Energy Efficiency and Energy Rebound Effect in Pakistan

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Abstract

Energy is at the center of worldwide concern, and estimating energy rebound effects is of critical importance for energy policy. In this research the impact of technical development that causes increase in energy consumption is calculated, which is based on the estimation of the three components of the production function: i.e. labor, capital and aggregate energy consumption. Pakistan's energy rebound effect in terms of technological progress is estimated over the past 37 years for the period of 1984-2021, with a Cob-Douglas production function. The outcomes show that the energy rebound effect varies significantly from year to year, with an average level of -244.246%. This specifies that energy conservation potential is achieved by technological progress. Technological developments, lead to improved efficiency of energy and reduced energy utilization. Therefore, improving the energy consumption structure could help to decrease the energy rebound effect and increase energy conservation. It is therefore recommended to relay more on non-renewable resources instead of renewable resources, new inventions and better energy policies could decrease the consumption of energy.

Key words: *energy rebound effect, technological improvement, energy saving, energy efficiency*

Introduction

Most of the people all over the world are dependent on non-renewable energy resources, which are depleting with the passage of time. (Tronchin et al 2018). It is the desire of countries all over the world to decrease energy consumption and increase energy saving therefore they have shifted their dependency towards renewable energy resources. But there is increase in energy consumption due to rapid economic development and deviations of human behavior. (Jin and Kim 2019). This problem has created energy crises problem which need to be overcome. Technological improvement has caused increased in consumption of energy instead of saving energy. (Bentzen, J. et al 2004). Pakistan is a developing economy; having Gross domestic product per capita equal to 1473.86 USD in 2021 (Pakistan Economic Survey, 2021). Its demand for energy consumption increases due to GDP escalations. The demand for energy is rising as Pakistan continues to witness increased urbanization and industrialization. As a principal fuel consumption in Pakistan, total energy consume in Pakistan is 60 million TOE in the year 2021. The industrial sector consumes highest energy which is 40.1%. It is highest among all other segments of the economy, in which energy is used. The manufacturing sector of Pakistan is considered to take great responsibility for consuming more energy for the requisite of growth and development. It is required to decline energy consumption.

Following is the transport sector where consumption of energy is 29.9%. Energy consumption in domestic sector is also high which is 21.0%. Hence, it is essential for Pakistan to improve its energy efficiency in all segments of the economy (Energy Year Book 2021). Pakistan is experiencing troubles associated with increased energy demand and energy supply. Therefore, energy efficiency improvement is tremendously essential for saving energy. New inventions have been made but we could not overcome the energy crises problem to decrease energy consumption in Pakistan. This problem has asked much attention from government and academia. Which is the motivation to conduct research on this study.

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Energy rebound effect is an essential subject matter in energy economics. In economics, the energy rebound impact is the decline in energy saving that is caused by innovative equipment's, due to behavioral or other general reactions. These reactions decrease the advantageous impact of the fresh innovations. This phenomenon is called energy rebound effect (Saunders 1992). It specifies that energy consumption decreases due to technological improvement. But behavioral change or some other measures causes rise in energy utilization. Thus, the lost part of saved energy is consumed more which is called the energy rebound effect (Gillingham 2015).

The goal of the research study is to find the technological advancement that causes energy efficiency enhancement leads to energy rebound effect in the economy of Pakistan. There are no evidences found on research studies conducted on energy rebound effect in Pakistan. It is therefore important to find the origins of energy crises in Pakistan, whether the energy crises are due to energy shortage, supply side management, demand side management, or people over utilization of energy due to the enhancement in technology.

Our key objective in this research is to measure the consumption of more energy i.e. electricity, gas, coal etc. due to technological improvement or we are saving aggregate energy after technological improvement. A lot of studies are found on energy rebound effect to measure its magnitude all over the world but no research is found on the measurement of the magnitude of the rebound effect of energy in Pakistan. This is the research gap of this study that has to be conducted in Pakistan. This study will concentrate on the technological development that is caused by energy efficiency enhancement leads to energy rebound effect in the economy of Pakistan.

Literature review

Yan, Ouyang and Du (2019) estimated the rebound effects in the Chinese economy. A two-stage method, was adopted to measure the macroeconomic rebound effects of energy depends on panel data collected from thirty provinces of China from 1997 to 2015. With this approach the energy consumption elasticity about the energy efficiency was estimated which leads directly to measure rebound effect. The resultant rebound effect in short-run as well as in long-run as 88.55% and 77.50% respectively. Additionally, it was found that the rebound effects in the eastern developed region continually falls whereas it increased in the western region.

