	0.416
	Cyprus	0.483	0.548	0.454	0.478	1.000	0.534	1.000	0.745	0.846	0.651	0.535	0.522	0.498	0.554	0.619	0.631
	Czech Republic	0.200	0.231	0.282	0.346	0.377	0.181	0.315	0.310	0.375	0.354	0.254	0.266	0.270	0.367	0.400	0.302
	France	0.689	1.000	1.000	1.000	0.919	0.947	0.977	0.986	0.967	0.938	0.924	0.926	0.925	0.937	0.946	0.939
	Greece	0.466	0.597	0.669	0.631	0.574	0.527	0.534	0.571	0.566	0.560	0.574	0.579	0.557	0.606	0.655	0.578
	Hungary	0.483	0.469	0.317	0.331	0.639	0.369	0.658	0.590	0.673	0.608	0.450	0.428	0.426	0.508	0.654	0.507
	Ireland	0.452	0.846	0.853	0.842	0.804	0.797	0.823	1.000	1.000	1.000	1.000	1.000	1.000	0.845	1.000	0.884
	Italy	0.465	1.000	1.000	1.000	0.782	0.900	0.921	0.896	0.919	0.886	0.875	0.880	0.866	0.899	0.854	0.876
	Luxembourg	0.298	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.953
	Malta	0.399	0.510	0.627	0.669	0.953	0.641	0.922	1.000	1.000	1.000	0.523	0.546	0.519	0.659	0.722	0.713
	Netherlands	0.403	0.830	0.747	0.781	0.688	0.859	0.879	0.864	0.822	0.750	0.904	0.897	0.879	0.921	0.832	0.804
	Portugal	0.573	0.747	0.762	0.732	0.655	0.665	0.678	0.692	0.748	0.719	0.693	0.751	0.706	0.784	0.746	0.710
	Romania	0.767	1.000	0.851	0.444	1.000	0.327	0.456	0.349	0.360	0.382	0.246	0.255	0.298	0.375	0.422	0.502
	Slovak Republic	0.342	0.353	0.214	0.228	0.520	0.358	0.491	0.453	0.607	0.551	0.370	0.384	0.419	0.497	0.624	0.427
	Slovenia	0.494	0.670	0.710	0.713	0.659	0.628	0.688	0.641	0.652	0.582	0.532	0.529	0.539	0.566	0.642	0.616
	Spain	0.487	0.868	0.846	0.828	0.676	0.733	0.733	0.718	0.713	0.693	0.671	0.691	0.681	0.717	0.716	0.718
	United Kingdom	0.487	0.762	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950
	Average	0.496	0.751	0.735	0.715	0.739	0.645	0.737	0.724	0.735	0.709	0.654	0.659	0.656	0.692	0.727	0.692

Source: Developed by the author.

Figure 2 shows the trends of environmental efficiency in the BSR and the non-BSR over time. We can easily observe that these two regions have a similar trend during the sample period. The environmental efficiency scores of the non-BSR are all better than those of the BSR during 1996—2008, however, the environmental efficiency scores of the BSR turn better than that of the non-BSR in 2009. Historically, the non-Baltic region has always been more developed than the BSR, and thus in the non-BSR better environmental technologies can be diffused more efficiently than in the BSR. The Kyoto Protocol formally implemented in 2005 pushes for efficient environmental technology diffusion from non-Baltic states to Baltic states, which may be why the environmental efficiency of the BSR surpasses that of the non-BSR in 2009. Another possible reason for the environmental efficiency score of the BSR surpassing that of the non-BSR in 2009 is directly related to the impending final closure in 2009 of Ignalina, Lithuania's only nuclear power plant (Streimikiene, 2007). Table 3 also shows that the environmental efficiency score in Lithuania jumps from 0.549 in 2008 to 1 in 2009.

