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A futuristic view of energy saving and related energy rebound effect in Bangladesh using complete decomposition model (CDM)

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Abstract

In this paper Complete Decomposition Model is used to compute the future energy saving pattern from the difference of the 'trend' and 'real' values of energy consumption. The 'trend' is defined as a sum of activity effect and the energy use in the base year. The 'real' is defined as a sum of energy consumption in the base year and the change in energy consumption due to the activity effect, structural effect and intensity effect. This analysis is carried out in respect of Bangladesh for the period 2008-2030. The economic sectors that are taken in to account are agriculture, industry and service. The futuristic view shows that Bangladesh can save about 47.47 MTOE in agriculture sector and 34.96 MTOE from service sector. On the other hand, industry sector, which is accounted for 58% of the total energy consumption, failed to save energy, rather the country consumed 227 MTOE more energy than usual. The energy rebound effect that relies upon the activity effect and structural effect has also been estimated to examine the energy uses pattern of these sectors. The aggregate energy rebound effect was found to be 1480 MTOE, of which activity effect and structural effect contribute 91.21% and 8.78% respectively.

Key Words: Complete Decomposition Method, Energy saving, Energy rebound effect, Bangladesh.

Introduction

The decomposition method is an effective tool for energy demand analysis and also for energy and environmental description (Ang, 2000). This approach takes into account the relationship between energy consumption in different sectors of economic activity and energy-related economy. It gives a differential and quantities view of the implementation of energy conservation measures. The forefront study of the application of the decomposition of energy conservation was presented by others (Sun 2003). However, most of the studies were limited to two economic dimensions such as energy intensity and GDP. We have extended the method to analyze the energy saving of different economic sectors of Bangladesh projected over the period 2008-2030.

Energy saving reflects the effects of technological progress and structural changes of an economy. Energy saving indicates the total reduction of energy use if the overall economic activity remains unchanged. If the effectiveness of production technology increases, energy saving takes place. Again, if the share of a sector of the total production volume decreases, energy saving may also occur. Energy saving also takes into account the structural shift such as the shift towards the use of services instead of energy commodities (Punyong, 2008).

The energy rebound effect captures the development that takes place if technological change is not directly included. It is the calculation of a sector's response in terms of energy consumption to the development of the value added plus the structural effect. The energy rebound effect is a reflection of the indirect effect of technological development on energy use insofar as technological development increased economic growth accompanied as structural shift in the economy.

In this study, the three dimension complete decomposition model was formulated to analyze the energy saving and energy rebound effect of different sector in Bangladesh. The study analyzed data of the period 2007-2030, as an attempt to assess the extent of the acclaimed success in Bangladesh.

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Materials and Methods

We have used the available up-to-date data from different national and international sources like Bangladesh Bureau of Statistics (BBS), Bangladesh Power Development Board (BPDB), Petrobangla, Asian Development Bank (ADB), and the World Bank (WB), etc. The annual data of Gross Domestic Product (GDP) is converted into US$ at the rate of 2000. The GDP and commercial energy consumption of 2007 are considered as base values. In 2008, the GDP growth rate was 5.2% and it is considered at 10% in 2030. This is the proposed futuristic goal of the present government as documented in election manifesto and expressed in vision 2021.The contribution of agriculture, industrial and service sector GDP are 22%, 28% and 50% respectively in 2007 (BBS, 1992-2008). This figure will increase to 13%, 45% and 42% respectively in 2030. In 2008, the energy growth rate was 8% and it will rise to 9.5% in 2030 (BBS, 1992-2008). The contribution of commercial energy consumption in agriculture, industrial and service sector are 11%, 46% and 43% respectively in 2007 (BBS, 1992-2008). This figure rose to 5%, 62% and 33% respectively in 2030. The energy co-efficient was 1.53 in 2007 and this figure is estimated to be 0.95 in 2030.

The Complete Decomposition Method was used to construct the energy saving model in different sector. The model starts with *GDP*-related energy intensity,

E_t is the sum of sector's energy consumption E_{it}:

$$E_t = \sum_i E_{it} \quad \text{---------- (1)}$$

Where i is the index of sector.

