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Energy Intensity: A Decomposition Exercise for Pakistan

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1. INTRODUCTION

Since the recent energy crises, the research in this strand has increased considerably. A variety of its dimensions have been examined in the literature. For instance, higher energy prices; instability in the supplies of its various components; its rapid depletion and global warming are some of its dimensions, which have been the focus of discourse among both researchers and policy-makers. Equally, energy intensity measuring the energy consumption to GDP ratio has been an important component of energy policies [Ang (2004); Liu and Ang (2007); Jimenez and Mercado (2013)]. In particular, there is a special focus on sorting out the contribution of energy efficiency—ratio of sectoral specific energy consumption to sectoral GDP—to alienate the impact of efficiency on energy intensity from other relevant factors. This is because energy efficiency is recognised as one of the most cost-effective strategies to address crosscutting issues of energy security, climate change and competitiveness [IDB (2012)]. Consequently, the information regarding energy intensity, its efficiency or activity aspects are useful tools for policy decisions and evaluation and are regularly in practice in most of the advanced countries.

Pakistan is currently faced with severe energy crisis. In particular, it is facing formidable challenges in meeting its energy requirements and providing adequate energy to users at affordable costs. Electricity shortage is continuously widening since 2006-07. For instance, the gap between demand and supply of electricity increased to the level of 5000 MW in 2011.[1] Such shortages have adverse consequences for the economy of Pakistan. According to Abbasi (2011), energy shortages have cost the county up to 2 percent of GDP per annum. Similarly, Siddiqui, *et al.* (2011) proclaim that the loss in industrial output due to power shortages is estimated to be from 12 percent to 37 percent. They have also forced the closure of hundreds of factories, paralysing production and exacerbating unemployment. Additionally, they imperil much-needed investments in development and infrastructure. Despite these facts, Pakistan's energy intensity per unit of GDP is higher

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[1]During the month of May in 2011, the shortfall had surpassed 7000 MW. See for the details Malik (2012).

relative to Countries like India, USA, Germany, Japan and China [Allcott and Greenstone (2012); IEA (2012c)]. Also, in case of Pakistan, it has taken a rising trend over time. For instance, the consumption of oil in 1972 was 12 percent of its consumption level in 2011. Similarly, it was 9 percent in case of gas and 7 percent in case of electricity. At the same time, gross value added in 1972 was 14 percent of its 2011 level. These trends show that we are now using more energy per each unit of economic activity.

However, to overcome energy crisis and achieve energy security, we must have to bring efficiency in the usage of energy. But before any successful policy formulation, our academia and policy makers must be aware of the past trends and current status of the energy intensity. So far, commendable research has been done on energy issues in Pakistan but most of the studies have been conducted in the context of changes in energy prices and their relation to economic growth, inflation and other macroeconomic indicators [Malik (2007, 2008, 2012); Kiani (2009); Jamil and Ahmed (2010); Syed (2010); Khan and Ahmad (2011); Siddiqui, *et al.* (2011)]. To our knowledge, the only study conducted on energy intensity in Pakistan is done by Alam and Butt (2001) which uses Sun (1998) 'complete decomposition method'. The Sun (1998) method of decomposition, based on jointly created and equally distributed principle, is weaker as compared to recently developed decomposition techniques. Second, the current energy crises have intensified since 2005, so the study by Alam and Butt (2001) has been a little bit older now. In this paper, we make an endeavor to address these two issues. The study provides an empirical decomposition of energy intensity into its constituent factors, efficiency and economic activity for Pakistan. We apply Fisher Ideal Index Decomposition Approach (IDA) and cover a period from 1972 to 2011. In our analysis, we show the effects of change in efficiency and changes in activities on the change in energy intensity. This study contributes to the literature in three main aspects. First, the time of the study is of particular importance. It covers the period that includes all the three major oil price shocks as well as the recent energy crisis in Pakistan. Second, instead of considering the overall energy consumption, we first construct the indices at component level and then aggregate the individual indices to understand the overall trends. This has allowed us to see the intensities pattern of oil, gas and electricity separately. Finally, we have used the most suitable decomposition tools recommended in most recent literature.

Rest of the paper is organised in four sections. Section 2 reviews the decomposition methodologies and their empirical implications. Detailed methodology and the construction of variables are discussed in Section 3. In Section 4, we provide the details of our empirical analysis. Section 5 concludes the paper.