Empirical results — Energy efficiency

Next we compute the energy efficiency for Baltic and non-Baltic states, as displayed in Table 4. The table presents that the average energy efficiency scores in the BSR and non-BSR are 0.632 and 0.720, respectively, implying that the BSR should reduce energy consumption by 36.8% and the non-BSR should reduce it by 28.0% in order to remove energy inefficiency. Table 4 also shows that the energy efficiency scores vary in each DMU during the sample period. In the BSR, Denmark has the highest energy efficiency score (0.976), while the lowest score (0.323) appears in Estonia. In the non-BSR UK has the highest energy efficiency score (0.955), while the energy efficiency scores in Bulgaria, Czech Republic, Hungary, and Slovak Republic are the worst, below 0.5.

Figure 3 demonstrates the trends of energy efficiency performances in the BSR and non-BSR during the sample period. We note that although the energy efficiencies in these two regions have the same trend, the energy efficiency scores in the BSR are all lower than those in the non-BSR. Figure 3 also shows that the energy efficiency scores in the BSR have a large fluctuation during 1995—2000. After 2000, the BSR gradually caught up with the non-BSR.

BASREC was established in 1999 and began formal operations the following year. Energy efficiency is one of the 5 working groups in BASREC. By observing BASREC's environment and energy policies, it is clear that the EU is actively participating in its activities. The EU is able to provide a sustainable energy policy and share the know-how of energy technology with the BASREC countries. Hence, the paths of energy efficiency in the BSR and non-BSR have gradually come closer, with the energy efficiency in the BSR even catching up with that in the non-BSR in 2009.

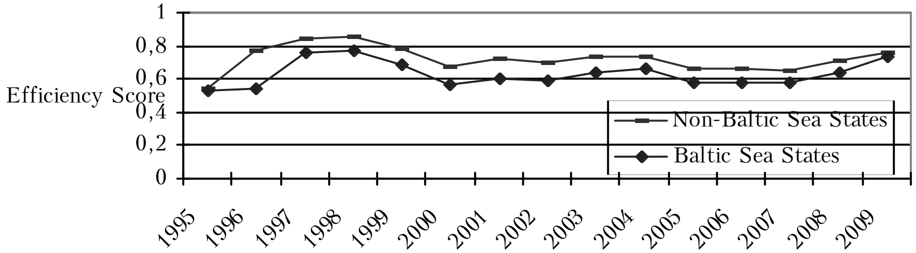
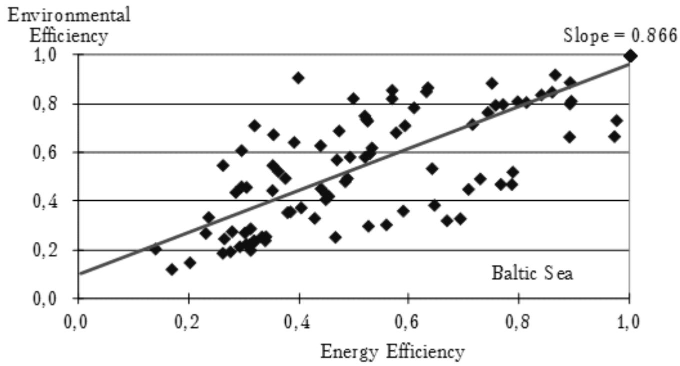


Figure 3. **Trend of energy efficiency,** *developed by the author*

Table 4. **Energy efficiencies of Baltic Sea and non-Baltic Sea states during 1995–2009**