Zhang (2019) estimated energy rebound effect in China by means of LMDI decomposition approach and use data for the period 1997-2017. He finds that energy efficiency causes energy rebound effect and indicated that China is facing the problems of high economic growth as well as environmental safeguard. The rebound effects on average is 34.86% in China. It is further found that the extent of the energy rebound effects is changing with the passage of time.

Jin and Kim (2019) Following an output-based data analysis approach, it was considered that maximum economic growth is obtained while using total factors of production. Data was collected from 1971 to 2012 in Korea regarding factors of production and economic growth, presented by capital stocks, aggregate energy consumption and employed labor force. The paper found around 100% rebound effect due to macroeconomic development. The statistical results of the study show rebound effect of 1% in most cases. The paper considers energy as a factor of production and concludes that it is wasted economically, which is equivalent to rebound effects of energy.

Bentzen, J. et al (2004) Used time series data to find the rebound effect by using DOLS dynamic ordinary least squares method in the industrial

sector of US. The rebound effect on average is 24%. The energy price shocks during 1970s causes improvement in technological development. It is assuming that energy saving will result in decrease in energy prices. This will cause increase in energy consumption and thus causes energy rebound effect.

Cullen and Craglia (2020) examined the energy rebound effect in Great Britain to find answer to the question that whether vehicle efficiency improvement results in energy savings. Data of roadworthiness tests for more than 275 million vehicles was analyzed it was revealed that that reaction to variations in travel cost differs among the vehicles' types and socio-economic conditions of different areas in Britain. The outcomes of the research depict that energy rebound effect in UK is around 4.60 %, suggesting that energy efficiency enhancements in the short-run least encourage to raise mileage. It was further found that big and least fuel-efficient vehicles respond passively to variation in fuel price when compared to smaller vehicles. Additionally, in urban areas drivers respond to fuel price more promptly to prices changes than in rural areas.

Broberg, Berg and Samakovlis (2015) using a general equilibrium approach and analyzed the rebound effect in industries in Sweden. According to the paper improved energy efficiency can have substantial effect on the economy that impedes the optimistic impact on actual saving of energy. A quantifiable general equilibrium model was used to find the extent of the overall rebound impact in the Sweden. The consequences of the estimation show that the rebound effect rests on numerous elements including the degree of the energy efficiency development and the way labor marketplace is shaped. The study found the rebound effect Swedish industry was between 40–70% consequent to 5% growth in energy efficiency. The paper concludes that energy efficiency increases in energy-intensive production only where the rebound effect gets much higher.

Theoretical Background

In 1865, William Stanley Jevons explained the energy rebound effect in his famous book "The Coal Question". He argued that the innovation of the coal engine in England was more efficient because coal was used by many people, and it was economically viable for many applications. Ultimately, this causes to escalation in demand for coal and a much higher use of coal, but in exchange, demand for coal for certain applications decline. It is a conceptual misunderstanding to think that it leads to a reduction in consumption, the truth is to the contrary" (Jevons 1866).

Although, recent authors credited Daniel Khazzoom for reintroducing the energy rebound effects concept into the literature. He introduced the idea that there is an indirect correlation between reduced energy use in the production of final consumer goods due to changes in fuel prices and increased energy efficiency. (Khazzoom 1980). His research was built on improving the energy efficiency of home appliances, but his remarks on the rebound effect apply to the economy as a whole. A common example is a more energy efficient automobile. If the distance traveled by car becomes more economical, unnecessary travel distance will increase, and fuel consumption will deteriorate at high speeds. Another example is the popularization of incandescent light bulbs following the introduction of light emitting diodes as an energy saver. If the energy rebound effect exceeds 100%, improvements in fuel efficiency and technological developments are wasted on increasing demand for additional energy. This phenomenon is called the Jevons paradox (Jevons 1866).

Technological improvement results in rise in consumption of energy. This phenomenon is called "Khazzoom Brookes hypothesis". (Harry Saunders 1992). He explained his view by multiple neo-classical models, and

discovered that the assumption is true in diverse situations of consumption of energy. Technological improvement can increase the consumption of energy by making energy inexpensive and by increasing economic growth, which causes increase in energy consumption. These results, which are shown by Harry Saunders causes the policy makers to consider energy rebound effect. This work provides a basic ground for describing the trouble of the energy rebound effect in Pakistan. Therefore, this research study will find the energy efficiency development leads to rebound effect in Pakistan.