The total energy consumption E_t is a function of three variables:

1) LEVEL OF OUTPUT, A_t, which measures aggregate sectoral activity either in economic or physical units and consists of sectoral inputs:

$$A_t = \sum_i A_{it} \quad \text{---------- (2)}$$

2) ENERGY INTENSITY OF SECTORS, I_{it}, defined as sectoral energy consumption E_{it} per unit of activity A_{it}:

$$I_{it} = E_{it} / A_{it} \quad \text{---------- (3)}$$

3) STRUCTURAL PARAMETER, S_{it}, defining the share of sectors i in the aggregate sectoral output in the year t:

$$S_{it} = A_{it} / A_t \quad \text{---------- (4)}$$

The following equations decompose total energy consumption into the terms of activity, structure and energy intensity:

$$Et = \sum_i (A_t \text{ X } S_{it} \text{ X } I_{it}) \quad \text{---------- (5)}$$

$$= \sum_i (A_t \text{ X } [A_{it}/A_t] \text{ X } [E_{it}/A_{it}]) \quad \text{---------- (6)}$$

In the decomposition approach, changes in energy consumption between the base year and year t can be divided into activity, intensity and structure effects:

$$\Delta E_{ot} = E_t - E_o \quad \text{---------- (7)}$$
$$= \sum_i (A_t \text{ X } S_{it} \text{ X } I_{it}) - \sum_i (A_o \text{ X } S_{io} \text{ X } I_{io})$$

$$= GDP_{effect} + S_{effect} + I_{effect} \quad \text{---------- (8)}$$

Where, GDP_{effect}, S_{effect} and I_{effect} represents activity effect, structural effect and intensity effect respectively. Following the decomposition method (Sun. 1998, Sun. 2001) these three effects can be decomposed as below.

$$\text{Activity effect } (GDP_{effect}) = \sum_i (\Delta A_t S_{io} I_{io}) + (1/2)\Sigma\Delta A_t (S_{io} \Delta I_{it} + \Delta S_{it} I_{io}) + (1/3)\sum_i (\Delta A_t \Delta S_{it} \Delta I_{it}) \quad \text{---------- (9)}$$

$$\text{Structural effect } (S_{effect}) = \sum_i (A_o \Delta S_{it} I_{io}) + (1/2)\sum_i \Delta S_{it} (A_o \Delta I_{it} + \Delta A_t I_{io}) + (1/3)\sum_i (\Delta A_t \Delta S_{it} \Delta I_{it}) \quad \text{---------- (10)}$$

And

$$\text{Intensity effect } (I_{effect}) = \sum_i (A_o S_{io} \Delta I_{it}) + (1/2)\sum_i \Delta I_{it} (A_o \Delta S_{it} + \Delta A_t S_{io}) + (1/3)\sum_i (\Delta A_t \Delta S_{it} \Delta I_{it}) \quad \text{---------- (11)}$$

Here,

E_t, E_0 = Total energy used in year t and 0 (base year)
$I_{io} + \Delta I_{it}$, I_{io} = energy intensity of sector i in year t and 0, respectively
$S_{io} + \Delta S_{it}$, S_{io} = output share of sector i in year t and 0
$A_o + \Delta A_t$, A_o = level of aggregated activity in year t and 0
$\Delta A_t = A_t - A_0$
$\Delta S_{it} = S_{it} - S_{io}$ and
$\Delta I_{it} = I_{it} - I_{io}$
From equation (7), the 'real' energy consumption in the year t can be expressed as.

$$\textit{Real} = E_t = \Delta E_{ot} + E_o \quad \text{---------- (12)}$$

The GDP_{effect} is used to predict the 'trend' of the energy consumption in year t as in the following equation.

Trend $= GDP_{effect} + E_o$ ---------- (13)

Energy saving is defined as the difference between Trend and Real. Thus,

ψ = Real - Trend

$=\Delta E_{ot} + E_o - GDP_{effect} - E_o$

$=\Delta E_{ot} - GDP_{effect}$

$= GDP_{effect} + S_{effect} + I_{effect} - GDP_{effect}$

$= S_{effect} + I_{effect}$ ---------- (14)

Energy saving is achieved only if $\psi < 0$, which indicates that the actual increase of energy consumption (real) is less than what should have, otherwise, resulted from the growth of the economy (trend). This condition implies that the energy consumption has been comparatively reduced (saved), which is the indicator of the success of the energy conservation plan. In contrast, if $\psi > 0$, energy saving is not achievable.