2. REVIEW OF DECOMPOSITION LITERATURE

In order to decompose aggregates into their component parts, different decomposition methodologies have been developed and applied in empirics. These different methodologies can be broadly divided into four groups: Shift Share Analysis (SSA), Growth Accounting Analysis (GAA), Index Decomposition Analysis (IDA) and Structural Decomposition Analysis (SDA) [Fengling (2004)]. SSA is mainly observed in regional studies and GAA is used in decomposing identity [Fengling (2004); Szép (2013)]. In the same manner, the Index Decomposition Analysis (IDA) and Structural Decomposition Analysis (SDA) are widely used in energy and emission studies [Ang and Zhang (2000)]. However, the choice between these two methodologies largely depends on their ease of application and data requirements. SDA uses information from input-output Tables while IDA uses aggregate data at the sector-level. The advantage of IDA is its lowest data requirement along with its strong theoretical foundation [Hoekstra and Bergh (2003); Fengling (2004); Liu and Ang (2007)]. In contrast, SDA can distinguish between a range of technological effects and final demand effects that are not possible in the IDA. However, Hoekstra and Bergh (2003) have formally shown that IDA techniques can be transferred to SDA. Similarly Boer (2009) proved that the generalised Fisher approach, introduced in IDA is equivalent to SDA. Because of this equivalence and its lower data requirements, IDA remains a popular tool of decomposition.

In the energy decomposition, IDA is extensively used since 1980s. The earlier literature in which the energy intensity is decomposed into contributions from structural and efficiency effects left an unexplained residual term [Bossanyi (1983); Boyd, *et al.* (1988); Li, *et al.* (1990); Howarth, *et al.* (1991); and Park (1992)]. The long-mean Divisia index, proposed by Ang and Choi (1997), was an improvement to these earlier techniques because it leaves no residual term. Since then several other perfect methods have been developed by different authors.[2] For instance, Sun (1998) introduced Refined Laspeyres Index (RLI), which is based on the principle of jointly created and equally distributed principle. Similarly, Mean Rate of Change Index (MRCI) by Chung and Rhee (2001) leaves no residue. Further, the decomposition technique of Albrecht, *et al.* (2002), which is based on Shapley Value and the Log Mean Divisia Method and Modified Fisher Ideal Index method by Fengling (2004) are yet other approaches that are perfect in decomposition.

All of these methods have been extensively used in empirical studies.[3] In case of energy intensity, different approaches have come up with different results on the relative roles of the efficiency and structural effects. For instance, Kander and Lindmark (2004) found that efficiency was a major factor in the improvement of energy intensity in case of Sweden. Similarly, a number of other case studies have been conducted and have come up with similar results [Liao, Fan, and Wei (2007) for China between 1997-2002; Metcalf (2008) for U.S. between 1970-2001; Sahu and Narayanan (2010) for Indian manufacturing between 1990-2000; Shahiduzzaman and Alam (2012) for Australia between 1978-2009; Song and Zheng (2012) for China between 1995-2009; Szép (2013) for Czech Republic, Slovakia, Slovenia, Poland and Hungary between (1990-2009)]. In most of the studies, at disaggregate level analysis, the share of structural changes increases even when the same methods of decomposition were used [Karen, *et al.* (2004) for China; and Huntington (2010) for U.S. The possible justification is that aggregations cause the overstatement of the contribution of sub-sector energy productivity improvements while assigning insufficient weight to the role of sectoral shift. Despite this disadvantage, the aggregate level studies are preferred due to their relatively comprehensive coverage. Likewise, the literature places emphasis on the efficiency

[2]A method is regarded as perfect if it leaves no residual term.

[3]Boyd and Roop (2004) and Metcalf (2008) used Fisher ideal index for U.S, Hatzigeorgiou, *et al.* (2008) used arithmetic mean Divisia method for Greece, Mairet and Decellas (2009) used log mean Divisia method for France, Sahu and Narayanan (2010) used the Laspeyres index approach and the Divisia index approach for Indian manufacturing industries for 1990-2008, Zhao, *et al.* (2010) used log mean Divisia method while Song and Zheng (2012) used Fisher ideal index for China, Szép (2013) examined energy intensity for Czech Republic, Slovakia, Slovenia, Poland and Hungary between 1990 and 2009 using eight different decomposition methods (results were almost same for all of the methods).

effects in reducing energy intensity, especially in the advanced countries [Ang (2004); Fengling (2004); Liu and Ang (2007); Ang, *et al*. (2009)].