Methodology for Energy Rebound Effect in Economy

To find the rebound effect in Pakistan, a neoclassical growth model is used. Using time series data of the four variables that is output Y, labor L, aggregate energy consumption i.e. coal oil gas etc, E, and capital stock K are taken (Zhang 2019). Technological improvement causes rise in consumption of energy which is called energy rebound effect. Technological development which causes Potential Energy Savings is denoted by (PE) and the additional consumption of energy (QE) as a result of economic development (Wei 2020). Consequently, the rebound effect of energy is revealed in the equation as below:

$$RE = \frac{QE}{PE} \times 100\ \% \quad (1)$$

Energy efficiency can be find by the instrument, intensity of energy. Which can be measure by energy consumption per economic growth i.e. GDP. (Wei. T 2019). Given below is the equation of intensity of energy which is energy consumption and GDP:

$$EI_t = E_t / Y_t \quad (2)$$

Consumption of energy per GDP is called energy intensity, Y_t is the GDP output in economy in year t and E_t is the aggregate consumption of energy in t year in Pakistan's economy.

As there is improvement in efficiency of energy ($EI_t - EI_{t+1} = \Delta EIt$), intensity of energy decreases, and the potential saving of energy (PE) in Pakistan's economy in t+1 year will be as below:

$$PE_{t+1} = Y_{t+1}(\Delta EI_t) \quad (3)$$

Afterwards, additional consumption of energy (QE) in t + 1 year and change in output ($Y_{t+1} - Y_t = \Delta Y_t$) will be as below:

$$QE_{t+1} = T_{t+1}(\Delta Y_t)EI_{t+1} \quad (4)$$

In the above equation QE is the additional energy consumption, T_{t+1} is the technological development in year t+1. Hence, in year t+1, we find the magnitude of energy rebound effect is as follows:

$$RE_{t+1} = \frac{QE_{t+1}}{PE_{t+1}} * 100$$

$$RE_{t+1} = \frac{T_{t+1}(\Delta y_t)EI_{t+1}}{Y_{t+1}(\Delta EI_t)} * 100 \quad (5)$$

Equation (5) is the tool to find the rebound effect which properly find the impact of technological growth in Pakistan (Zhang 2019).

There are three input variables used in this model i.e. labor input, capital input and aggregate energy consumption which are used in growth model to measure the technological improvement that causes rebound effect in the economy of Pakistan (Lin & Tan 2017).

The economic growth is typically described as GDP output (Y_t) as a function of labor (L_t) and capital (K_t) (Saunders 1992):

$$Y_t = F(k_t, L_t) \quad (6)$$

In the above Eq (6) K is gross fixed capital formation, L is the labor and t is the time period. Aggregate Energy consumption is used as an essential factor in addition with capital and labor to enhance economic growth.

Given below is the Cob-Douglas productions function:

$$Y_t = A_t F(k_t, L_t, E_t) \quad (7)$$

In Equation (7) L_t show labor input in t year. Y_t represents GDP in year t. K_t show capital stock i.e. gross fixed capital formation. E_t show aggregate consumption of energy in t year. A represents Hicks neutral technological parameter, that is described as $A_t = Aoe^{rt}$. The neoclassical model contains all these variables i.e. consumption of energy, capital and labor are given below:

$$Yt = Aoe^{rt}\, K_t^{\alpha}\, L_t^{\beta}\, E_t^{\gamma} \quad (8)$$

Taking log of the Eq (8) then given is the eq (8) below:

$$\ln Y_t = \ln A_o + rt + \alpha \ln L_t + \beta \ln K_t + \gamma \ln E_t \quad (9)$$

In the above equation, α, β *and* γ are the elasticities of capital, elasticity of labor, and elasticity of energy consumption.

Variables gY_t, gK_t, gL_t, and gE_t represents growth-rate in capital, labor and aggregate consumption of energy in Pakistan. The equation is shown below:

$$gY_t = \alpha\, gK_t + \beta\, gE_t + \gamma\, gL_t + gA_t \quad (10)$$

The above Equation (10) represents gA_t is the technological improvement, which is represented by T that denotes technological improvement in year t. Consequently, the rate of technological improvement in economic growth in t year is given below:

$$T_t = \frac{gAt}{gYt} = \alpha_t \frac{gKt}{gYt} - \beta \frac{gLt}{gYt} - \gamma \frac{gEt}{gYt} \quad (11)$$

We will measure the rebound effects in Pakistan through Eq (8) to Eq (11). Here labour, capital and energy data is used to find output growth rate. Hence the results of regression are given in Eq (11). Increase in saving of energy and additional consumption of energy is measured by Eq (3) and (4), respectively. The Energy Rebound Effects of technological improvement is obtained by Eq (1).

Description of Data

For this research study, the time series data sample is used for the period of 1984–2021 from various sources i.e. Pakistan bureau of statistics and energy year book Pakistan.