The energy saving model (ψ) can be written as,

$$\begin{aligned}\psi &= S_{effect} + I_{effect} \\ &= \sum_i (A_o \Delta S_{it} I_{io}) + (1/2) \sum_i \Delta S_{it} (A_o \Delta I_{it} + \Delta A_t I_{io}) + (1/3) \sum_i (\Delta A_t \Delta S_{it} \Delta I_{it}) + \sum_i (A_o \Delta S_{io} \Delta I_{it}) + (1/2) \sum_i \Delta I_{it} (A_o \Delta S_{it} + \Delta A_t \Delta S_{io}) + (1/3) \sum_i (\Delta A_t \Delta S_{it} \Delta I_{it}) \\ &= \sum_i (A_o \Delta S_{it} I_{io}) + (1/2) \sum_i \Delta S_{it} (A_o \Delta I_{it} + \Delta A_t I_{io}) + \sum_i (A_o S_{io} \Delta I_{it}) + (1/2) \sum_i \Delta I_{it} (A_o \Delta S_{it} + \Delta A_t S_{io}) + (2/3) \sum_i (\Delta A_t \Delta S_{it} \Delta I_{it})\end{aligned}$$ ---------- (15)

Energy saving appears mathematically in these models as a negative value of ψ. Thus the negative values have S_{effect} and I_{effect}, represent the saving caused by the change of the respective dimensions.

Malaska *et al.* in 1999 proposed a group of metrics in order to relate the decomposition analysis to matters of sustainability. Dematerialization of energy production, immaterialization of consumption and rebound effect are important factors in shaping sustainable energy. We have analyzed the energy rebound effects of different sectors based upon Malaska's approach (Malaska *et al.,* 1999).

The equation for energy sustainability (*Es*) can be presented in the following matrix form

$$Es = \begin{pmatrix} E_{De} \\ E_{Sa} \\ E_{\mathrm{Re}} \end{pmatrix} = \begin{pmatrix} -1+0+0 \\ -1-1+0 \\ +0+1+1 \end{pmatrix} \begin{pmatrix} I_{effect} \\ S_{effect} \\ GDP_{effect} \end{pmatrix}$$

Where, E_{De} is dematerialization, E_{Sa} is immaterialization (energy saving) and E_{Re} is energy rebound effect

From solved of above matrix we get

$$Es = \begin{pmatrix} E_{De} \\ E_{Sa} \\ E_{\mathrm{Re}} \end{pmatrix} = \begin{pmatrix} -I_{effect} \\ -I_{effect} - S_{effect} \\ 0 + S_{effect} + GDP_{effect} \end{pmatrix}$$

Here,

E_{De} = Dematerialization = $- I_{effect}$

E_{Sa} = Immaterialization =Energy saving = $- (I_{effect}+S_{effect})$

E_{Re}=Energy Rebound effect = $S_{effect}+ GDP_{effect}$ ---------- (16)

The equation (16) is used in energy rebound effect calculation.

Results and Discussions

As the industrial sector consumes the major amount of energy and contributes to the economic development substantially, energy conservation activities have targeted this sector. Energy consumption in this sector during 2007-2030 was 1265.8 MTOE (see Table I). It accounted for 58% of the total energy consumption. Hence, energy conservation in this sector is vital. Emphasis will be placed on analyzing energy saving in this particular sector.

During the period 2008-2030 we observed that energy saving occurred in agriculture sector, of which -30.04 MTOE of energy saving was due to structural changes (S_{effect}), and -17.42 MTOE of energy saving was due to intensity changes (I_{effect}) as shown in Table II. The agriculture sector, however, failed to save energy in every year. In Table II it is found that trend value is greater than real value, that is, the value of is less than zero (trend of graph is decreasing), which is the condition for energy saving as shown in Figure 1.

Energy saving did not occur in industrial sector as shown in Table III. During the period 2008 to 2030 the extra energy consumption (227 MTOE) in industry sector came from structural change (S_{effect}) and intensity change (I_{effect}) with amounts of 231.7 MTOE and -4.6 MTOE respectively. In Table III it is found that 2007 to 2030 the real value is grater

Table I: Energy consumption, GDP and energy intensity in Bangladesh (BBS, 1992-2008)

