ENERGY INTENSITY: A DECOMPOSITION EXERCISE FOR PAKISTAN

Submitted By

Akbar Ullah

Pakistan Institute of Development Economics (PIDE), Islamabad

Dr. Karim Khan

Pakistan Institute of Development Economics (PIDE), Islamabad

Munazza Akhtar

University of Management & Technology (UMT), Sialkot Campus

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In this study an attempt has been made to decompose the change in energy intensity and consumption into efficiency and activity changes. The study covers the period from 1972 to 2011 and use Fisher Ideal Index decomposition method for the analysis. Our analysis showed that energy intensity has increased by 53 percent on average between 1972 and 2011 and around 72 percent of the increase is due to inefficiency in its use. That is, for the same unit of output we are now using more energy as compared to 1972. Most of the inefficiencies are in electricity consumption followed by gas energy. The oil sector is efficient as compared to gas and electricity and in this sector efficiency has improved during price hikes. Here the change in intensity is mainly due to structural changes. The main deriver of the change in aggregate energy intensity is electricity with its average intensity index value of 1.75. The aggregate intensity of oil and gas is falling following the recent price and supply crisis.

I. Introduction

Life on Earth is driven by energy. It is a fundamental requirement and energy per se is crucial to provide for adequate living such as food, water, health care, education, shelter and employment. Without sufficient energy the wheel cannot run on roads, industry and agriculture cannot sustain, hospitals and operation theaters cannot function, schools and laboratories cannot work and public and private sector businesses cannot operate.

Recent demographic, environmental, economic and energy trends point at energy issue as a major challenge for the near future (Cian, et al. 2013). The world energy crisis is evident from many perspectives: population growth, sharply rising oil and gas prices and rapid depletion of their supplies, armed conflicts in regions with major oil deposits, higher energy costs to poor nations seeking to develop higher standards of living, and instability of world energy supplies.

With the increasing international concern about energy prices, supply instabilities, rapid depletion and global warming, energy intensity measures have become important components of energy policies (Jimenez and Mercado, 2013). In particular, there is a special focus on distinguishing the contribution of energy efficiency to intensity changes from other relevant factors. The reason behind this distinction is the fact that energy efficiency is internationally recognized as one of the most cost-effective strategies to address crosscutting issues such as energy security, climate change, competitiveness, and the promotion of technology transfers (IDB, 2012). This information is useful tools for policy decisions and evaluation.

Pakistan is facing formidable challenges in meeting its energy requirements and providing adequate energy to users in a sustainable manner and at affordable costs. Due to this crisis the daily life has come to a standstill. Even more ominously the shortage is endangering the future economic and social prospects of the country, putting its very fabric under strain. Thus the energy challenge is of fundamental importance for our future prosperity.

Despite these facts, Pakistan's energy intensity per unit of GDP is not only higher compared to other Countries like India, USA, Germany, Japan and China, where the energy intensity in the past decades has declined despite the notable increase in aggregate gross output and energy use (Allcott and Greenstone, 2012; IEA, 2012c), but also increased over the past decades. Fore example, the consumption of oil in 1972 was 12 percent of its consumption level in 2011, 9 percent in case of gas and 7 percent in case of electricity where as gross value added in 1972 was 14 percent of its 2011 level. All these show that we are now using more energy per each unit of economic activity. There are various factors which may be responsible for such changes in energy intensity. At national level, these factors include energy efficiency, economic activity or structural changes and change in fuel mix etc (Park, 1992; Ang and Choi, 1997; Ma and Stern, 2008; Metcalf, 2008; Huntington, 2010; Reddy and Ray, 2011; Shahiduzzaman and Alam, 2012; Jimenez and Mercado, 2013; Marrero and Ramos-Real, 2013; Cian et al. 2013).

Since the 1980s a large body of theoretical and empirical literature has focused on decomposition of energy intensity changes into its constituent factors. But studies conducted before 1997 faces the problem of incomplete decomposition (see for example; Bossanyi, 1979; Jenne and Cattell, 1983; Reitler, et al. 1987; Boyd, et al. 1988; Doblin and Chaire, 1988; Li, et al. 1990; Howarth, 1991; Howarth and Schipper, 1992; Park, 1992; Park, et al. 1993). That is they leave an unexplained residual term. For more detail survey of earlier energy decomposition literature see Ang and Zhang (2000).

The first "perfect" index decomposition method was proposed by Ang and Choi (1997) known as the log-mean Divisia index method. Since then several other more perfect methods were developed by different authors such as; Sun (1998); Chung and Rhee (2001); Albrecht, et al. (2002); Ang, et al. (2003) and Fengling (2004). Recent extensive methodological studies and surveys on decomposition methods can be found in Ang and Liu (2003); Ang (2004); Boyd and Roop (2004); Fengling (2004); Ang, Huang, and Mu (2009); Shahiduzzaman and Khorshed, (2012). The general consensus in these studies is that index number theory can best serve the purpose of decomposition in national level studies.

As far as Pakistan is concerned, most of the studies have been conducted on energy in context of changes in energy prices and its relation to economic growth, inflation and other macroeconomic indicators (Aqeel and Butt, 2001; Siddiqui, 2004; Khan, 2008; Siddiqui and Haq, 1999; Malik, 2007, 2008, 2012; Kiani, 2009; Syed, 2010; Jamil and Ahmed, 2010; Khan and Ahmad, 2011).

According to our knowledge, the only study conducted on this topic in Pakistan is the one by Alam and Butt (2001).

The current paper provides an empirical decomposition of energy intensity changes into its constituent factors, efficiency and economic activity, in Pakistan for the period 1972-2011 by applying the Index Decomposition Approach (IDA), more specifically, the Fisher Ideal Index. Note that energy efficiency here means using less energy to produce the same amount (value added) of output. After this decomposition we are able to decompose the energy consumption change into efficiency and activity changes.

This study contributes in four main aspects. Firstly, the time of the study is of particular importance. It covered the period of all three major oil price shocks as well as the recent energy crisis in Pakistan. This has helped us to understand the particular changes in the trends that are likely to bring about by these shocks. Secondly, energy intensity could also be affected by the changes in fuel mix because of the differences in economic productivity among different energy types (Marrero and Ramos-Real, 2013). This problem is handled by disaggregated data for final consumption (by energy source) for each sector, which is a promising contribution of this paper.

Third, instead of considering the overall energy consumption for aggregate analysis, which involve overlapping and is difficult to match with national value added, we first construct the indexes at component level and then aggregated the said indexes to understand the overall trends. Finally, we have used the most suitable decomposition tools recommended in most recent literature.