Labor (L): Time series data of Employed labor force for the year 1984-2021is obtained from Pakistan bureau of statistics.

Energy variable (E): Time series data of energy consumption. i.e. coal, oil, gas etc. is obtained from Energy yearbooks of Pakistan for the time period of 1984-2021.

GDP Variable (Y): Output data i.e. real gross domestic product of Pakistan economy for the time period of 1984-2021is present on different base years. This data is converted into single base year. This time series data is obtained from Pakistan bureau of statistics.

GFCF. (Gross Fixed Capital Formation) Capital Stock K

Capital comprises assets and resources used in the production process such as buildings and infrastructures. Capital stock is used in Cobb- Douglas production functions which is an independent variable. Capital stock data is not available; therefore, it is necessary to construct this variable which is as follows. Time series data of gross fixed capital formation for the year 1984-2021is present in Pakistan bureau of statistics year book. (PIM) Perpetual inventory method is used to create capital stock K_t series through the following equations. (Alvi & Ahmed 2014).

$$k_0 = \frac{GFCFo}{\delta + g_{GFCF}}$$

$$k_t = (1-\delta)k_{t-1} + GFCF_t$$

The initial level of GFCF is GFKFo, K_o is the Capital stock, and the rate of depreciation is δ, it is assumed as 5 % per year. The average growth rate of GFCF is gGFCF. To measure the data for the rest of the years, the

following technique is used given by the following above equation. K_t is a stock of capital in current year, $GFCF_t$ is the Real Gross Fixed Capital Formation, K_{t-1} is a previous year capital stock, and δ is rate of depreciation, as stated before.

Estimation of Energy Rebound Effect in Pakistan's Economy

Stationarity of Data

All the variables i.e. employed labour force, gross fixed capital formation k, GDP Y, and energy consumed were tested by (ADF) Augmented-Dickey Fuller test after taking their logs. All the variables are non-stationary at I(0) level form. Then first difference of the data is tested using ADF test. All the variables are integrated of order I(1) that is these variables are stationary at first difference I(1). The stationarity outcomes are as follows.

Table.1 Stationarity of Variables

Variables	ADF Statistics I(1)	5% Critical Value	ADF Statistics I(0)	5% Critical Value	Stationarity
ΔlnGDP	-4.4783	-2.941	-2.0919	-2.938	I(1)
ΔlnE	-5.0688	-3.533	-0.7219	-2.938	I(1)
ΔlnELF	-6.0356	-3.533	0.13543	-2.938	I(1)
ΔlnKt	-2.5568	-1.949	-1.96306	-2.943	I(1)

Results in the above table 1 indicates that all the variables at first difference form are stationary. The outcome shows the long-term association between the variables. Here Ordinary Least Square method is appropriate only if residual from such regression is stationary at order I(1). The residual stats from such regression is statistically significant and stationary i.e. -5.289 at 5% level of confidence.

To test the relationship between variables, (OLS) method has been followed:

$$\ln Y_t = \ln A_o + rt + \alpha \ln K_t + \beta \ln E_t + \gamma \ln L_t \quad (9)$$

Table 2 *Results of regression analysis*

lnYt	α	lnKt	lnLt	lnEt
	1.03	0.40	0.59	0.26

Note: Significant at: p-value, 0.05.

Estimated value for R^2 is 0.79, and at 5 % significance level, all coefficients are significant statistically, indicating that the regression results are rational. As a consequence of regression analysis, the elasticity of labor to the output is 0.59, the elasticity of capital to output is 0.40, and the elasticity of energy to output is 0.26. This indicates that 0.59, 0.40 and 0.26 %age of capital, labor and energy inputs, the output of the Pakistan's economy increases by percentage points. There is increasing return to scale in the output, if the summation elasticities are greater than one. From the results, it is shown that the labor elasticity in the Pakistan economy (0.59) is greater than the elasticity of energy (0.263) and capital (0.407), specifying that Pakistan's economic growth depend on labor-centered growth. Labor input is the leading powerful tool. Due to labor intense economy, Pakistan's extensive labor force is a major force in Pakistan's economic development, so investors inevitably discard investments in technological improvement. In particular, various small businesses don't rise their share in technological growth. This condition has been upgraded in current years, technological development is essential for economic development and investors should invest more in technological development for Pakistan's economic growth. The transformation from a