However, the selection of suitable index decomposition method is very important for getting accurate results. Generally, a method, which leaves no residual is regarded as the most desirable. Such methods are referred to as perfect decomposition methods. Other desirable properties that IDA must satisfy to become a good decomposition method are adaptability, ease of use and interpretation, consistency in aggregation and robustness to zero and negative values [Liu and Ang (2007)]. The two methods that satisfy most of these properties are Log Mean Divisia techniques and Fisher Ideal Index [Ang (2004); Fengling (2004); Liu and Ang (2007); Ang, *et al*. (2009)]. Given its suitability, we use Fisher Ideal Index in our study like Metcalf (2008) and Song and Zheng (2012). Besides the perfect decomposition and its robustness to zero-negative values, the Fisher Ideal Index satisfies time-reversal test, factor reversal test and proportionality test as well.

3. METHODOLOGY FOR DECOMPOSITION OF ENERGY INTENSITY AND DATA

In this section, we provide the detailed methodology of the study. Also, we give a description of the construction of our variables.

3.1. The Decomposition Methodology

As is stated earlier, decomposition analysis is used to break down the aggregate series into understandable and meaningful components. In this study, our purpose is to use these techniques to decompose the change in aggregate energy intensity into changes in economic activity and changes in efficiency. Also, we decompose change in total consumption. For our analysis, the aggregate energy intensity is defined as the ratio of total energy consumption to aggregate output of the economy:

$$e_t = E_t / Y_t \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3.1)$$

$$e_t = E_t / Y_t = \sum_i E_{it} / Y_{it} \; Y_{it} / Y_t = \sum e_{it} s_{it} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3.2)$$

Where, E_t is aggregate energy consumption, Y_t is gross domestic product, Y_{it} is sectoral output and E_{it} sector specific intensity. We want to choose suitable analytical tools to decompose the aggregate changes in energy, Δe_t, into changes in economic activity and changes in efficiency, that is, into Δs_{it} and Δe_{it} respectively. For this purpose, we use Fisher Ideal Index. Fisher Ideal Index has many advantages over most of the other methods as are mentioned in the previous section.

Using e_0 to denote aggregate energy intensity in the base year, we construct energy intensity index and then derive its decomposition.[4]

$$e_t / e_0 \cong I_t = I_t^{act} I_t^{eff} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3.3)$$

[4]We are broadly following Boyd and Roop (2004).

Where, I_t^{act} is the corresponding 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 only by Fisher ideal index.[5] Once we have these indices, we can easily determine the amount of change in energy consumption, which is caused by changes in 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 not changed since the base year. Following Metcalf (2008), this is done below:

$$\Delta E_t = E_t - E_0 = \Delta E_t \left[\frac{\ln I_t^{act}}{\ln I_t} \right] + \Delta E_t \left[\frac{\ln I_t^{eff}}{\ln I_t} \right] = \Delta E_t^{act} + \Delta E_t^{eff} \quad \ldots \quad \ldots \quad (3.4)$$

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

3.2. The Construction of Variables

We carry out the decomposition analysis for various components of energy, *i.e.* oil, gas and electricity. Together, these three comprise about 90 percent of the total energy consumption in Pakistan. Here, we present the details of the data of all the three components. The energy year book reports the oil consumption data under six headings: household consumption; industrial consumption; agricultural consumption; transport consumption; power consumption; and other government consumption. In order to construct the indices, we need the contribution of each of these sectors to the national gross valued added. For this purpose, we make certain matching operations. For instance, for the share of household sector in gross value added, we use household final consumption expenditure.[6] Similarly, for the share of industrial sector, we take into account the industrial value added net of the electricity and gas distribution. This is because electricity and gas distribution is considered to compute the share of power sector in the total gross value added. The gross value added accruing from transport, storage, and communication is taken as the share of transport sector. For agricultural sector, its share in gross valued added is considered for the analysis.

The data on the consumption of gas is reported for seven sectors, i.e., household, commercial, industrial, cement, fertiliser, power, and transport sectors. To make it congruent to the national accounts data, we merge the data of cement and fertilisers with the industrial consumption of gas. In the same manner, the data of transport consumption is merged into the data of commercial sector. In the overall contribution of commercial sector to gross value added, we include the value additions of transport, storage and communications, wholesale and retail trade, and finance and insurance. The shares of the remaining sectors are constructed in a similar way to those, which are constructed in the case of oil sector.