A potential drawback of national level analysis is that our estimations could be sensitive to data disaggregation. For example, within a broad activity, changes from less energy-intensive sub-activities to more energy-intensive sub-activities could lead one to overestimate the changes in energy efficiency (and vice versa). That is, it is possible to interpret a result as an energy efficiency effect when it is really an activity effect within a broad sector. In general, it is preferable to have more disaggregated good quality data to obtain better estimates. In the case of California industry, an interesting finding by Metcalf (2008) is that a higher level of disaggregation did not significantly affect his estimations. However, Huntington (2010) found contrasting results using a more detailed dataset. In any case, the present exercise suggests a starting point. Further research should take advantage of available information to perform similar exercises with more disaggregated data.

Rest of the paper is organized into four sections. Section 2 provides detailed methodology of our study. Section three describes data construction. In section 4, we provide the details of our empirical analysis. Section 5 concludes the paper.

2. Methodology for Decomposition of Energy Intensity

Decomposition analysis is used to break down the aggregate series into understandable and meaningful components. It is a top down approach in which the whole is divided into its constituent parts. This analytical tool has been widely used in energy and environment related studies since mid-eighties. Our purpose is to use these techniques to decompose the aggregate energy intensity changes into economic activity changes and change in efficiency and using this we decompose total consumption change also. The aggregate energy intensity is defined as the ratio of total energy consumption to aggregate output of the economy;

$$e_t = {}^{E_t}\!/_{Y_t} \cdots\cdots\cdots (2.1)$$

Where, E_t is aggregate energy consumption and $\boldsymbol{Y_t}$ is gross domestic product. Multiplying and dividing by sectoral output $\boldsymbol{Y_{it}}$ and denoting sector specific intensity by E_{it} , we get the following ;

$$e_t = {}^{E_t}\!/\!_{Y_t} = \sum_i {}^{E_{it}}\!/\!_{Y_{it}}\, {}^{Y_{it}}\!/\!_{Y_t} = \sum e_{it} s_{it} \cdots\cdots\cdots(2.2)$$

According to this equation aggregate energy intensity is a function of sector specific energy intensity, which is referred to as energy efficiency in energy literature, and sector specific economic activity.

Our task here is the choice of suitable analytical tools which could help us to decompose the aggregate changes, Δe_t in the energy components intensities into economic activity and energy efficiency changes, that is, into, Δs_{it} and Δe_{it} respectively . Different decomposition methodologies have been developed to decompose the aggregate variable into its component parts (see for example, Ang and Zhang, 2000; Ang and Liu, 2003; Ang, 2004; Boyd and Roop, 2004; Fengling, 2004; Ang, Huang, and Mu, 2009). These methodologies can be classified into four broader groups, namely, index decomposition analysis (IDA), structural decomposition analysis (SDA), shift share analysis (SSA), and growth accounting analysis (GAA) Fengling (2004). Among this the index decomposition analysis (IDA) and structural decomposition analysis (SDA) are widely used in energy studies (Ang and Zhang, 2000).

Index decomposition analysis (IDA) determines the share that is made by each of the component in deriving the changes in the aggregate variable. This method relies heavily on index numbers theory. The general consensus in aforementioned studies is that index number theory can best serve the purpose of decomposition in national level studies. The selection of suitable index decomposition method is very important for getting accurate results. There are several desirable properties that IDA method must satisfy to become a perfect decomposition method. A method leaving no residual is generally regarded as the most desirable one and is referred as perfect decomposition method. The first "perfect" IDA method was proposed by Ang and Choi (1997) known as the log-mean Divisia index method II (LMDI II). There are several other more perfect methods such as; Sun (1998) "complete" decomposition method, which is based on the principle of "jointly created and equally distributed principle" and is known as "refined Laspeyres index (RLI)", mean rate-of-change index (MRCI) by Chung and Rhee (2001) which is formulated in the additive form that also leaves no residue in the decomposition result, Albrecht, et al (2002) presented a decomposition technique based on the Shapley value that is proved to be exactly the same as RLI (Ang, et al. 2003), Log mean Divisia (LMDI) method and Modified Fisher ideal index (MFII) method by Fengling (2004) are yet another IDA methods that are perfect in decomposition with other desirable properties.

In terms of ease of application and flexibility, the LMDI techniques, in particular LMD II, have several advantages over the other perfect decomposition methods by its simplicity. However, when there are zero or negative values in the data set, MFII could be adopted as the best method (Fengling, 2004). Beside the perfect decomposition and zero-negative values robustness, the Fisher ideal index has other desirable properties, as it satisfies time-reversal test, factor reversal test and proportionality test as well. Boyd and Roop (2004) were the first to use Fisher ideal index for complete decomposition of energy intensity change into economic activity and energy efficiency changes.

Keeping in view these properties of MFII, we apply it to decompose energy intensity change into economic activity and energy efficiency changes in Pakistan. In case of decomposition into two components the MFII and the simple FII are same, so the terms are used in same meaning here. Moreover we used multiplicative approach because it is better than the additive approach in case of annual time-series energy data (Fengling, 2004).

Using e_0 to denote aggregate energy intensity in the base year, we construct energy intensity index and it decomposition following Diewert (2001);

$$e_t / e_0 \cong I_t = I_t^{act} I_t^{eff} \cdots\cdots\cdots(2.3)$$

Where I_t^{act} is the activity index and I_t^{eff} is the efficiency index. As the equation indicates, the aggregate energy index is decomposed into activity and efficiency indexes with no residual term and this is guaranteed by FII (see appendix for detail). This decomposition is possible when we can construct sectors that account for total energy consumption in the economy and a measure of economic activities in each of these sectors.

With these indexes at hand we can easily determine the amount of energy consumption change which is due to efficiency and the part that is due to change in activity. Using E_0 to denote energy consumption that would have prevailed had energy intensity does not change since the base year; this is done below, see Metcalf (2008);

$$\Delta E_t = E_t - E_0 = \Delta E_t \left[\frac{\ln I_t^{act}}{\ln I_t} \right] + \Delta E_t \left[\frac{\ln I_t^{eff}}{nI_t} \right] = \Delta I_t^{act} + \Delta I_t^{eff} \ldots\ldots\ldots(2.4)$$

Here the term ΔE_t indicate change in energy consumption which is the difference, $E_t - E_0$ between actual consumption in a given year and the consumption which would have occurred had energy intensity remain at it 1972 level. As clear from the equation, this has enabled us to decompose a given change in energy consumption, relative to base year, into efficiency and activities changes.