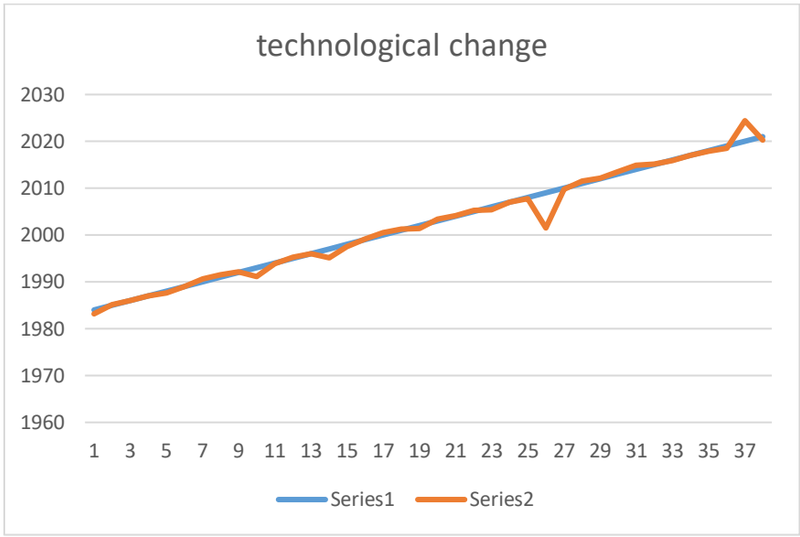
labor concentrated economy to a technological concentrated economy is only possible through increased investment in technological change, improve technological change, and inventing various technologies, and new resources. Augmented Dicky fuller stats of residuals in regression analysis is -5.289 at 5% degree of confidence. Which indicates that regression analysis is effective because it indicates the stationarity. Hence variables are cointegrated. Based on the result of equation (8) above and by means of the following equation

$$T_t = \frac{gAt}{gYt} = \alpha_t \frac{gKt}{gYt} - \beta \frac{gLt}{gYt} - \gamma \frac{gEt}{gYt} \quad (11)$$

The technological change is found by using data, which is given in figure 1 below and outcomes are given in table 3.

Figure 1

Technological change economy-wide

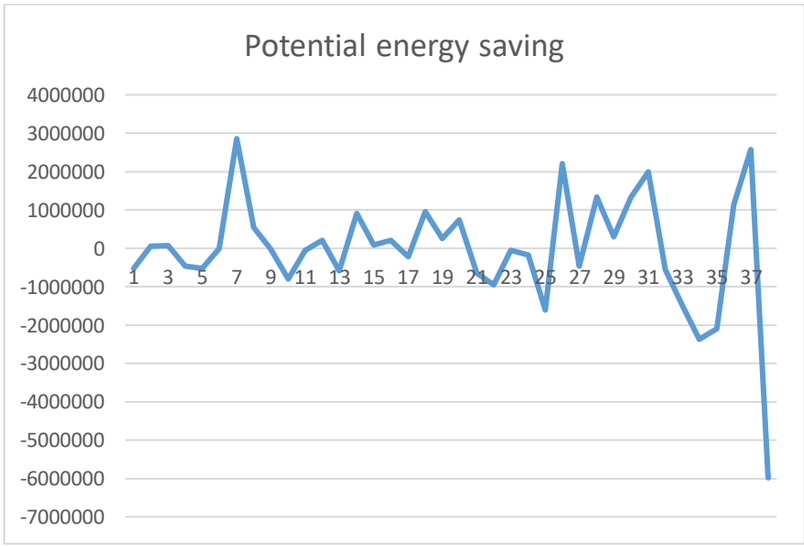


The saving of energy is determined by equation (3) and its consequences are given in figure 2 below and table 3.

$$PE_{t+1} = Y_{t+1}(\Delta EI_t) \quad (3)$$

Figure 2

Potential energy saving economy-wide

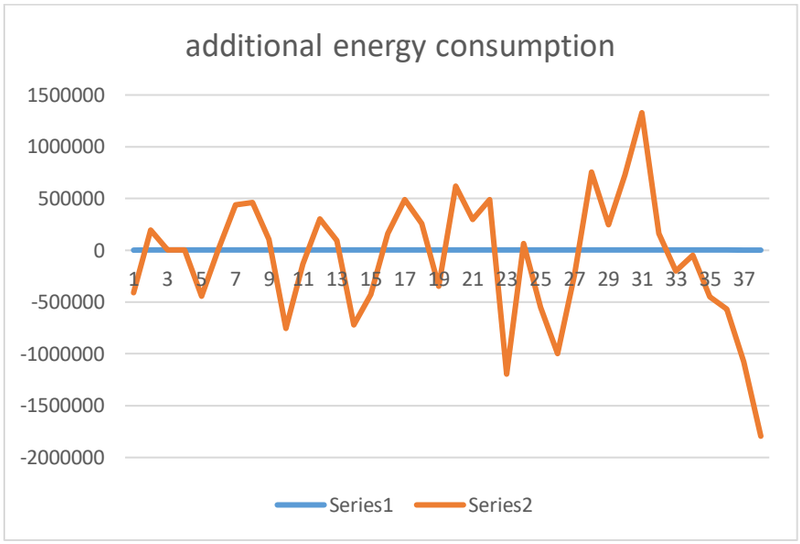


Additional consumption of energy is determined by eq(4) which are given in table 3 and additional energy consumption is given in figure 3 below.