[5]For instance, see the appendix for details.
[6]We are following Metcalf (2008) in this calculation.

In the case of electricity, the consumption of traction, street light and other government sector are eliminated from the total electricity consumption. This is not going to make any difference because collectively the share of these sectors in the total consumption of electricity is less than 7 percent. Consequently, for our analysis of the electricity sector, we consider four sectors, i.e. household, commercial, industrial, and agriculture.

Finally, the gross value addition of each of the mentioned sectors is in constant prices of 2000. The data is taken from four sources: Energy Year Books; Statistical Supplements; Hand Book of Statistics; and the World Development Indicators of the World Bank. The descriptive statistics of the various sectors is summarised in the appendix.

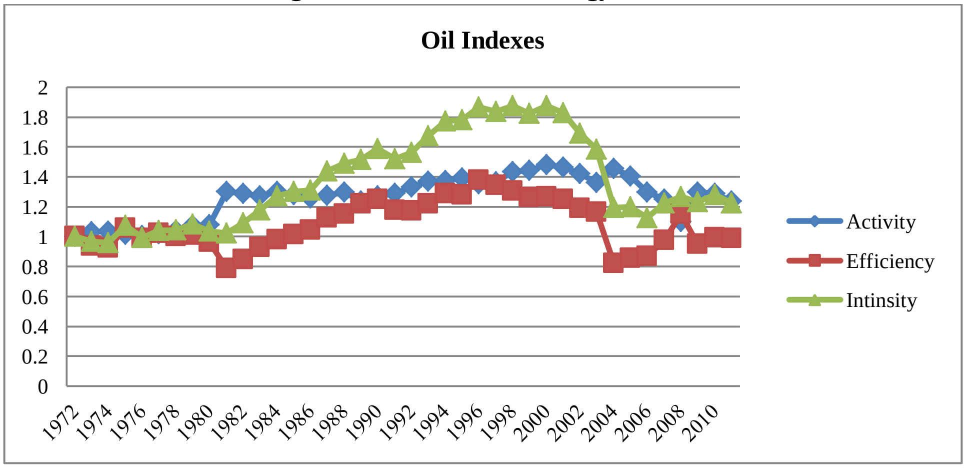
4. RESULTS OF THE DECOMPOSITION ANALYSIS

In order to carry out the detailed analysis of the changes in intensity, we have done separate analysis for each of the three major energy components. In this section, we provide the details of our empirical results one by one.

4.1. Oil Energy

The decomposition of oil intensity between 1972 and 2011 is presented in Figure 4.1. Overall, the oil intensity is 22 percent higher in 2011 as compared to that of 1972. The highest intensity is in the year 2000, which is 88 percent higher as compared to that of 1972. On average per annum, intensity is 37 percent higher than that of 1972. However, the indices of activity and efficiency are giving divergent patterns. For instance, the activity index is 24 percent higher in 2011 as compared to 1972 while the efficiency index is 1 percent lower in 2011 as compared to its base value. The highest value of activity index is 1.48, which is in the year 2000 while the highest value of efficiency index is 1.38 in 1996. Besides, the activity index remains above its 1972 level for whole time period covered in this study. Since 1980, the indices show rising trends for the onward two decades with the activity index dominating the efficiency index. This means that during this period the share of oil using sectors increased in relative terms. However, after 2000 we have experienced sharp reduction in oil intensity with efficiency as a dominant factor in this change.

Fig. 4.1. Trends in Oil Energy Indices



The data of oil consumption indicate that total oil consumption in 2011 would have been 3387509 tonnes lower had the energy intensity remained at its 1772 level.[7] Equation 3.4. can be used to decompose this change into the changes in activities and a change in efficiency. According to our analysis, change in economic activities cause oil consumption to increase by 3596498 tonnes in 2011 as compared to 1972. In contrast, the change in efficiency causes oil consumption to drop by 217989 tonnes in 2011. The year wise details of this analysis are given in the appendix.