Bangladesh	2007	2015	2020	2025	2030	2007-2030
EC (MTOE)	28.72	53.66	85.35	136.46	214.82	2188.57
GDP (mill. US$)	60412	100309.84	158612.7	255447.4	411400.5	4137693
I (KGOE/US$)	0.4754022	0.53	0.538	0.534	0.522	0.528
Agriculture sector						
EC (MTOE)	3.25	5.097	6.828	10.74	10.74	143
GDP (mill. US$)	12478	20061.96	28550.29	35762.63	53482	639487
I (KGOE/US$)	0.26	0.254	0.239	0.2098	0.2	0.22
Industry sector						
EC (MTOE)	13.24	27.08	133.19	81.19	133.19	1265.8
GDP (mill. US$)	17192	32099	57100	109842	185130	1669264
I (KGOE/US$)	0.76	0.84	083	0.73	0.71	0.75
Service sector						
EC (MTOE)	12.21	21.46	70.89	46.39	70.89	774.8
GDP (mill. US$)	30742	48148	172788	109842	172788	1828941
I (KGOE/US$)	0.42	0.44	0.41	0.42	0.41	0.42

Table II: Energy saving in agriculture sector

Year	Activity Effect (MTOE)	Structural Effect (MTOE)	Intensity Effect (MTOE)	Del Eot (MTOE)	Real Energy.. consm (MTOE)	Trend energy. consm (MTOE)	Energy saving (MTOE)
2008	0.168	0.211	-0.216	0.163	28.883	28.88	-0.0058
2009	0.350	0.219	-0.134	0.435	29.155	29.07	0.0849
2010	0.559	0.059	-0.080	0.538	29.258	29.27	-0.0211
2011	0.793	0.061	-0.025	0.830	29.551	29.51	0.0364
2012	1.045	0.064	0.034	1.144	29.864	29.76	0.0986
2013	1.328	-0.121	-0.138	1.068	29.788	30.048	-0.259
2014	1.690	-0.127	-0.121	1.441	30.161	30.41	-0.2488
2015	2.083	-0.134	-0.103	1.846	30.566	30.803	-0.2368
2016	2.509	-0.141	-0.082	2.286	31.006	31.229	-0.223
2017	2.834	-0.590	-0.365	1.878	30.598	31.554	-0.956
2018	3.409	-0.629	-0.389	2.390	31.110	32.129	-1.0191
2019	4.042	-0.672	-0.415	2.953	31.673	32.76	-1.0881
2020	4.737	-0.719	-0.445	3.573	32.293	33.457	-1.164
2021	4.851	-1.551	-0.921	2.379	31.099	33.57	-2.472
2022	5.397	-1.938	-1.043	2.415	31.135	34.12	-2.982
2023	6.180	-2.081	-1.129	2.970	31.690	34.90	-3.210
2024	7.041	-2.238	-1.223	3.578	32.298	35.76	-3.462
2025	7.986	-2.4106	-1.328	4.247	32.967	36.706	-3.738
2026	8.691	-2.952	-1.526	4.213	32.933	37.411	-4.4779
2027	9.780	-3.183	-1.675	4.921	33.641	38.500	-4.8588
2028	10.97	-3.437	-1.842	5.697	34.417	39.695	-5.278
2029	12.288	-3.715	-2.026	6.546	35.266	41.008	-5.7417
2030	13.728	-4.021	-2.231	7.476	36.196	42.448	-6.2523
2008-30	112.47	-30.049	-17.42	64.99	725.55	773.03	-47.477

than trend value which is an unsatisfactory condition of energy saving. Punyong 2008, stated that the energy saving in Thai industry was 1401.95 KTOE (over consumption instead of saving) during the period 1998 to 2002.

Energy consumption in service sector during the period 2007 to 2030 was 774.8 MTOE (see Table I). It accounted for 35.4% of the total energy consumption. During the period 2008-2030 we observed that energy saving occurred in service sector, of which -71.68 MTOE of energy saving was due