$$QE_{t+1} = T_{t+1}(\Delta Y_t)EI_{t+1} \quad (4)$$

Figure 3

Additional energy consumption economy-wide



Energy rebound effect in Pakistan's economy is determined by eq(5) which are given in table 3 and presented in figure 4 given below.

$$RE_{t+1} = \frac{T_{t+1}(y_{t+1}-y_t)EI_{t+1}}{Y_{t+1}(EI_t-EI_{t+1})} * 100 \quad (5)$$

Figure 4

Energy rebound effect economy-wide

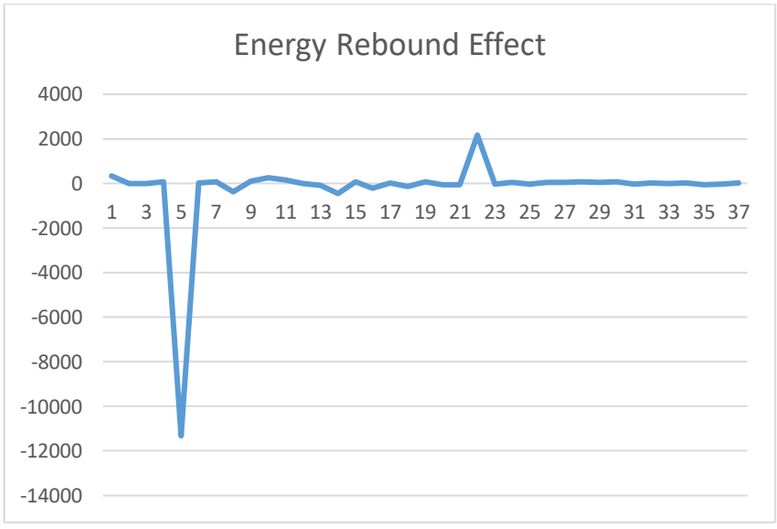


Table 3. Energy rebound effect economy wide

YEARS	TECHNOLOG-ICAL CHANGE RATE	ENERGY INTENSITY Ei=E/Y	ENERGY SAVING	ADDITIONAL ENERGY CONSUMP-TION	REBOUND EFFECT
1984	-0.82958	43.95192	-517189	-412381	79.73503
1985	0.170371	43.77033	58425.66	192202.2	328.9689

1986	0.004276	43.54447	77293.94	3812.067	4.931909
1987	0.000129	44.82635	-464182	114.6504	-0.0247
1988	-0.4155	46.19318	-526799	-447314	84.91175
1989	0.013882	46.19344	-104.924	11883.95	-11326.2
1990	0.601328	39.42392	2860017	439427.6	15.36451
1991	0.558547	38.20026	543479	462151.5	85.03575
1992	0.07867	38.25772	-27452.8	101177.9	-368.552
1993	-1.89494	39.88934	-795874	-757466	95.17412
1994	-0.15407	39.98724	-49841	-131279	263.3955
1995	0.295432	39.59196	211420.3	301424.5	142.5713
1996	0.062792	40.62411	-588486	90034.96	-15.2994
1997	-1.90798	39.05509	909822.9	-723404	-79.5104
1998	-0.54608	38.89989	93138.03	-430371	-462.079
1999	0.166329	38.56292	210682.4	161046	76.44018
2000	0.515311	38.91121	-226272	490049.6	-216.576
2001	0.28991	37.49617	952911.5	258122.8	27.08781
2002	-0.58842	37.13298	250376.9	-348947	-139.369
2003	0.440559	36.12299	735562.2	619025.4	84.15677
2004	0.142646	36.94658	-645981	295460.6	-45.7383
2005	0.216723	38.06858	-946204	486531.1	-51.4193
2006	-0.6703	38.13067	-55273.3	-1199433	2170.006
2007	0.033023	38.32239	-180128	62377.53	-34.6296
2008	-0.29432	39.95645	-1611838	-551131	34.1927
2009	-7.43808	37.72332	2210702	-998393	-45.1618
2010	-0.24269	38.17609	-459783	-236678	51.47596
2011	0.554343	36.91117	1331080	752971.8	56.56849
2012	0.165566	36.63124	305870.7	244861.4	80.05388
2013	0.507106	35.47007	1315517	723881.8	55.02643
2014	0.855494	33.77845	1994158	1327001	66.54445
2015	0.098454	34.22583	-548799	161191.1	-29.3716
2016	-0.1024	35.38361	-1485034	-202825	13.65794
2017	-0.01981	37.13885	-2368854	-49257.7	2.079389
2018	-0.15679	38.61097	-2096715	-452163	21.56528
2019	-0.51016	37.82728	1139381	-570866	-50.1032
2020	4.410975	36.05028	2571448	-1079137	-41.9661
2021	-0.78647	40.02855	-5983853	-1796358	30.02009