As we compare the trends in our indices with the changes in oil prices, some interesting results emerge. The global economy has experienced three big shocks in oil prices. The first was in 1973 when the Organisation of Petroleum Exporting Countries (OPEC countries) imposed embargo on oil exports in response to Arab-Israel war. The second shock occurred in 1979, which was mainly caused by the Islamic Revolution in Iran. From 1983 to 1998, oil prices remained stable both in domestic as well as international markets. However, since 1999 the world is experiencing a third big oil price shock in the global history. In their meeting in March 1999, the OPEC countries agreed to cut the oil production with a view to increasing the prices of crude oil to around $20 per barrel. As a consequence, the oil prices very quickly surpassed the $20 per barrel with a dramatic increase in the new century. For instance, in 2003-04 oil prices were 11 percent higher than those of 2002-03 and around 41 percent higher in the following year compared to those of 2003-04. In the same manner, in 2007-08 oil prices were 53 percent higher as compared to those in the preceding year. Continuing with the rising pattern, the prices reached to a record level of about $150 per barrel in 2008-09.

The comparison of oil price history with Figure 4.1, in particular with the efficiency index, shows that the indices remained almost stable during the whole 1970s. In 1980, efficiency started improving, which continued until 1984. During this period, the efficiency was better than that of 1972. Onwards, the indices have steadily increased and this increasing trend continues up to 1998. After 2000, the aggregate intensity strongly falls and the dominant factor for this fall can be seen as the efficiency index. For instance, the efficiency index falls from 1.16 in 2003 to 0.82 in 2004 and during the same period, oil prices increased by 41 percent as compared to preceding year. This trend holds not only for the international prices but also for the domestic variation in the prices of furnace oil, HOBC, HSD etc. If the relation holds true, it implies that whenever oil prices increase, we increase efficiency in its use. This is an important implication and requires in-depth analysis. After the year 2000, the activity index also shows declining trend; however, it is not as pronounced as the efficiency index.

4.2. Gas Energy

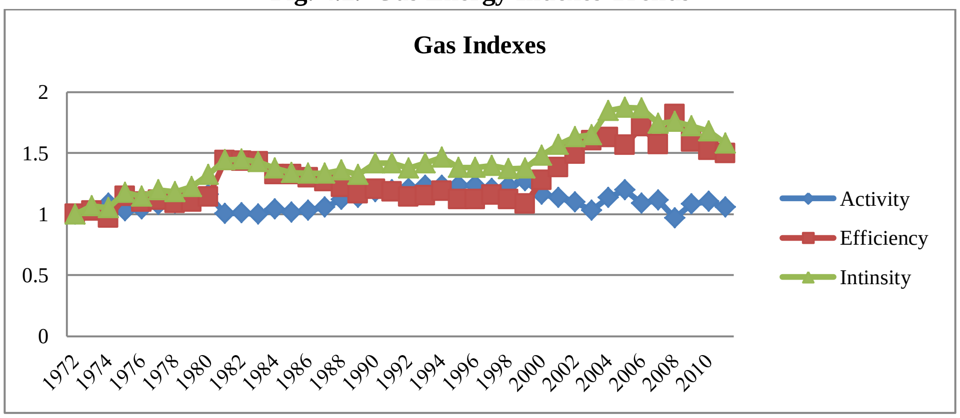
In this sub-section, we extend our analysis to the case of gas. The decomposition analysis of gas intensity, shown in Figure 4.2, indicates that gas intensity in 2011 is 58 percent higher as compared to that of 1972. The intensity is the highest in 2005, which is 87 percent higher than that of 1972. On average, the gas intensity is 43 percent higher than 1972 for the onward period. The index of activity is dominated by the index of efficiency. For instance, the activity index in 2011 is 06 percent higher as we compare it

[7]Note that it does not include the consumption under the other government heading.

with that of the 1972. In contrast, the efficiency index is 50 percent higher in 2011. The highest value of activity index is 1.27 in 1999 while the highest value of efficiency index is 1.81 in 2008. In the same way, the lowest value of the efficiency index is estimated at 0.97 in 1974. In general, the efficiency index remains above its 1972 level for most of the period covered in this study. As is evident from the figure below, the aggregate intensity index is strongly driven by the efficiency index in case of gas consumption.

Moreover, the intensity index goes through two notable upward spikes, one in around 1981; and the second is the most prolonged one beginning in 2000 and lasts up to 2008. 2008 onwards, we have experienced a declining trend in gas intensity with efficiency as the dominant factor in this change. One factor for the higher intensity in the beginning of 21st century can be the policies of the Musharraf administration, which converted most of electricity or oil run industries to gas. For instance, one critical sector in this regard is transport sector. In 1998, transport sector was using 490 (mm cft) of gas, which increased to 113055 (mm cft) in 2011. Again, a striking feature is that the increase is mainly dominated by the efficiency changes rather than the activity changes.