3. Data Construction

Instead of decomposing the overall energy change into activity and efficiency changes we have carried out the decomposition analysis on the energy components, considering the three major energy components; oil, gas and electricity. This will help us in understanding the intensity of each individual component and the reason behind the change in intensity of each component. Moreover, this three component account for about 90 percent of the total energy consumption in Pakistan. The data and sector construction for each component is discussed in details in the paragraphs that follow.

The energy year book report the oil consumption data under six heading; household, industry, agriculture, transport, power and other government. To construct the indexes we required the contribution of each of this sector to the national gross value added. For this purpose we have made certain matching operations. To determine the household sector share of gross value added we have used household final consumption expenditure following (Metcalf, 2008). For the industrial sector share, industrial value added net of Electricity and Gas Distribution was considered and electricity and gas distribution contribution was considered as share of power sector in gross value added. Gross value added coming from transport, storage and communication was taken as the share of transport sector. The oil consumption under the heading of other government was deduction from total oil consumption because no proper matching was possible. The total share of the other government is 1.6 percent in oil consumption so that this type of deduction will not reduce the relevance of the analysis. Here, another important thing to note is that, although this may not be a perfect match but what is important for us is the change over time rather the exact level at a given time so that one needs not worry much about the perfect matching.

The gas consumption data is reported under, household, commercial, industrial, cement, fertilizer, power and transport sectors. To match this with the national production data we have merged cement and fertilizer data with industrial consumption of gas. Similarly, transport consumption is merged in commercial sector. To measure commercial sector contribution in gross value added we have added the value additions of transport, storage and communication, wholesale and retail trade and finance and insurance sectors. The remaining sectors were constructed similar to the case of oil sector.

In case of electricity sector, consumption under traction, street light and other government sector were eliminated from the total electricity consumption. This will not make much difference because the combine share of these sectors in the total electricity consumption is less than 7 percent. The sectors considered in electricity sector are; household, commercial, industrial and agriculture. Finally the gross value addition of each mentioned sector in constant prices of 2000 were considered. The data are taken from energy year books, statistical supplements, hand book of statistics and World Bank WDI data set. For descriptive statistics of sectors see appendix.

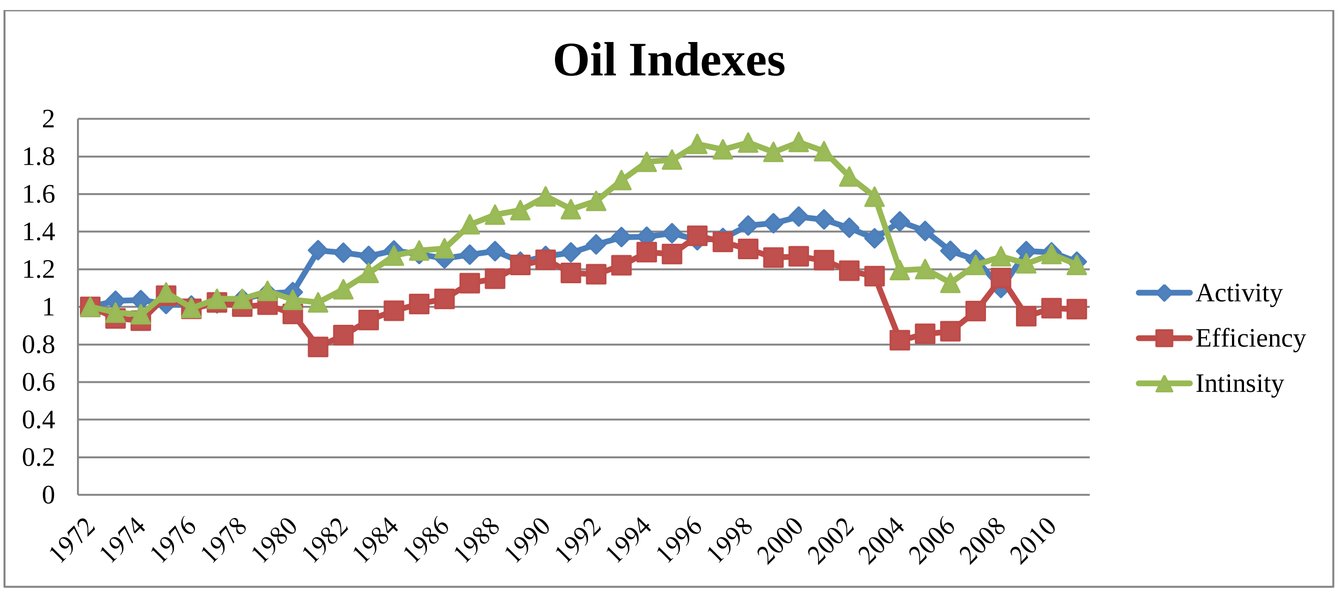
4. Results of Decomposition Analysis

To get more detail information on intensity changes, we have carried out separate analysis for each of the three major energy components. This has helped us to handle the changes that may have occurred from change in fuel mix in the economic activity.

4.1Oil Energy

The decomposition of oil intensity between 1972 and 2011 is presented in figure (4.1). In 2011 the oil intensity is 22% higher as compared to 1972. The highest intensity is in 2000 which is 88 percent higher as compared to the base year of 1972 while the average intensity is 37 percent higher as compared to the base year. The activity index is 24 percent higher where as the efficiency index is 1 percent lower in 2011 as compared to their base values. The highest value of activity index is 1.48 in 2000 while the highest value of efficiency index is 1.38 in 1996 with its lowest value of 0.79 in 1981. The activity index remains above its 1972 level for whole period. As clear from the figure below, beginning in 1980 the indexes has smoothly increased for next two decades with activity index the dominating one. This means that during this period the share of sectors using oil increased in relative terms. After 2000 we have experience sharp reduction in oil intensity with efficiency as the dominant factor in this change.

Figure 4.1. Oil Energy Indexes Trends



The oil consumption data indicate that total oil consumption (note that consumption under other government heading is ignored) in 2011 would have 3387509 tonnes lower had energy intensity remain at its 1772 level. Equation (2.4) can be used to decompose this change into activity and efficiency changes. According to this equation change in economic activity cause oil consumption to increase by 3596498 tonnes in 2011 as compared to 1972. The change in efficiency causes oil consumption to reduce by 217989 tonnes in 2011 (the result for each year is given in appendix).