Category	Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average
Baltic Sea States	Denmark	0.640	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.976
	Estonia	0.311	0.168	0.465	0.525	0.311	0.201	0.278	0.264	0.301	0.339	0.261	0.292	0.275	0.304	0.557	0.323
	Finland	0.351	0.608	0.765	0.787	0.785	0.568	0.568	0.523	0.706	0.727	0.630	0.521	0.518	0.633	0.498	0.613
	Germany	0.453	0.890	0.890	0.893	0.890	0.858	0.839	0.811	0.975	0.971	0.796	0.769	0.756	0.864	0.749	0.827
	Latvia	1.000	0.230	0.741	0.713	0.591	0.361	0.390	0.491	0.468	0.487	0.374	0.439	0.483	0.519	0.472	0.517
	Lithuania	0.527	0.139	0.531	0.575	0.438	0.235	0.295	0.261	0.318	0.353	0.284	0.304	0.295	0.351	1.000	0.394
	Poland	0.588	0.338	0.667	0.691	0.448	0.310	0.448	0.378	0.384	0.403	0.319	0.317	0.332	0.427	0.645	0.446
	Sweden	0.398	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.960
	Average	0.534	0.547	0.757	0.773	0.683	0.567	0.602	0.591	0.644	0.660	0.583	0.580	0.582	0.637	0.740	0.632
Non-Baltic Sea States	Austria	0.530	0.977	0.987	0.970	0.926	0.878	0.885	0.892	0.871	0.866	0.861	0.893	0.890	0.907	0.883	0.881
	Belgium	0.328	0.782	0.844	0.838	0.811	0.631	0.642	0.649	0.832	0.867	0.705	0.697	0.657	0.723	0.672	0.712
	Bulgaria	1.000	1.000	1.000	1.000	0.312	0.126	0.167	0.153	0.180	0.201	0.140	0.138	0.141	0.171	0.419	0.410
	Cyprus	0.708	0.672	0.871	0.933	1.000	0.702	1.000	0.797	0.905	0.821	0.742	0.712	0.668	0.733	0.820	0.806
	Czech Republic	0.274	0.277	0.514	0.579	0.327	0.225	0.300	0.294	0.336	0.365	0.280	0.288	0.292	0.382	0.444	0.345
	France	0.489	1.000	1.000	1.000	0.981	0.947	0.977	0.986	0.967	0.938	0.924	0.926	0.925	0.937	0.946	0.930
	Greece	0.717	0.813	0.884	0.840	0.782	0.726	0.722	0.725	0.704	0.739	0.769	0.744	0.722	0.783	0.791	0.764
	Hungary	0.504	0.469	0.646	0.628	0.473	0.347	0.467	0.508	0.542	0.578	0.387	0.362	0.355	0.418	0.695	0.492
	Ireland	0.606	0.885	0.947	0.918	0.926	0.948	0.983	1.000	1.000	1.000	1.000	1.000	1.000	0.998	1.000	0.947
	Italy	0.544	1.000	1.000	1.000	0.973	0.952	0.956	0.921	0.919	0.910	0.905	0.891	0.883	0.918	0.854	0.908
	Luxembourg	0.315	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.954
	Malta	0.526	0.651	0.797	0.948	0.953	0.786	0.965	1.000	1.000	1.000	0.658	0.682	0.644	0.804	0.952	0.824
	Netherlands	0.424	0.830	0.847	0.852	0.848	0.859	0.879	0.803	0.910	0.914	0.802	0.839	0.758	0.921	0.751	0.816
	Portugal	0.649	0.747	0.762	0.732	0.673	0.684	0.686	0.692	0.748	0.720	0.702	0.726	0.678	0.784	0.746	0.715
	Romania	0.835	1.000	0.851	0.980	1.000	0.333	0.366	0.269	0.280	0.304	0.248	0.264	0.298	0.358	0.449	0.522
	Slovak Republic	0.383	0.353	0.475	0.518	0.436	0.303	0.350	0.328	0.412	0.449	0.315	0.324	0.343	0.407	0.618	0.401
	Slovenia	0.512	0.670	0.710	0.713	0.659	0.572	0.573	0.532	0.569	0.602	0.474	0.474	0.476	0.556	0.595	0.579
	Spain	0.499	0.868	0.846	0.828	0.763	0.733	0.733	0.718	0.713	0.693	0.671	0.691	0.681	0.717	0.716	0.725
	UK	0.564	0.762	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.955
	Average	0.548	0.777	0.841	0.857	0.781	0.671	0.718	0.698	0.731	0.735	0.662	0.666	0.653	0.711	0.755	0.720