Fig. 4.2. Gas Energy Indexes Trends

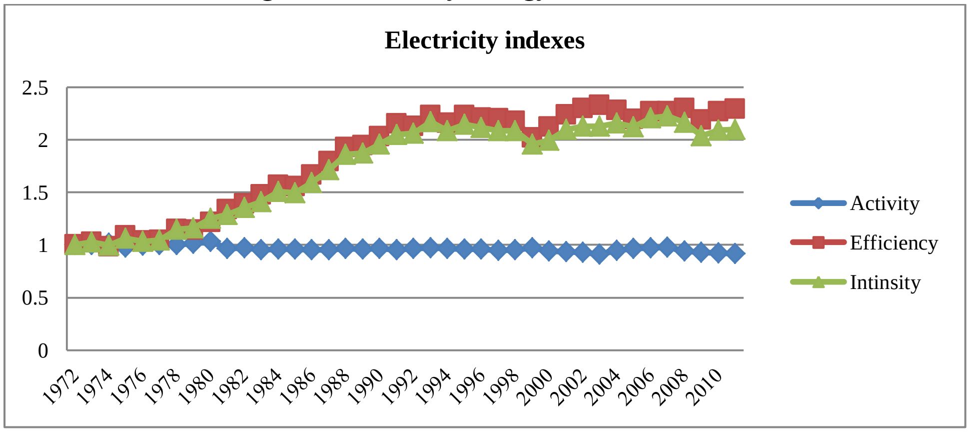


The gas consumption data indicate that total gas consumption of 1240672(mm cft) in 2011 would have been 784286.2 (mm cft) had energy intensity remained at its 1772 level. The increase is jointly shared by the activity and efficiency factors. For instance, the increase in gas consumption caused by the change in economic activity is estimated to 55458.55 (mm cft) in 2011 as we compared it to the level of 1972. Similarly, the change in efficiency causes gas consumption to increase by 400927.3 (mm cft) in 2011 compared to the level of 1972. The year wise details of the changes in indices are given in the appendix.

4.3. Electricity Energy

This section provides the blueprints of the intensity of electricity. The details of the decomposition analysis are shown in figure 4.3. Overall, the intensity of the electricity is 110 percent higher in 2011 as compared to that of 1972. This difference is highest in the year 2007 where the index is 122 percent higher than that of the base year. For all the periods onwards the base year, the index is on average 75 percent higher than that of the base year. So far the decomposition is concerned; the activity index is 08 percent lower whereas the efficiency index is 129 percent higher compared to their corresponding values in 1972. The efficiency effect is dominating the activity effect for almost the whole period covered in this study. The highest value that the activity index takes is 1.03 in 1980 while the highest value that efficiency index takes is 2.33 in 2003. The efficiency index remains above its base year value for almost the whole period covered. As a consequence, the aggregate intensity index is perfectly guided by the efficiency index in case of electricity consumption. As is shown in the figure, both the aggregate index and the efficiency index are increasing over time while the activity index remains static and sometimes is slightly below its 1972 level. The analysis shows that each unit of output produced in Pakistan uses more and more electricity with each passing year.

Fig. 4.3. Electricity Energy Indexes Trends



Given our analysis, the total electricity consumption of 71845 (GWH) in 2011 would have been 34215.9 (GWH) had the energy intensity remained at its base year level. This translates that our electricity consumption is 110 percent higher than would have been had the energy intensity remained at the level of the base year. We have shown above that most of the increase in the consumption of electricity is mainly driven by the inefficiency in the use of electricity. For instance, the change in economic activity causes the consumption of electricity to decrease by 4386.27 (GWH) in 2011 as compared to 1972. In contrast, the change in efficiency causes electricity consumption to increase by 42015.37(GWH) in 2011 as compared to 1972. The year-wise details for the whole period of the analysis are given in the appendix.