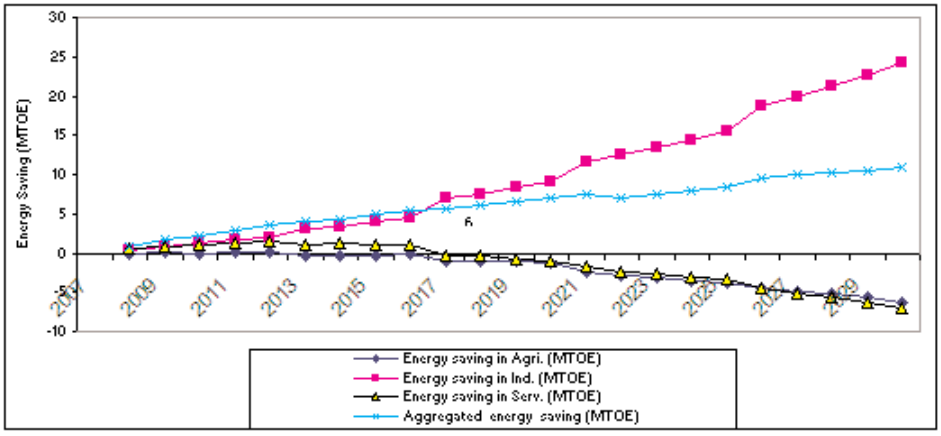

Fig. 1: Sector wise energy saving

to structural changes (S_{effect}), and extra energy (36.72 MTOE) came from intensity changes (Ieffect) as shown in Table IV. In Table IV it is found that trend value is greater than real value, that is, the value of ψ is less than zero (trend of graph is decreasing), which is the condition for energy saving as shown in Figure 1.

The analysis shows that, during the period 2008-2030, the total energy saving indicator in Bangladesh was 144.66 MTOE (positive value means over-consumption instead of saving). This indicator when resolved into three sectors namely agriculture, industry and service respectively, their corresponding values turns out to be -47.47 MTOE, 227.10 MTOE and -34.96 MTOE respectively. Since the energy consumed by the agriculture sector was only 9.8% of the total energy consumption, its contribution to the energy saving is minimal. In our previous analysis it was found that during the period of 1990 to 2007 only agriculture saves energy, on the other hand industry and service sectore failed to save energy. During the period 2008 to 2030 the extra-

Table III: Energy saving in Industrial sector

Year	Activity Effect (MTOE)	Structural Effect (MTOE)	Intensity Effect (MTOE)	Del Eot (MTOE)	Real Energy.. consm (MTOE)	Trend energy. consm (MTOE)	Energy saving (MTOE)
2008	0.697	-0.219	0.555	1.032	29.752	29.416	0.335
2009	1.449	-0.228	0.953	2.174	30.893	30.169	0.724
2010	2.396	0.797	0.527	3.721	32.440	31.115	1.325
2011	3.398	0.831	0.797	5.026	33.746	32.117	1.628
2012	4.476	0.866	1.091	6.433	35.152	33.196	1.957
2013	6.144	2.066	1.058	9.268	37.988	34.864	3.125
2014	7.819	2.172	1.221	11.21	39.933	36.539	3.393
2015	9.7423	2.311	1.808	13.86	42.582	38.4623	4.120
2016	11.738	2.436	2.028	16.20	44.923	40.458	4.465
2017	15.093	5.416	1.524	22.03	50.753	43.813	6.940
2018	18.154	5.778	1.627	25.56	54.280	46.874	7.406
2019	21.731	6.242	2.243	30.22	58.935	50.451	8.485
2020	25.471	6.685	2.404	34.56	63.281	54.191	9.089
2021	30.549	10.632	0.975	42.15	70.876	59.269	11.607
2022	35.507	13.847	-1.254	48.10	76.821	64.227	12.594
2023	40.649	14.882	-1.419	54.11	82.832	69.369	13.462
2024	46.30	16.018	-1.606	60.71	89.432	75.020	14.412
2025	52.507	17.267	-1.816	67.95	96.678	81.227	15.45
2026	60.754	21.114	-2.460	79.40	108.128	89.47	18.653
2027	68.330	22.784	-2.905	88.21	116.929	97.05	19.878
2028	76.640	24.616	-3.410	97.85	126.566	105.36	21.206
2029	85.756	26.627	-3.984	108.3	137.119	114.476	22.643
2030	95.756	28.832	-4.634	119.9	148.675	124.476	24.198
2008-30	721.061	231.777	-4.676	948.2	1608.722	1381.62	227.101

