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ENERGY REBOUND EFFECT IN INDUSTRIAL SECTOR OF PAKISTAN

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Abstract

Energy plays an important role in the economic development of a country. Pakistan has made continuous struggles to save energy through technological development, but the energy rebound effect is weakening the impact. Here the question arises, Does technological improvement lead to an energy rebound effect in the industrial sector of Pakistan? The energy rebound effect is the consumption of additional energy due to technological improvement instead of decreasing energy consumption. The objective of this research paper is to find the magnitude of the energy rebound effect in the industrial sector of Pakistan. Data on overall energy consumption, employed labor force, gross fixed capital formation, and real GDP is taken from the period of 1984-2021. A neo-classical growth model is used to estimate the energy rebound effects in Pakistan's industrial sector. Estimated results through regression analysis show that the energy rebound effect on average is -104.388% for Pakistan's industrial sector over the period 1984-2021. This means that there is no overutilization of energy in the industrial sector of Pakistan. The rebound effect over the last ten years, i.e., from 2011 to 2021, is 39.63%. Note that the rebound effect has been present in Pakistan's industrial sector in the past decade only. The trend of energy rebound effects varies significantly over different time phases. The significance of this research paper indicates that technological improvement is essential for saving energy, but we are over-utilizing energy instead of saving energy due to technological improvement as is shown in the last decade only. It is recommended to improve technological progress, the shift from non-renewable resources to renewable resources, energy price mechanisms, and tax adjustments to save energy.

Keywords: *Energy rebound effect, technological improvement, energy efficiency, energy consumption, industrial sector.*

Introduction

Energy has remained the main component and played a critical role in the economic growth of Pakistan's economy. In recent times, the non-renewable energy crisis such as oil, gas, etc. has increased across the world and has affected underdeveloped countries that have scarce resources and need to develop new and renewable energy resources (Tronchin et al. 2018). Pakistan is an underdeveloped country, with scarce resources, and is confronting an acute energy crisis. In 2021, Pakistan's entire energy consumption reached 60208443 TOE (Energy Year Book 2021). Furthermore, the shares of oil and coal utilization are maximum. In the meantime, with the rising population and economy, energy demand is also rising. Consumption of energy has increased which causes a shortage of energy in the economy. Pakistan's economic development is dependent on energy consumption which is a driving force for rapid economic progress. Decreasing energy consumption can lead to lower economic growth. Therefore, solving the conflict between rapid economic development and energy saving has become an important subject matter and area of concern.

Economist Harry Saunders in 1992, acquired the term "Khazzoom Brookes hypothesis" to explain the notion that technological improvements in contrast result in an increase in energy consumption. He demonstrated energy efficiency developments through technological advancement via a multiplicity of growth models of neoclassical and revealed that the hypothesis is correct in different circumstances of energy consumption. Fuel efficiency improvements can intensify the use of energy in binary ways: producing fuel seems more efficiently economical than other inputs and by growing economic development, that consequences in a surge in the consumption of energy. These outcomes, which show the Khazzoom Brookes hypothesis, demand that energy interpreters and policymakers consider the energy rebound effect. This effort contributes a foundation for analytical research and plays a substantial part in describing the trouble of the energy rebound impact. The two main possibilities of the rebound effect are:

Technological improvement causes economic growth which causes an increase in energy consumption. Secondly, technological improvements result in large overall energy savings. In this research we find, does the impact of aggregate energy efficiency improvement caused by technological progress in the industrial sector leads to the energy rebound effect in Pakistan. This is the area of concern that is to be focused on in our research paper.

Research Question

Does aggregate energy efficiency improvement led by technological progress lead to an energy rebound effect in Pakistan's industrial sector?

Objective

To determine the magnitude of aggregate energy efficiency improvement caused by technological progress leads to an energy rebound effect in Pakistan's industrial sector.

Problem Statement

Non-renewable energy resources are being depleted all over the world. The focus of countries all over the world has shifted towards a decrease in energy consumption and increased energy saving. However fast economic growth and changes in the behavior of people have often caused an increase in the consumption of energy. This created great concerns for people to overcome the energy crisis problem. New technologies have been invented to decrease energy consumption but still, we are far away from reaching our desired target. People increase the utilization of energy instead of decreasing energy consumption due to technological progress. In this research study, we find whether there is a decrease in energy consumption or overutilization of energy due to technological improvement in the industrial sector of Pakistan's economy. A lot of studies have found on energy rebound effects all over the world, but no research has been found on the rebound effects in Pakistan's industrial sector.

Significance of the Study

Innovation and technological development have been the major contributors to economic development across the world. The significance of this research paper indicates that technological improvement is essential for saving energy, but we are over utilizing energy instead of saving energy due to technological improvement. In this research study, we will find out whether we are over utilizing energy or we are saving energy due to technological improvement. In this way, we would be able to know the root cause of the energy crises in Pakistan.

Hypothesis

H1: Aggregate energy efficiency improvement caused by technological progress leads to an energy rebound effect in Pakistan's industrial sector.

Research Methodology

In this study, we use the neo-classical growth model to find the rebound effect in Pakistan's industrial sector. The regression technique is used to estimate the energy rebound effect.