Results and Discussions

The estimated results showed that the energy rebound effects does not exist in Pakistan's economy. The energy rebounds effect on average is -244.246%. The energy rebound effect in 80s-decade, 90s-decade 2000's decade and 2010 decade is -1544.62%, -47.94%, 205.06%, and 20.40% respectively as shown in table 3. Related to the former studies on the measurement of very low energy rebound effects averaged around 11% caused by UK policies for energy efficiency for the year 2000–2010, throughout the Britain's economy found by (Barkera, Ekinsb and Foxona 2007). Results in this research indicates that the energy rebound effect for Pakistan's economy is more astonishing than the energy rebound effect for the other countries in the world. As the ongoing condition of Pakistan's economic growth is in general growth stage, the outcomes are rational. The energy rebound effect presented by Liao and Wang is 54.4% on average in China for the years 1994-2017. but in Pakistan the results are surprising where it is -244.246% on average for the years 1984-2021. The energy rebound effect is changing during various time periods. From Table 3, it shows that the technological development effect on saving of energy

and intensity of energy is a vibrant procedure. In 1984,1987-1989,1992-1994, 1996, 2000, 2004-08,2010,2015-18 and 2021 the magnitude of saving of energy was adverse. It is related to the economic growth of Pakistan's economy in various time phases.

In the previous decade i.e. from 2010-2021 the energy rebound effects in Pakistan's economy is 20.40% which support the reliability of the outcome acquired from previous research. The fluctuation of the energy rebound effect in the Pakistan's economy is high in (2000-2009). The average rebound effects for this period are 205.06%. This is caused by high consumption of energy, that causes increase in high economic growth. In the 1990-1999 decade, the rebound effects of Pakistan's economy practiced an intense fall to -47.94% on average. The average energy rebound effect for 1984-1990 is -1544.62%. The negative rebound effect is presenting less consumption of energy in Pakistan. In Pakistan, the rebound effects on average is -244.246%. This is due to the technological improvement, which causes to consume less energy in Pakistan. People shifted to the consumption of renewable energy resources. Most of the houses, buildings and government organizations have installed the utilization of solar energy to save energy. People are using inverter split air conditioner, energy efficient hybrid cars, energy saver bulbs etc. to consume less energy and thus they are saving more that leads to low rebound effect in Pakistan on average.

Sound structural policies and improved economic management accelerated progress between 2000 and 2008. During Pervez Musharraf's tenure from 1999 to 2008, some 11.8 m new jobs were produced and the debt ratio fell from 100% to 55%. Pakistan's foreign exchange reserves improved from $ 1.2 billion US in October and November 1999 to $10.7 billion US on June 30, 2004. Investment rate rose to 23% of gross domestic product, inflation fell and US$14 billion inflow of foreign capital funded several sectors of the economy. The exchange rate was constant during this time period. All income targets were met on time and development allocation improved by approximately 45 %. These improvements, which may be due to debt relief and economic changes, have offered millions of dollars' worth of U.S. Aid in interchange for support of Pakistan in the U.S led war on terrorism that has led to rise in energy consumption in the economy that leads to growth, and the rebound effect is high. This is 205.06% for the decade in the 2000s.

Furthermore, the rebound effects of the Pakistan's economy are higher than 100% in different years i.e. 1985,1994,1995 and 2006. In these years, Pakistan improved its economic development, causing more energy consumption than the energy savings. In 2006, when the economic growth was on peak, there was higher rebound effect. Through the observed outcomes, it is revealed that the rebound effects exist in Pakistan's economy, and in different time periods there is different variations in energy rebound effect. Generally, the energy intensity of Pakistan's economy showing a falling trend. In 1984-89,1996,2021 there was a considerable rise in the energy intensity, but this does not depict that technological improvement cannot diminish the intensity of energy in the Pakistan's economy. There are many years that causes surge in economic development in Pakistan that could be the cause of increase in energy intensity. Due to this cause, the intensity of energy in the Pakistan's economy may increase in some years, causing negative energy savings. As compared with the technologically advanced countries, the rebound effects in Pakistan is slightly small, and the total energy rebound effects is less than 100% in most of years. This shows that the technological growth in Pakistan increase the energy efficiency, and the rebound effects shows an indirectly descending trend.