Table IV: Energy saving in Service sector

Year	Activity Effect (MTOE)	Structural Effect (MTOE)	Intensity Effect (MTOE)	Del Eot (MTOE)	Real Energy.. consm (MTOE)	Trend energy. consm (MTOE)	Energy saving (MTOE)
2008	0.647	-0.223	0.711	1.134	29.604	29.367	0.487
2009	1.346	-0.232	1.0879	2.202	30.672	30.065	0.856
2010	2.189	-0.518	1.459	3.130	31.600	30.908	0.942
2011	3.105	-0.539	1.746	4.311	32.781	31.825	1.206
2012	4.091	-0.563	2.055	5.583	34.053	32.811	1.492
2013	5.364	-0.897	1.972	6.437	34.907	34.084	1.0734
2014	6.827	-0.944	2.164	8.047	36.517	35.547	1.220
2015	8.307	-0.979	1.933	9.261	37.731	37.027	0.953
2016	10.009	-1.033	2.139	11.115	39.585	38.729	1.106
2017	11.800	-1.826	1.549	11.523	39.994	40.521	-0.277
2018	14.194	-1.948	1.651	13.896	42.366	42.914	-0.297
2019	16.593	-2.050	1.187	15.730	44.200	45.313	-0.863
2020	19.448	-2.195	1.270	18.523	46.994	48.168	-0.925
2021	22.285	-2.827	1.200	20.657	49.127	51.005	-1.627
2022	25.338	-4.108	1.617	22.846	51.316	54.058	-2.492
2023	29.009	-4.417	1.689	26.282	54.752	57.729	-2.728
2024	33.043	-4.757	1.767	30.053	58.523	61.763	-2.990
2025	37.475	-5.131	1.850	34.194	62.664	66.195	-3.281
2026	41.700	-6.209	1.616	37.107	65.577	70.420	-4.593
2027	46.906	-6.703	1.589	41.792	70.262	75.626	-5.114
2028	52.617	-7.244	1.548	46.92	75.391	81.337	-5.695
2029	58.884	-7.838	1.493	52.538	81.008	87.604	-6.345
2030	65.758	-8.490	1.420	58.688	87.159	94.478	-7.069
2008-30	516.939	-71.682	36.720	481.97	1136.787	1177.499	-34.962

Table V: Aggregated energy saving

Year	Energy saving in agri. (MTOE)	Energy saving in industry. (MTOE)	Energy saving in service (MTOE)	Aggregate energy saving (MTOE)
2008	-0.005	0.335	0.487	0.817
2009	0.0849	0.724	0.855	1.665
2010	-0.0211	1.325	0.942	2.245
2011	0.036	1.628	1.206	2.871
2012	0.098	1.956	1.492	3.547
2013	-0.259	3.125	1.073	3.939
2014	-0.248	3.393	1.220	4.365
2015	-0.236	4.120	0.953	4.836
2016	-0.223	4.464	1.106	5.347
2017	-0.956	6.940	-0.276	5.707
2018	-1.019	7.406	-0.297	6.089
2019	-1.088	8.4847	-0.863	6.533
2020	-1.164	9.089	-0.925	7.001
2021	-2.472	11.607	-1.627	7.507
2022	-2.982	12.594	-2.492	7.121
2023	-3.210	13.462	-2.728	7.524
2024	-3.462	14.412	-2.990	7.960
2025	-3.738	15.4509	-3.281	8.431
2026	-4.478	18.654	-4.593	9.583
2027	-4.859	19.878	-5.114	9.906
2028	-5.279	21.206	-5.695	10.231
2029	-5.742	22.643	-6.345	10.556
2030	-6.252	24.198	-7.069	10.876
2008-30	-47.477	227.101	-34.962	144.66

energy consumption (144.66 MTOE) in Bangladesh came from Structural change (S_{effect}) and intensity changes (I_{effect}) have values 130.05 MTOE and 14.62 MTOE respectively.

The energy rebound effect, which is the combined result of activity effect and structural effect, is found to increase in agriculture, industry and service sector as shown in Figure 2.

In agriculture sector rebound effect increased by 25.6 fold in 2030, compared to that in 2008 (Table VI). Again, rebound effect increased by 262 fold and 135 fold in industry and service sector respectively in 2030 compared to 2008. The aggregate rebound effects increased by 149.5 fold in the timeperiod of 2008 to 2030 of which activity effect contributes 1350.46 MTOE and structural effect contributes