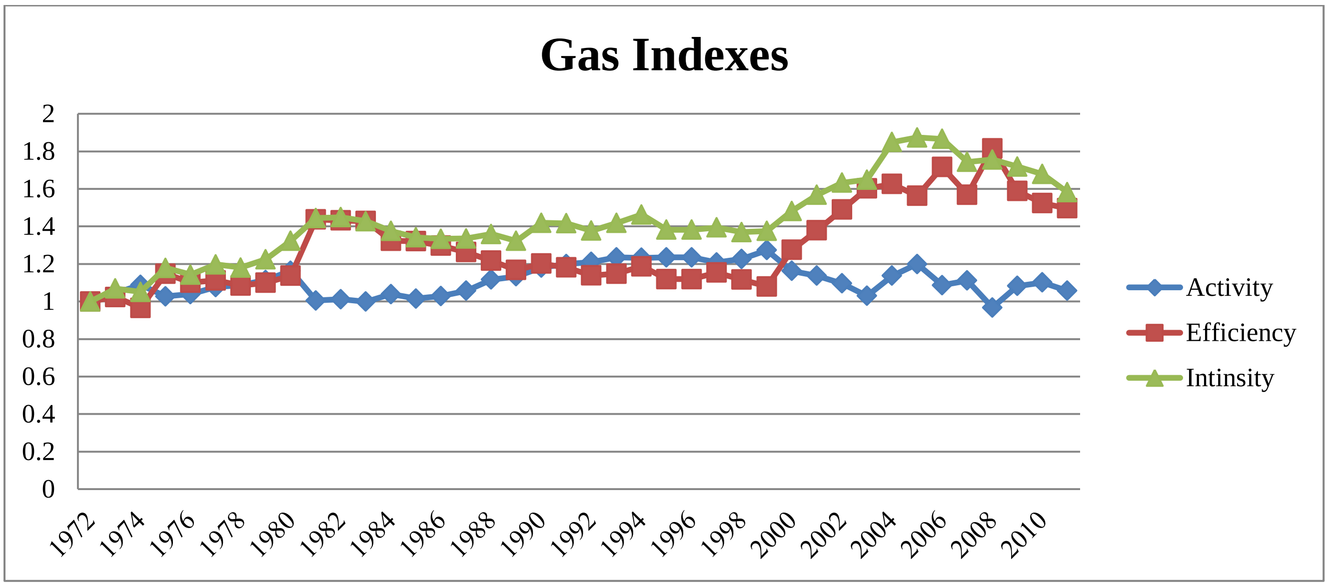
If we compare the trends in our indexes with the oil price changes, some interesting results emerge. Global economy has experienced three big oil shocks; the first time in 1973 when oil export has been stopped by OPEC countries in response of Arab-Israel war. The second shock occurs in 1979; ironic revolution cut off the sovereignty of shah, so, oil production in Iran dramatically decreased. Between 1983-1998 oil prices remain stable in both international and domestic markets. Since 1999, we are experiencing a third big oil shock in global history. OPEC met in March 1999 and agreed to cut production, with goal of increasing crude prices to around or just above $20 per barrel. As result the oil prices very quickly crossed the $ 20 per barrel mark with a dramatic increase in new century. In 2003-04 oil prices were 11% higher of their 2002-03 level and 41% higher in the following year compared to 2003-04. In 2007-08 oil prices were 53% higher as compared to their preceding year and in 2008-09 reached to a record of $150 per barrel.

Compare this history with figure (4.1), particularly with the efficiency index. During the 1970s the indexes remain almost stable. In 1980, efficiency has started improving which continue until 1984. During this period the efficiency was better than 1972(the efficiency index value remain below one). Thereafter the indexes have steadily increased and this increasing trend continues upto 1998. After 2000 the aggregate intensity strongly falls and this change was dominated by the intensity index. The value of efficiency index fell to 0.82 in 2004 from its 1.16 value in 2003. This was the year where oil prices were increased by 41% as compared to preceding year. This trend holds not only for international prices but also for the domestic price variation of furnace oil, HOBC, HSD etc. If this relation hold true than it implies that whenever oil prices increased we have brought efficiency in its use. This is an interesting topic with strong policy implications and requires in-depth analysis. After 2000 the activity index also show declining trend but it is not as pronounced as the efficiency index.

4.2 Gas Energy

The decomposition of gas intensity between 1972 and 2011 is presented in figure (4.2). In 2011 the gas intensity is 58% higher as compared to 1972. The highest intensity is in 2005 which is 87 percent higher as compared to the base year of 1972 while the average gas intensity is 43 percent higher as compared to the base year. The activity index is 06 percent higher where as the efficiency index is 50 percent higher in 2011 as compared to their base values. The highest value of activity index is 1.27 in 1999 while the highest value of efficiency index is 1.81 in 2008 with its lowest value of 0.97 in 1974. The efficiency index remains above its 1972 level for most of the period. As clear from the figure below, the aggregate intensity index is strongly guided by the efficiency index in case of gas consumption. The intensity index goes through two notable upward spikes, one in around 1981and the second is the most prolong one beginning in 2000 and last upto 2008. After 2008 we have experience declining trends in gas intensity with efficiency as the dominant factor in this change. One reason for the increasing intensity in the beginning of new century can be the result of Musharaf administration policies where most of the industries were converted on gas which was previously using electricity or oil. Similar is the case of transport sector. For example, in 1998 the gas used in this sector was 490 (mm cft) but in 2011 it use increased to 113055 (mm cft). The interesting thing here is that according to our analysis the increase is dominated by efficiency rather than activity change, that is, we are using more gas per unit of output as compared to earlier time.