Literature Review

Shao, Huang & and Yang (2014) observed the rebound effect in China between 1954–and 2010 applying the latent variable approach. In this study, a different estimation model for the measurement of the energy rebound effects was developed which is based on Brookes' explanation and the IPAT equation. Results of the research study indicate that the energy rebound effect was found in China at an average of 39.73%. The rebound effect in the pre-and post-reforms and opening-up of China's economy in 1978 was 47.24% and 37.32% respectively, characterized by strong variation and a continuously descending trend, which pointed towards the contribution of political stability and market economy in the efficacy of energy saving policies. Yu, Moreno & and Crittenden (2015) examined the regional rebound effect in Georgia, USA by using a (CGE) model, a computation general equilibrium model for the project area. The research found that with the development in economy-wide energy efficiency on the manufacturing level, a moderate economy-wide rebound effect was observed. It further found that though prices of energy slightly decrease, concerning local production and demand, different sectors react to price variation relatively differently. Similarly, improvements in energy efficiency in specific sectors cause different economy-wide effects. The paper concludes that generally, a larger rebound effect is expected in case the central sector is the energy-producing sector, transport sector, or a more production elastic sector.

Siderius & and Poldner (2021) analyze various forms of rebound effects by reviewing the Dutch textile industry being transient to a circular system and suggest suitable reduction plans to ensure the transition. According to the paper, the rebound effect happens when enhancement in energy efficiency due to technological improvements cannot deliver promising results because of behavioral economic instruments. The presence of an energy rebound effect in a Circular Economy may result in environmental gains due to technological improvements. The research shows that there is the least awareness about the energy rebound effects amongst the main stakeholders, and it identifies rebound effects in the Dutch textile industry. Bentzen, J. et al (2004) estimated the energy rebound effects in the US manufacturing sector and stated that the energy price shocks during the 1970s have generally led to the search for energy-efficient technologies if ultimate gains in energy saving will result in reduced per unit energy price. This will help in raising energy consumption and counter the initial decrease in sources of energy. Using the dynamic ordinary least squares method (DOLS) on time series data, rebound effect in the US production sector and while permitting irregular price effects the rebound effect resulted around 24% for the industrial sector in the US. Li, Zhang, and Liu (2016) analyzed the energy rebound effects in the industrial sector of China adopting an Output Distance Function approach. The results based on the analysis of 36 industrial sectors during the years 1998 to 2011 found the total energy rebound effect as 88.42%, which indicates mitigation of the probable energy saving.

The research found that the equipment in high-tech industrial sectors has a lesser rebound effect which can help in energy savings if such firms are encouraged. The paper recommends that the magnitude of rebound effects permit different strategies for energy savings in the industrial sectors of China. Wei et al. (2020) evaluated the energy rebound effects of coal-intensive industries in China. The LMDI decomposition approach was applied to examine the factors that affect the consumption of coal in these industries. The findings of the study indicate that total industrial production and structural modifications had speeded up coal consumption, whereas, on the other hand, energy intensity reduced coal consumption. Additionally, technological progress improved the rate of industrial growth. It was also revealed that the rebound effect exists in coal energy-intensive industries which amount to 35.07% in the year 2016, showing a growing trend from 1990 to 2016. The paper asserts that this study will assist the decision-makers in designing policies for coal conservation and the reduction of carbon emissions.

Li, and Xiaoyan (2020) conducted a research study on the energy rebound effect of the industrial sector in China, based on evidence from three typical industries. The study identified the potential strategy for 2018 to 2025 and subsequently designed the implementation plan for major industries like petroleum and gas, construction, and transport. The outcomes of the research show that the rebound effect in the short term was estimated as 17.5%, 18.2%, and 13.4%, respectively for the above industries. Similarly, the cumulative reduction in carbon emission was 18.2%, 14.8%, and 16.9%, respectively. However, the energy rebound effect in the long term, the collective energy saving was estimated as 21.3%, 22.3%, and 18.5%, respectively and the aggregate carbon emission reduction was found as 19.7%, 18.1%, and 23.7%, respectively. It was also found that the short-term rebound effect was larger as compared to the long-run effect.

Li and Yonglei (2012) studied the rebound effect from different industrial perspectives in China. The paper used panel data from three industries and measured the rebound effect. The outcomes of the research indicate that energy efficiency is the key factor of the rebound effect. Moreover, the small rebound effect of the secondary industry reveals its response to variations in energy efficiency. The researcher believes that it is caused by the increase in investment in elementary industries and the relaxation of the constraint over high energy usage enterprises. The paper concludes that the comparatively higher figure of rebound effect in China should be considered by policymakers. Zhang (2019) studied that technological improvement causes an energy rebound effect in the industrial sector and stated that China has been confronting the dual issues of economic development as well as environmental safeguards. The paper used the data from 1997 to 2017 using the LMDI decomposition method and examined the rebound effects in China. The paper examined the rebound effects from 3.67% to 134.18% in China, averaging 34.86%. The effect of technical development on energy efficiency is a vigorous practice and the magnitude of the rebound effects is found to change over time.