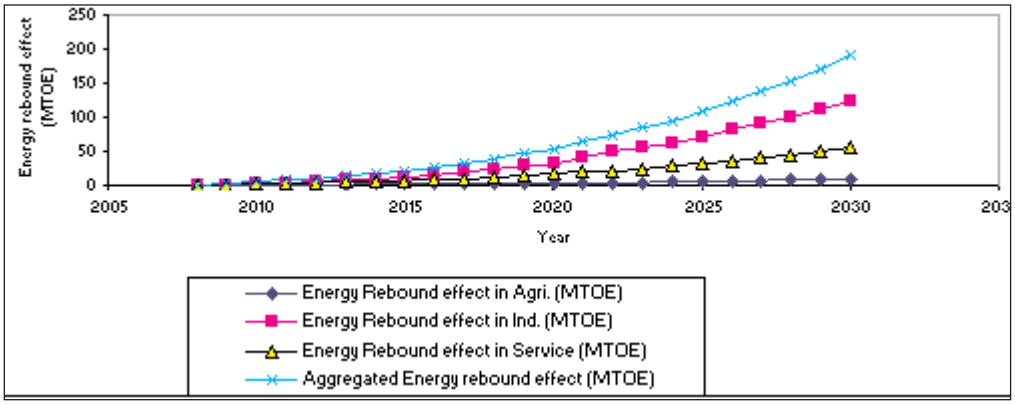

Fig. 2: sector wise energy rebound effect

Table VI: Aggregate energy rebound effect

Year	Energy rebound effect in Agri. (MTOE)	Energy rebound effect in Ind. (MTOE)	Energy rebound effect in Service (MTOE)	Aggregated Energy rebound effect (MTOE)
2008	0.379	0.477	0.4242	1.281
2009	0.569	1.221	1.114	2.904
2010	0.618	3.194	1.671	5.483
2011	0.855	4.228	2.565	7.648
2012	1.1093	5.342	3.527	9.978
2013	1.2067	8.2106	4.466	13.883
2014	1.563	9.991	5.883	17.438
2015	1.949	12.053	7.327	21.330
2016	2.368	14.175	8.976	25.519
2017	2.244	20.508	9.9738	32.726
2018	2.779	23.932	12.245	38.956
2019	3.369	27.973	14.543	45.885
2020	4.0180	32.156	17.253	53.427
2021	3.300	41.181	19.457	63.939
2022	3.4589	49.354	21.229	74.043
2023	4.099	55.532	24.592	84.222
2024	4.802	62.318	28.285	95.406
2025	5.5756	69.775	32.344	107.695
2026	5.7392	81.868	35.490	123.098
2027	6.597	91.114	40.203	137.914
2028	7.5386	101.256	45.373	154.168
2029	8.5723	112.383	51.045	172.000
2030	9.707	124.588	57.268	191.564
2008-2030	82.420	952.838	445.257	1480.515

129.98 MTOE respectively. From rebound effect analysis it is found that the technological development has increased in industry and service sector rather than agriculture sector and our structure of economy is shifting from agriculture to industry, but with no good effect in respect of energy saving. The reason is that there have been more structural changes than new innovations in industries.

Conclusion

This paper presents a detailed analysis of energy saving and energy rebound effect in Bangladesh. It can be concluded that,

1) In the time period of 2008 to 2030, energy saving occurred in agriculture sector of an amount -47.47 MTOE.

2) Energy saving did not happen in industrial sector. Extra energy consumption (227 MTOE) in industry sector came from structural change (S_{effect}) and intensity change (I_{effect}) with amount of 231.7 MTOE and -4.6 MTOE respectively.

3) Energy saving occurred in service sector. During the period 2008 to 2030 the energy consumption (-34.96 MTOE) in service sector came from structural change (S_{effect}) and intensity change (I_{effect}) with amount of -71.68 MTOE and 36.72 MTOE respectively.

4) The aggregate energy saving in Bangladesh was +144.66 MTOE in the time period of 2008 to 2030. The positive value indicates the over-consumption instead of saving which is the general characteristic of infrastructure building period.

5) The aggregated rebound effects increased by 149.5 fold in the time period of 2008 to 2030 of which activity effect contributes 1350.46 MTOE and structural effect contributes 129.98 MTOE respectively. From rebound effect analysis it is found that the technological development has increased in industry and service sector rather than agriculture sector and our structure of economy is shifting from agriculture to industry, but with no good effect in respect of energy saving. The reason is that there have been more structural changes than new innovations in industries.

It appears that as in most developing countries there has been more stress on administrative measures for structural changes than scientific and technological innovations in industries, which we consider to be the main barriers to energy saving through greater efficiency.

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