Figure 4.2. Gas Energy Indexes Trends

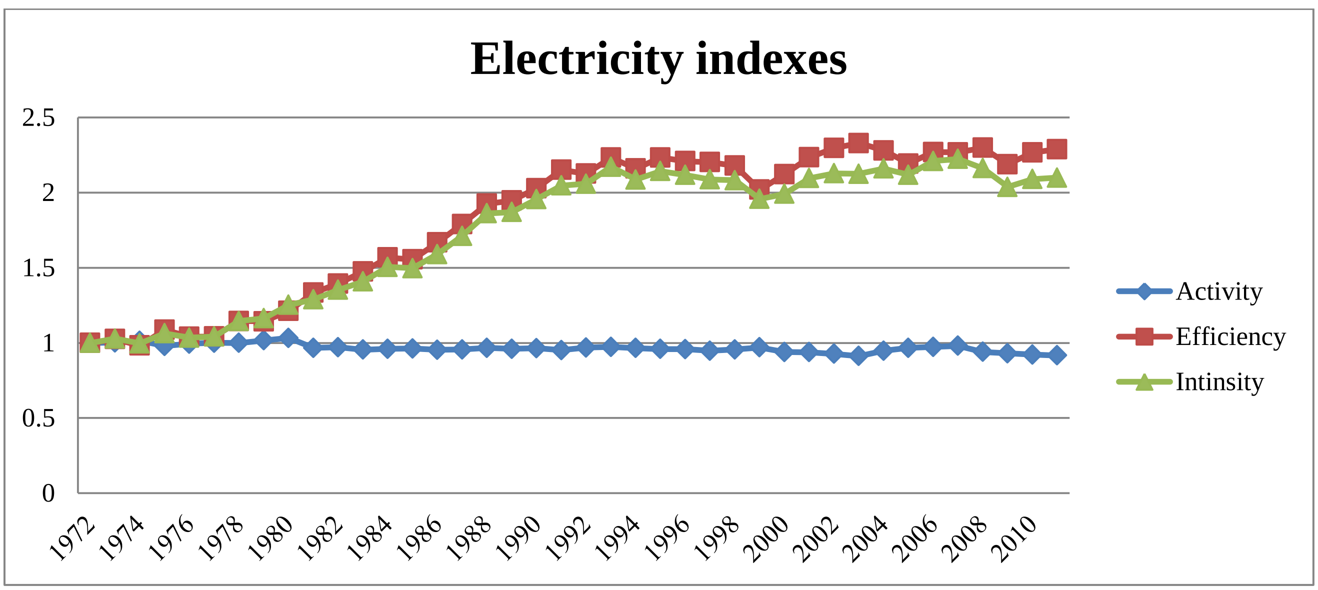


The gas consumption data indicate that total gas consumption of 1240672(mm cft) in 2011 would have 784286.2 (mm cft) had energy intensity remain at its 1772 level. Using Equation (2.4) we again decompose this change into activity and efficiency changes. According to this, change in economic activity caused gas consumption to increase by 55458.55 (mm cft) in 2011 as compared to 1972. The change in efficiency causes gas consumption to increase by 400927.3 (mm cft) in 2011 (the result for each year is given in appendix).

4.3 Electricity Energy

The decomposition of electricity intensity between 1972 and 2011 is presented in figure (4.3). In 2011 the electricity intensity is 110 percent higher as compared to 1972. The highest intensity is in 2007 which is 122 percent higher as compared to the base year of 1972 while the average electricity intensity is 75 percent higher as compared to the base year. The activity index is 08 percent lower where as the efficiency index is 129 percent higher in 2011 as compared to their base values. The highest value of activity index is 1.03 in 1980 while the highest value of efficiency index is 2.33 in 2003. The efficiency index remains above its 1972 level for all most all of the period. As clear from the figure below, the aggregate intensity index is perfectly guided by the efficiency index in case of electricity consumption. The intensity and efficiency goes hand in hand, increasing for the whole study period, while the activity index remains static and slightly below its 1972 level. This analysis shows that each unit of output produced in Pakistan uses more and more electricity with each passing year.

Figure 4.3 Electricity Energy Indexes Trends



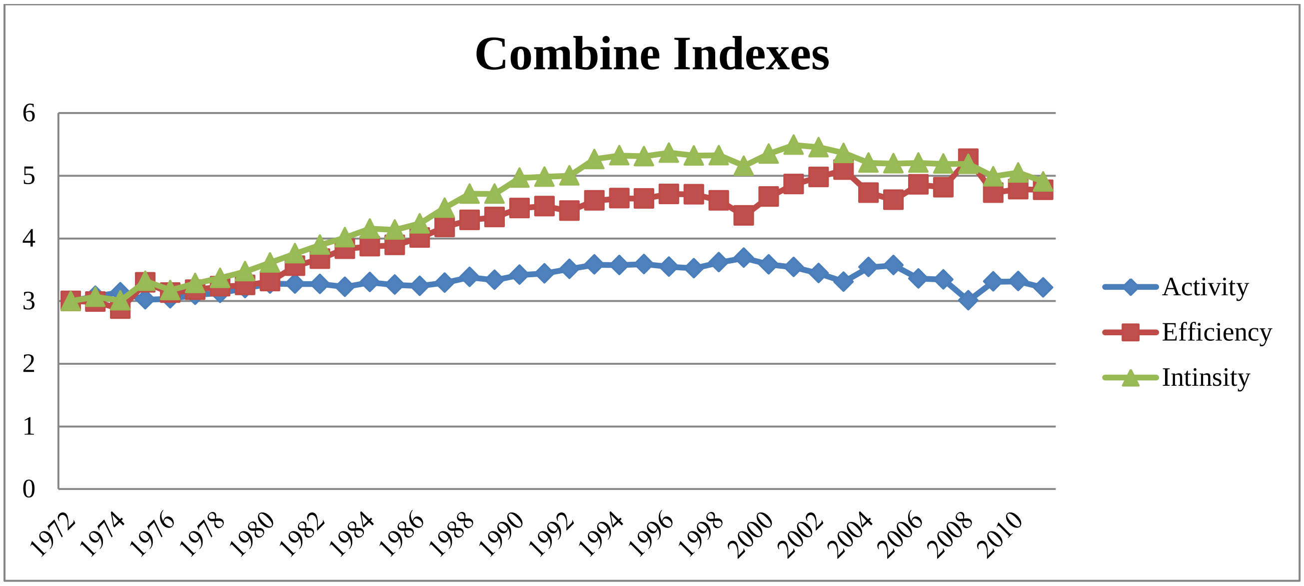
The electricity consumption data indicate that total electricity consumption of 71845 (Gwh) in 2011 would have 34215.9 (Gwh) had energy intensity remain at its 1772 level. Using Equation (2.4) we again decompose this change into activity and efficiency changes. According to this, change in economic activity caused electricity consumption to decrease by 4386.27 (Gwh) in

2011 as compared to 1972. The change in efficiency causes electricity consumption to increase by 42015.37 (Gwh) in 2011 (the result for each year is given in appendix).