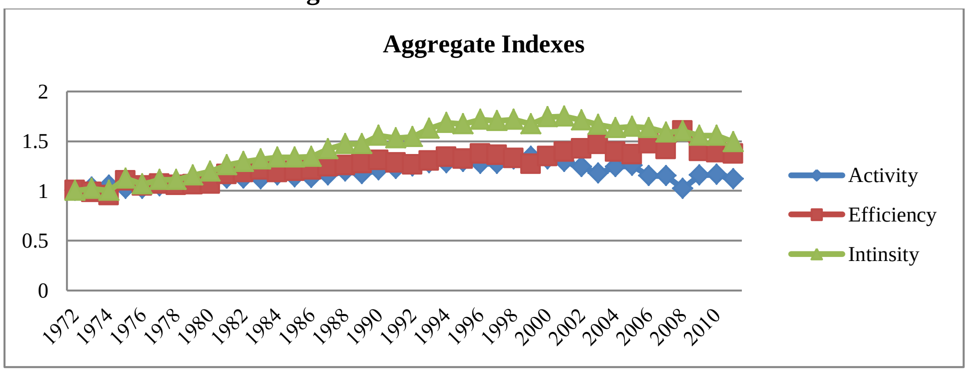
4.4. Discussion

We have shown above that the changes in efficiency guide the changes in intensity in case of gas and electricity while change in activities is a dominant factor in case of oil. There are definitely some cases where an increase in efficiency index in one sector was accompanied by a corresponding decrease in other sector.[8] In order to truly understand the dynamics of efficiency indices, we aggregate the indices and check whether the change in

[8]For instance see the oil and gas efficiency indices after 2000.

efficiency is mere a transfer of activity from one component to another or is just a real wastage of energy. In this regard, we have taken the weighted average of the respective individual indices of each component. Weights are given according to the contribution of each energy component in the total energy consumption. This analysis is shown in Figure 4.4. The resulting aggregate activity index smoothly increases and reaches its maximum value 1.4 in 1999. This trend is mostly explained by the oil energy. However, after 2000, the index is falling, which may be due to the severe shocks to the gas supply and oil prices, which are evident throughout the first decade of this century. This demonstrates that the share of sectors using energy in the total gross value added is falling after 2000. The main justification is that in the initial decades of independence, our economy was moving away from less energy intensive agricultural sector to more intensive industrial sector. But in recent decades, the trend is completely different: both the agriculture and industry are losing their shares to another less energy intensive services sector. Given the sectoral transformation of the economy, this result is not surprising.

Fig. 4.4. Combined Indexes Trends



The aggregate efficiency index shows that increasing energy use per each unit of output is the dominant factor of the increase in intensity during the study period. The index is smoothly increasing for most of the period with the highest value of 1.6 for the year 2008. Ultimately, this has guided the change in energy intensity in Pakistan since 1972. It is clearly evident that after 1998, the fluctuations in this index are caused by the indices of gas and oil.

In conclusion, it is stated that energy intensity in Pakistan increases by 45 percent on average between 1972 and 2011. A critical feature of the increase is that 52 percent of the increase is caused by the inefficiency associated with the use of energy. Alternatively, for the same unit of output, we are using more energy now as compared to the per unit use of 1972. Most of the inefficiencies arise in the consumption of electricity, followed by gas sector. This translates into that oil sector is relatively efficient as we compare it with gas and electricity. In particular, the oil price hikes have beneficial effects on improving the efficiency in oil sector.

5. CONCLUSION

The study is motivated by the recent energy crises in Pakistan. Most of the existing literature in case of Pakistan deals with the energy prices and their impact on other macroeconomic variables like economic growth, inflation, employment etc. To our knowledge, there is no commendable work on the energy intensity side. We are filling this gap by providing a complete analysis of the energy intensity. Our analysis of energy is components-wise to see the trends in different components like oil, gas and electricity. The study, covering the period from 1972 to 2011, uses the decomposition method of Fisher Ideal Index. We disaggregate the change in aggregate energy intensity into changes in the efficiency and changes in the activities. Our analysis shows that aggregate energy intensity has steadily increased over time until the recent years. The consumption of electricity in 1972 was 7 percent of its consumption in 2011. At the same time, the gross value added in 1972 was 14 percent of its level in 2011. This implies that growth in the consumption of electricity is greater than the growth rate of gross value added.

According to our results, energy intensity in Pakistan increased by 45 percent on average between 1972 and 2011 and 52 percent of the increase is due to the worsening efficiency in its use. In other words, the use of energy per unit of output has increased significantly since 1972. The inefficiencies in the consumption of electricity are dominating, followed by the inefficiencies in gas sector. For instance, in case of electricity, the average index of efficiency is 1.82, which implies that a given amount of output is now produced with 1.82 (GWH) of electricity on average whereas the same amount of output required only 1 (GWH) in 1972. In comparison, the average value of activity index is 0.97, again in case of electricity, which is showing that the share of electricity intensive sectors in total gross value added is declining. In case of the consumption of gas, the average value of efficiency index is 1.29 and the average value of activity index is 1.11. It implies that the level of efficiency also has declined in case of the consumption of gas. Unlike electricity and gas sectors, the oil sector is relatively efficient. For instance, the average value of efficiency index in case of oil is 1.08 while the average value of activity index is 1.26.