Conclusion and Recommendations

The results in this research study reveals that the energy rebound effect does not exist in the economy of Pakistan. The rebound effect on average in Pakistan's overall economy is -244.24% for the period 1984–2021, and a fluctuating trend can be obtained during the study period. It is showing that in the 1980s era approximately Rebound effect was negative. Which depicts that people were consuming less energy due to technological improvement. The potential energy conservation by technological improvement is attained in this era. In the next decade of 1990s, again rebound effect was negative and the consumption of energy was low due to technological progress. In the 2000s era rebound effect was very high which shows high energy consumption due to technological progress. Next is the 2010s decade where rebound effect is positive but showing a declining trend. This means that technological progress decrease energy consumption in the last decade. The technical change in Pakistan economy played an important role in energy saving. Furthermore, due to economic and political instability, energy efficiency and technological improvement was not improved in several specific years, causing an increase in energy consumption. On average it is proved that energy rebound effect in Pakistan's economy is -244.24%. which shows that we are consuming less energy because of technological advancement. Hence through this study we came to know that shortage of energy is not due to over utilization of energy in Pakistan. There may be other reasons for energy crises that is energy shortage, demand side management, supply side management, circular debt etc.

There are recommendations for reducing energy rebound effect in Pakistan which are as follows.

1. Promote technological inventions. Technological improvement is essential for improving energy efficiency and decreasing energy intensity, and it is a key component of decreasing the rebound effects. Technological improvement can save energy as well as to tackle climate degradation and save resources. The technological improvement is important for energy saving and CO_2 emission reductions. Hence, depends on Pakistan's domestic circumstances, we should promote technological inventions, industrial upgradation, so as to attain the objective of energy saving and CO_2 emissions reductions while promoting economic growth and development in Pakistan economy.

2. The most important reason of energy consumption rise is low prices of energy, which are opposite to the objective of energy saving and CO_2 production declines. The previous studies exhibit that it is low energy prices that causes increase in energy consumption in China (Zha, Kavuri & Si 2017). As soon as energy prices increases in Pakistan in the current couple of months in 2022 and 2023, energy consumption has been decreased. Pricing of energy structure should be improved from several features, such as market regulations, subsidies adjustments, taxation and so on, instead of simply increasing prices of energy. The useful utilization of resources should be guaranteed. Consider the reform of prices of petrol, for example; in order to support the reform, we should, lift price controls on petrol, advance the trading Pattern, building up an independent and consistent trading policy, and allow the market to play a self-regulatory part in energy production policies. It is challenging for the government to permit reforms when there is shortage of energy. The reforms of pricing of energy in Pakistan should be directed at market determined prices and the policies of energy, except the monitoring functions, should be released gradually.

3. Improve the structure of energy to change and advance the energy consumption pattern. Renewable energy, such as solar and wind, can substitute oil and gas in the future. Though, because of the high costs and

limited technological improvement, it will take some time to extensively substitute nonrenewable energy. Consequently, we should dedicate more resources and time for further research studies of renewable energy, but at present level we should also support the effective consumption of nonrenewable energy without wasting it.

Further research can be conducted, based on several types of energies to estimate the energy rebound effect in different sectors of the economy, so as to give possible procedures for decreasing the rebound effect and improving energy efficiency to save energy and reduce CO_2 production policies. We should provide the chance to Pakistan's economic growth, improve industrial structures, decrease the dependency of economic development on energy, actively cope with the difficulties and challenges, achieve industrial upgradation, , encourage the application of energy saving and CO_2 production policies gradually, rise the fraction of green economy, and decrease energy consumption so as to attain the objective of energy saving; Through these approaches we can accomplish our promises to the world.

Limitations and Future Direction of Research

This research study finds the energy rebound effect in Pakistan's economy. Where aggregate energy consumption was taken that is coal, oil, gas etc. to find the over utilization of energy resources due to technological development. This study also has some limitations like other research studies. This study did not find in which sector of Pakistan's economy, energy rebound effect is high specifically. Proper research is required to know the energy rebound effect in each sector of the economy i.e. agriculture sector, industrial sector and services sector. In this way researchers, policy makers and government would easily implement policies in specific sector if they identify the exact origin and foundation of energy crises in Pakistan.

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