4.4 Discussion on the Results

Our individual analysis have showed that efficiency changes guide the intensity changes in case of gas and electricity and activity change is dominant on average in case of oil. But in some cases an increase in efficiency index in one sector was accompanied by a corresponding decrease in the other sector (see oil and gas efficiency indexes after 2000, for example). To be more confident about the result that whether the change in efficiency indexes is just transfer of activity from one energy component to another (change in fuel mix) or is a real waste of energy we have combine the indexes. In this analysis we have just added up the respective individual indexes of each component. Each of the three combine index will now take a value of three for the base year. If the combine efficiency index takes a value of greater than three it implies that inefficiencies increases relative to the base year. Look at figure 3.4. The combine activity index has smoothly increased and reached its maximum value of 3.69 in 2000. After 2000 it is falling, with touching its 1972 level in 2011. This trend in the activity index is explained for the most part by the oil sector. This latter trend may be due to the severe gas supply and oil price crisis in the first decade of the present century. As this three component account for more than 90 percent of the energy consumption, we can conclude that the structure share of Pakistan economy, in perspective of energy consumption, is almost the same in 2011 as was in 1972. This result may surprise the readers. The fact is that although in initial decades of independence our economy was moving away from less energy intensive agriculture sector to more intensive industrial sector. But in recent decades the trend is completely different: both the agriculture and industry are losing their share to another less energy intensive services sector. If this is truly than this result may not be much surprising.

Figure 4.4. Combine Indexes Trends



The efficiency index tell totally different story. Our combine index show that most part of the increase in intensity during the study period is due to increasing energy use per each unit of output. The index increased smoothly and remains above 4 for the most part with highest value of 5.3 in 2009. This index remained dominant for the whole period in guiding the energy intensity change in Pakistan. Note that the fluctuations in this index after 1998 are due to gas and oil indexes.

To sum up, our analysis showed that energy intensity in Pakistan increased by 53 percent on average between 1972 and 2011 and around 72 percent of the increase is due to inefficiency in its use. That is for the same unit of output we are now using more energy as compared to 1972. Most of the inefficiencies are in electricity consumption followed by gas sector. The oil sector is efficient as compared to gas and electricity and in this sector efficiency has improved during price hikes.

5. Conclusion

The aggregate energy intensity in Pakistan has steadily increased over time until the recent years. The consumption of oil in 1972 was 12 percent of its consumption level in 2011, 9 percent in case of gas and 7 percent in case of electricity where as gross value added in 1972 was 14 percent of its 2011 level. In this study an attempt has been made to decompose the change in energy intensity and consumption into efficiency and activity changes. The study covers the period from 1972 to 2011 and use Fisher Ideal Index decomposition method for the analysis. Our analysis showed that energy intensity in Pakistan increased by 53 percent on average between 1972 and 2011 and around 72 percent of the increase is due to inefficiency in its use. That is, for the same unit of output we are now using more energy as compared to 1972. Most of the inefficiencies are in electricity consumption followed by gas energy. In electricity case the average value of efficiency index is 1.82, which means that a given amount of output is now produced with 1.82 Gwh of electricity on average whereas the same amount required only 1 Gwh in 1972. The average value of activity index is 0.97 in case of electricity. For gas consumption, the average value of efficiency index is 1.29 and activity index value is 1.11.The oil energy sector is efficient as compared to gas and electricity sources. In case of oil, the average value of efficiency index is 1.08 and activity index value is 1.26. Here the change in aggregate intensity is mainly due to structural changes. The main deriver of the change in aggregate energy intensity is electricity with its average intensity index value of 1.75. The aggregate intensity of oil and gas is falling following the recent price and supply crisis.

The change in efficiency index seems to be somehow related with price changes. Whenever price hikes taken place oil efficiency index has greatly improved. Moreover our analysis has showed that energy sources with relatively low prices are proven to increased inefficiencies. This is an interesting topic for future research and if prove true has important policy implications.

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Appendix: The construction of Fisher ideal index is given below

First we construct Laspeyres and Paasche activity and efficiency indexes. The Laspeyres activity and efficiency indexes are

$$L_t^{act} = \frac{\sum_i e_{i0} s_{it}}{\sum_i e_{i0} s_{i0}} \ldots\ldots\ldots(A1) \qquad L_t^{ef} = \frac{\sum_i e_{it} s_{i0}}{\sum_i e_{i0} s_{i0}} \ldots\ldots\ldots(A2)$$

The Paasche activity and efficiency indexes are

$$P_t^{act} = \frac{\sum_i e_{it} s_{it}}{\sum_i e_{it} s_{i0}} \ldots\ldots\ldots(A3) \qquad P_t^{ef} = \frac{\sum_i e_{it} s_{it}}{\sum_i e_{i0} s_{it}} \ldots\ldots\ldots(A4)$$

Now the Fisher ideal indexes for activity and efficiency are given as

$$I_t^{act} = \sqrt{L_t^{act} P_t^{act}} \cdots\cdots\cdots(A5) \qquad I_t^{ef} = \sqrt{L_t^{ef} P_t^{ef}} \cdots\cdots\cdots(A6)$$

Using this we can construct the aggregate energy index (2.3) as below

$$e_t / e_0 \cong I_t = I_t^{act} I_t^{eff} \cdots\cdots\cdots(A7)$$

Table A1. Descriptive Statistics of Sectors Included in the Analysis

Sector		Economic Activity		Intensity	
	Components	Mean	SD	Mean	SD
Household	Oil	2209813	1074383	0.3242	0.2077
	Gas	--	--	0.0317	0.0171
	Eletricity	--	--	0.005	0.0027
Commercial	Oil	830726	526754	--	--
	Gas	--	--	0.0262	0.0171
	Electricity			0.0027	0.0004
Transport	Oil	274094	168383	20.4162	2.9852
	Gas	--	--	--	--
	Electricity	--	--	--	--
Agriculture	Oil	686997	293882	0.4062	0.2536
	Gas	--	--	--	--
	Electricity	--	--	0.0065	0.0016
Industry	Oil	698696	410210	--	--
	Gas	--	--	--	--
	Electricity	--	--	0.0152	0.0017
Industry Net of Electricity	Oil	617727	373753	1.8379	0.8543
	Gas	--	--	0.4281	0.0531
	Electricity	--	--	--	--
Electricity	Oil	80969	45366	29.98	20.7199
	Gas	--	--	2.3744	0.8548
	Electricity	--	--	--	--

Source: SPB, WB, Ministry of Finance, Hydrocarbon Development Institute of Pakistan