Source: Developed by the author



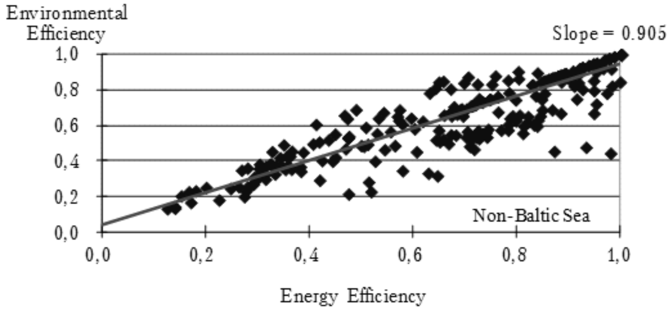


Figure 4. **The relationship between energy efficiency and environmental efficiency,** *developed by the author*

In Figure 4 we take energy efficiency as an independent variable and environmental efficiency as a dependent variable to establish a linear regression. A linear regression of Baltic Sea states data yields a slope of 0.866 and an intercept of 0.095. For non-Baltic Sea states, a linear regression analysis yields a slope of 0.905 and an intercept of 0.040. The statistical data show that the R-square of the linear regression in non-Baltic states is higher than that for Baltic states. Table 5 lists more detailed regression results.

Table 5. **Linear regression analysis of energy and environmental efficiencies**

Region	Variable	Coefficient	Std. Error	t-Statistics	Prob.
BSR	Constant	0.095	0.034	2.789	0.006
	Energy efficiency	0.866	0.050	17.474	0.000
	R-squared	0.721			
	Prob(F-statistics)	0.000			
Non-BSR	Constant	0.040	0.019	2.114	0.035
	Energy efficiency	0.905	0.025	36.559	0.000
	R-squared	0.825			
	Prob(F-statistics)	0.000			

Source: Developed by the author

Comparing the R-squared values between the BSR and non-BSR shows that the data of the non-BSR are more clustered than those of the BSR. Moreover, the regression model of the non-BSR has higher explanatory ability than that of the BSR. In Table 4 the positive relationship and statistical significance between energy efficiency and environmental efficiency indicate that the improvement of energy efficiency is helpful for improving environmental efficiency. Since the slope (0.905) of the linear regression for the non-BSR is larger than that (0.866) for the BSR, the improvement degree of environmental efficiency in the non-BSR is larger than that in the BSR given the same promotion degree of energy efficiency in these two regions.

Conclusion

The BSR is a test case for the EU, which would push the environmental improvement and advanced efficient energy use in the Baltic Sea states. In order to achieve the EU target, the traditional estimation index developed by IAEA, UNDESA, IEA, EEA, and EUROSTAT is used to monitor environmental and energy efficiencies in the BSR. The traditional index only takes greenhouse gas emissions and energy use into account as a single input to produce GDP as an output, while ignoring other critical inputs are capital and labor employment. Some papers have applied environmental and energy indices to study certain areas. These regions include China, Japan, and the OECD countries. To our best knowledge, no paper has yet examined, nor compared the environmental and energy efficiencies in the BSR and non-BSR under the total-factor framework. Hence, this paper implements the total-factor framework to estimate and compare environmental and energy efficiencies between the BSR and non-BSR.

The study's results indicate that environmental efficiency in the BSR surpassed that in the non-BSR in 2009. In respect to of energy efficiency, the BSR has gradually caught up with the non-BSR. The relationship between the environmental and energy efficiencies in these two regions demonstrates that energy efficiency improvement is helpful for environmental efficiency. In addition, the environmental efficiency in the non-BSR has a larger progression than that in the BSR given the same improvement range in the energy efficiency.

In this study we effectively applied environmental and energy estimation tools with the total-factor concept to monitor the environmental and energy efficiencies in the BSR and non-BSR in the EU. The EU is struggling to ensure proper environment and energy development in the BSR. If the EU's test case is successful in the BSR, then the BSR would be a good case for international cooperation in the environmental and energy fields.

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Стаття надійшла до редакції 21.11.2013.