In summary, the change in aggregate intensity is mainly caused by the inefficiencies. The main deriver of the change in aggregate energy intensity is electricity with its average intensity index of 1.75. The aggregate intensity of oil and gas is falling following the recent prices and supply crisis. Countries like China, USA, and India have experienced significant gains in the aggregate energy intensity over the past years. In these countries, improvements in efficiency are regarded as the catalyst behind the changes in energy intensity. In contrast, in Pakistan efficiency has worsened over time instead of improving. In general, the change in efficiency index in Pakistan seems to be somehow related to the price changes. For instance, whenever the price hikes have taken place, oil efficiency index has improved. Additionally, our analysis shows that energy sources with relatively low prices are more prone to increased inefficiencies. This is an important area for future research; in particular with relevance to policy formulation.

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

$$L_t^{act} = \frac{\sum_i e_{i0} s_{it}}{\sum_i e_{i0} s_{i0}} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (A1)$$

$$L_t^{ef} = \frac{\sum_i e_{it} s_{i0}}{\sum_i e_{i0} s_{i0}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(A2)}$$

The Paasche activity and efficiency indexes are

$$P_t^{act} = \frac{\sum_i e_{it} s_{it}}{\sum_i e_{it} s_{i0}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(A3)}$$

$$P_t^{ef} = \frac{\sum_i e_{it} s_{it}}{\sum_i e_{i0} s_{it}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(A4)}$$

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

$$I_t^{act} = \sqrt{L_t^{act} P_t^{act}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(A5)}$$

$$I_t^{ef} = \sqrt{L_t^{ef} P_t^{ef}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(A6)}$$

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

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

Table A1

Descriptive Statistics of Sectors Included in the Analysis

		Economic Activity		Intensity	
Sector	Components	Mean	SD	Mean	SD
Household	Oil	2209813	1074383	0.3242	0.2077
	Gas	–	–	0.0317	0.0171
	Electricity	–	–	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 Index	Due to Activity	Efficiency Index	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.

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Comments

Energy intensity in Pakistan is more than double to that of the world average and more than five times to that of Japan and the UK. For resource constrained economies like Pakistan it is more cost effective to increase its energy security and ease supply constraints through efficiency in its use and conservation compared to exploiting/ building new sources of energy.

Energy efficiency is regarded as an important component in national energy strategy but so far it is the most neglected area in Pakistan's energy strategies and plans. In this context, this study is a significant attempt in terms of examining the change in energy intensity over the years and decomposing this change in terms of activity and efficiency. I have few suggestions:

Besides correcting some typo's and editorial mistakes which made it difficult for the reader to understand, some in-depth analysis on changes in energy intensity for the main economic sectors would make this study even more interesting and useful. Because when analysing energy intensity for Pakistan it is important as well as useful from policy perspective to identify those economic activities that are crucial to reduce energy consumption. Similarly, there is a need to highlight potential strategies and measures for improving the efficiency of final energy use with reference to particular economic activities. Since you have already collected energy consumption details at the sector level which might help you in some sort of discussion on efficiency of energy end uses for sub-activities. Moreover, while discussing and analysing energy intensities some discussion on electrification over the years would make the discussion more valuable. Likewise, when you are discussing positive changes in oil intensity it may be because of negative changes in other sources of energy.

Similarly, in the analysis of your results you can make some comparison with the studies for other countries. For instance, China has decreased its energy intensity significantly through improvement of energy efficiency; whereas structural-mix changes played a low, but positive role in decreasing the energy intensity. But in Pakistan as your results show it's the opposite. Similarly in India, energy efficiency also played a positive role, but, the industrial structure has become more energy-intensive because of the increasing share of energy-intensive sub-sectors, which offsets the impact of energy efficiency on energy intensity. So you need to discuss on how other countries have enhanced efficiency in the use of energy.

Even, you can compare your results with the previous study on Pakistan by Alam and Butt (2001) (you mentioned in your paper) to highlight the significance of your study and your results.

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