Table A2. Oil Consumption Decomposition

Year	E-E^ (tonnes)	Activity Index	Change Due to Activity	Efficiency Index	Change Due to Efficiency
1972	0	1.00	0	1.00	0
1973	-71123.5	1.03	72154.99	0.94	-143278
1974	-99043.7	1.04	85272.88	0.93	-184317
1975	194409.1	1.02	41235.18	1.06	153173.9
1976	-15271.2	1.01	14929.45	0.99	-30200.7
1977	115246.5	1.02	51754.2	1.02	63492.28
1978	125501.8	1.04	120104.4	1.00	5397.38
1979	260575	1.07	226153.2	1.01	34421.72
1980	124849.2	1.08	254885.2	0.96	-130036
1981	85207.14	1.30	941485.5	0.79	-856278
1982	355269.5	1.29	1007013	0.85	-651744
1983	729035	1.27	1055317	0.93	-326282
1984	1150859	1.30	1251281	0.98	-100422
1985	1375348	1.28	1296462	1.02	78886.04
1986	1519733	1.26	1284095	1.04	235637.8
1987	2265023	1.28	1524955	1.13	740067.9
1988	2699635	1.30	1754870	1.15	944764.6
1989	2966072	1.24	1532993	1.22	1433079
1990	3544186	1.27	1833546	1.25	1710640
1991	3294799	1.29	1995895	1.18	1298904
1992	3842105	1.33	2464075	1.17	1378030
1993	4694140	1.37	2870828	1.22	1823312
1994	5603384	1.37	3106205	1.29	2497180
1995	5972654	1.39	3417268	1.28	2555386
1996	7047755	1.35	3425000	1.38	3622754
1997	6927567	1.37	3549863	1.35	3377704
1998	7679937	1.43	4397130	1.31	3282807
1999	7349618	1.44	4500968	1.26	2848649
2000	8151257	1.48	5075029	1.27	3076228
2001	7822836	1.46	4947586	1.25	2875250
2002	6749384	1.42	4499642	1.19	2249742
2003	5977893	1.36	4021050	1.16	1956843
2004	2140302	1.45	4494238	0.82	-2353936
2005	2400226	1.40	4444422	0.86	-2044195
2006	1617995	1.30	3494033	0.87	-1876038
2007	3009863	1.25	3347383	0.98	-337520
2008	3760082	1.10	1500483	1.15	2259600
2009	3292826	1.30	4108234	0.95	-815408
2010	4120181	1.29	4237332	0.99	-117152
2011	3378509	1.24	3596498	0.99	-217989

See text for Construction

Table A3. Gas Consumption Decomposition

Year	E-E^(mm cft)	Activity Index	Change Due to activity	Efficiency Index	Change Due to Efficiency
1972	0	1.00	0	1.00	0
1973	8213.916	1.04	5362.295	1.02	2851.621
1974	-11474.9	1.09	-19557.6	0.97	8082.723
1975	23808.13	1.03	3889.607	1.15	19918.52
1976	19652.4	1.04	5600.364	1.10	14052.04
1977	27860.49	1.08	11433.79	1.11	16426.71
1978	27389.14	1.09	13890.4	1.09	13498.74
1979	36083.72	1.11	19236.49	1.10	16847.23
1980	55737.73	1.16	30087.99	1.14	25649.74
1981	81504.18	1.00	1036.355	1.44	80467.82
1982	88396.04	1.01	2743.793	1.43	85652.24
1983	90009.15	1.00	-208.002	1.43	90217.15
1984	82220.45	1.04	9948.178	1.32	72272.27
1985	81194.71	1.02	4156.875	1.32	77037.83
1986	84537.01	1.03	8233.405	1.30	76303.6
1987	89890.42	1.06	17273.95	1.26	72616.48
1988	102317.7	1.12	36863.71	1.22	65454.03
1989	96523.41	1.13	43193.57	1.17	53329.84
1990	130896.1	1.18	62182.63	1.20	68713.52
1991	136895.7	1.20	71403	1.18	65492.68
1992	133301.8	1.21	79328.93	1.14	53972.92
1993	150814.6	1.24	91252.58	1.15	59562
1994	174298.7	1.23	95780.51	1.19	78518.17
1995	151260.9	1.23	98560.72	1.12	52700.18
1996	161239.7	1.23	105035.9	1.12	56203.77
1997	168991.7	1.21	95931.31	1.15	73060.35
1998	164100.5	1.23	106536.4	1.12	57564.07
1999	173455.2	1.27	131420.5	1.08	42034.72
2000	234326.5	1.16	89841.59	1.27	144485
2001	278199.6	1.14	79586.36	1.38	198613.3
2002	319491.4	1.10	59631.08	1.49	259860.4
2003	343280.9	1.03	19946.36	1.60	323334.6
2004	482849.4	1.14	101100.6	1.63	381748.8
2005	541543.6	1.20	156607.3	1.56	384936.4
2006	567841.6	1.09	76096.43	1.72	491745.1
2007	520711.4	1.11	98938.83	1.57	421772.6
2008	549193	0.97	-31969.9	1.81	581162.8
2009	530910.8	1.08	77380.62	1.59	453530.1
2010	516655.6	1.10	96539.04	1.52	420116.5
2011	456385.8	1.06	55458.55	1.50	400927.3

See text for construction

Table A4. Electricity Consumption Decomposition

Year	E-E^(Gwh)	Activity	Due to activity	Efficiency	Due to Efficiency
1972	0	1.00	0	1.00	0
1973	147.1306	1.00	14.25343	1.03	132.8772
1974	-20.094	1.01	76.58612	0.98	-96.6802
1975	271.3448	0.98	-92.2112	1.09	363.556
1976	210.6708	0.99	-34.184	1.04	244.8548
1977	263.4431	1.00	1.67046	1.04	261.7726
1978	967.3281	1.00	-1.69634	1.15	969.0245
1979	1142.583	1.02	127.4104	1.14	1015.173
1980	1899.576	1.03	272.4253	1.21	1627.15
1981	2314.522	0.97	-309.645	1.33	2624.167
1982	3040.936	0.97	-300.997	1.39	3341.933
1983	3748.127	0.96	-503.867	1.47	4251.994
1984	4830.246	0.96	-482.532	1.57	5312.778
1985	5155.73	0.96	-488.386	1.55	5644.115
1986	6518.233	0.95	-670.08	1.67	7188.312
1987	8319.675	0.96	-697.942	1.79	9017.617
1988	10721.78	0.97	-576.98	1.93	11298.76
1989	11343.9	0.96	-729.227	1.95	12073.13
1990	13043.9	0.96	-703.4	2.03	13747.3
1991	15001.11	0.95	-1043.28	2.15	16044.38
1992	16013.47	0.97	-706.488	2.13	16719.95
1993	18444.27	0.97	-650.369	2.23	19094.64
1994	17850.8	0.97	-840.403	2.16	18691.2
1995	19730.41	0.96	-1070.89	2.23	20801.31
1996	20562.7	0.96	-1156.37	2.21	21719.07
1997	20358.5	0.95	-1475.6	2.20	21834.11
1998	20956.88	0.96	-1298.36	2.18	22255.24
1999	19312.85	0.97	-893.759	2.02	20206.61
2000	20781.92	0.94	-1908.99	2.12	22690.91
2001	23440.61	0.94	-2022.77	2.24	25463.38
2002	24872.55	0.93	-2499.79	2.30	27372.35
2003	25961.16	0.91	-3157.89	2.33	29119.05
2004	28765.17	0.95	-2030.25	2.28	30795.41
2005	30233.22	0.97	-1383.39	2.19	31616.61
2006	34602.73	0.97	-1169.79	2.27	35772.53
2007	37391.74	0.98	-905.152	2.27	38296.89
2008	36803.11	0.94	-2926.09	2.30	39729.19
2009	33439.63	0.93	-3361.8	2.19	36801.43
2010	36181.78	0.92	-3992.01	2.27	40173.79
2011	37629.1	0.92	-4386.27	2.29	42015.37

See text for construction

Figure A1. Change in Consumption Relative to Base Year Intensity (in Tonnes)

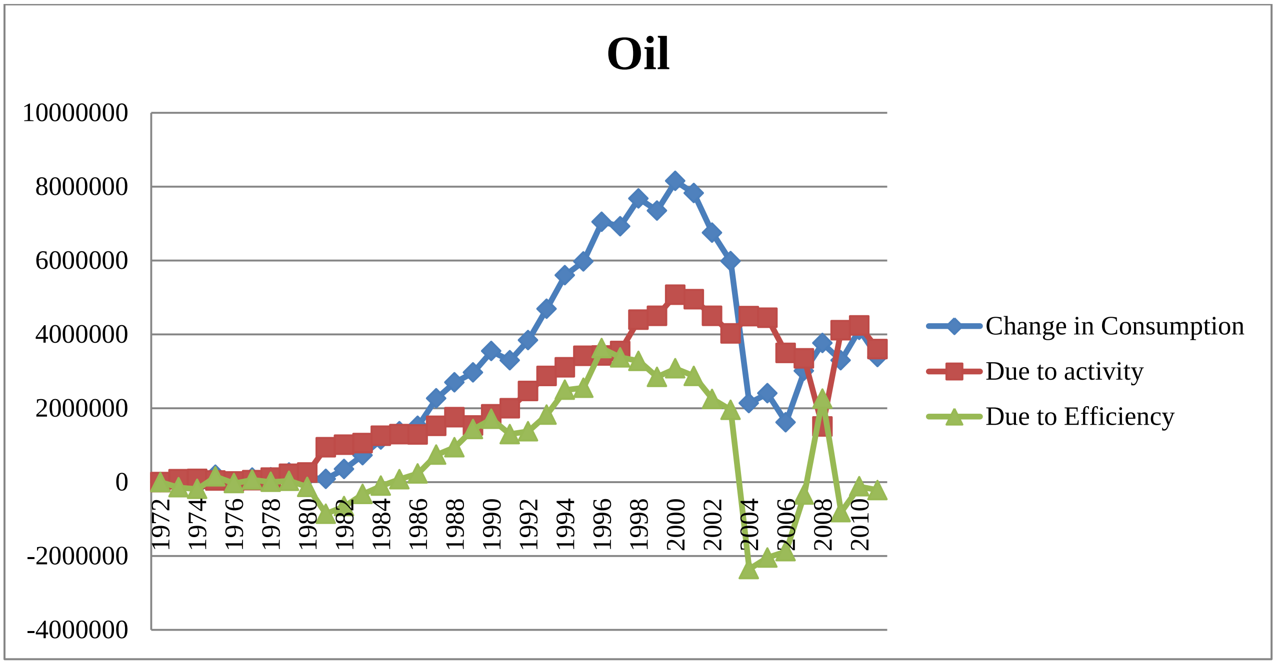

Figure A2. Change in Consumption Relative to Base Year Intensity (in mm cft)

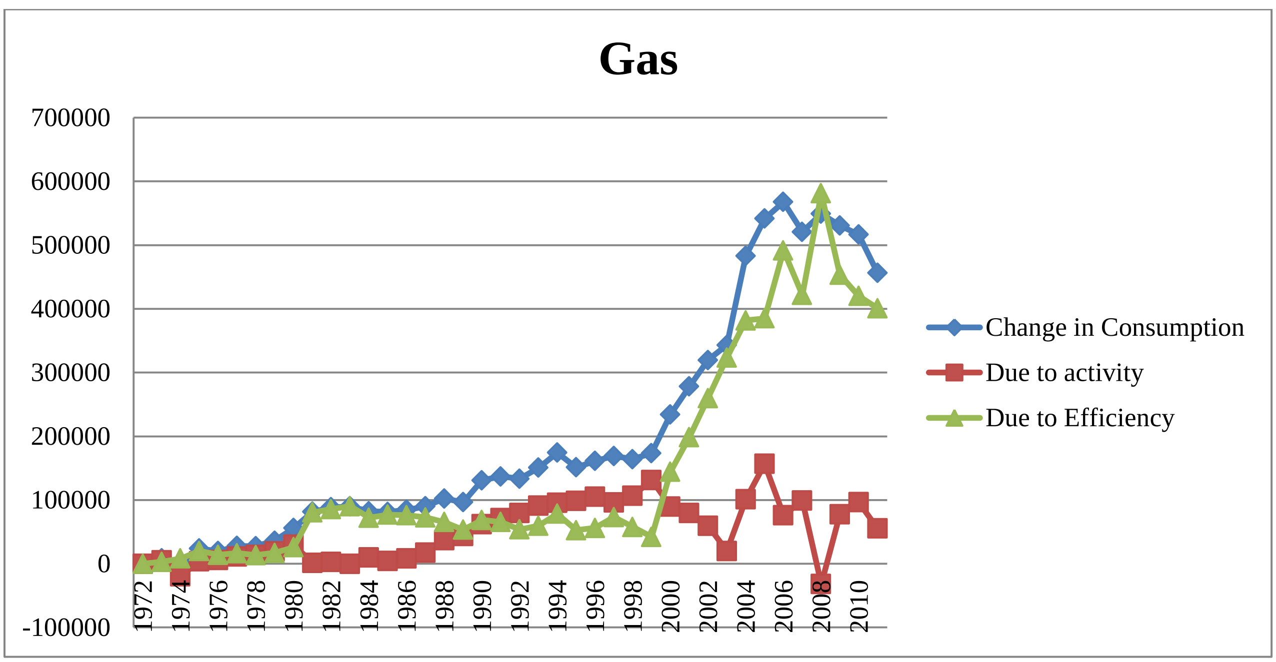

Figure A3. Change in Consumption Relative to Base Year Intensity (in Gwh)