Methodology For Calculating the Energy Rebound Effect in The Industrial Sector Of Pakistan:

Different methods have been used in previous studies to find the energy rebound effect so far such as the computational general equilibrium model, 2SLS model, etc. but we are considering the neo-classical growth model to find the energy rebound effect in the industrial sector of Pakistan due to availability of data. The model of the research study has used three input elements i.e., labor, capital, and energy used in the Cob-Douglas productions function and Solow residual model to estimate the technological variation in the energy sector in Pakistan.

Economic growth, in neoclassical economics, is normally explained as growth in the output (Y) as a function of capital (K) and labor (L):

$$Y_t = F(k_t, L_t) \quad \textbf{(1)}$$

In Eq(1) t is the period.

Energy in this research is taken as an important component along with labor and capital to produce total output. Taking the Cob-Douglas productions function as below:

$$Y_t = A_t F(k_t, L_t, E_t) \quad \textbf{(2)}$$

In Eq (2) Yt shows the contribution to the increase in total output in t year. Kt represents the stock of capital and Lt Labor input in t year. It denotes energy utilization in the year. A denotes Hick's neutral technological parameter, which is explained as $A_t = Aoe^{rt}$. Resultantly, the model including all three factors i.e. capital, labor, and energy given in the neo-classical production functions can be as below:

$$Yt = Aoe^{rt} K_t^{\alpha} L_t^{\beta} E_t^{\gamma} \quad \textbf{(3)}$$

Taking the logarithm of Eq (3) we get below:

$$\ln Yt = \ln A_o + \alpha \ln Kt + \beta \ln Lt + \gamma \ln Et \quad \textbf{(4)}$$

Where *α*, *β, and γ* are the output elasticity of labor, capital, and energy.

The output Growth rate in labor, capital, and total energy utilization in Pakistan is represented by the variables gY_t, gK_t, gL_t, and gE_t. Hence the equation can be as follows:

$$gY_t = \alpha\, gK_t + \beta\, gL_t + \gamma\, gE_t + gA_t \quad \textbf{(5)}$$

In Eq (5) gA_t is the Solow residual, which denotes the role of technological variation in t year. Resultantly, the rate of technical change in output in year t can be as below:

$$T_t = \frac{gAt}{gYt} = \alpha_t \frac{gKt}{gYt} - \beta \frac{gLt}{gYt} - \gamma \frac{gEt}{gYt} \quad \textbf{(6)}$$

In the equation, T_{t+1} represents the impact of technological progress in t + 1 year.

Based on Eq (3) to Eq (6) and through related data, we find the existence of rebound effects in Pakistan. After finding technological progress in eq (6) we use it in eq (9) to find the additional energy consumption.

Change in energy consumption as an outcome of technological improvement, which is used as a measure of the energy rebound effect. Rebound effects evaluation is the Potential Energy Savings (XE) as a result of technological development and the Additional Energy Consumption (QE) as an outcome of output growth because of technological development (energy efficiency improvement) will be performed. Resultantly, the Energy Rebound Effect will be defined as below:

$$RE = \frac{Additional\ energy\ consumption\ (QE)}{Energy\ saving\ (XE)} \times 100\ \% \quad \textbf{(7)}$$

With the development in the efficiency of energy, the intensity of energy decreases($IE_t - IE_{t+1} = \Delta IEt$), and the potential energy saving (XE) in year t + 1 will be as below:

$$XE_{t+1} = \Delta IEt \times Y_{t+1} \quad \textbf{(8)}$$

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

$$QE_{t+1} = IE_{t+1} \times T_{t+1} \times \Delta Yt \quad \textbf{(9)}$$

The best tool to find Energy efficiency is energy intensity. Energy intensity can be measured by finding the consumption of energy per GDP if there is a light change in the energy input structure. Below is the correlation between energy consumption and GDP:

$$IE_t = E_t / Y_t \quad \textbf{(10)}$$

IE_t is the consumption of energy per GDP, Y_t

represents output in t year and E_t shows total energy consumption in t year.

Similarly, the calculation of energy rebound impact in t + 1 year is given below:

$$RE_{t+1} = \frac{QE_{t+1}}{XE_{t+1}} * 100 \quad \textbf{(11)}$$

$$RE_{t+1} = \frac{T_{t+1}(\Delta y_t)IE_{t+1}}{Y_{t+1}(\Delta IE_t)} * 100$$

This equation denotes that the tool to measure the energy rebound effects is to correctly find the impact of technological advancement in Pakistan.

Data for the period 1984 to 2021 is used to estimate output growth rate, labor, capital, and energy, and the contribution of the technological improvement in output is acquired by the growth rate and the consequences of regression in the shape of output elasticity of every input factor, into Eq (6). As a result of technological advancement, the surge in energy saving and energy consumption can be estimated by Eq (8) and (9), respectively. In conclusion, the Energy Rebound Effects of technical advancement can be acquired through Eq (11).

Data Description

Given the importance of the energy sector in Pakistan and the accessibility of data, the data sample was used from the period 1984–2021.

Output Y:

Data on the gross domestic product (real GDP) of Pakistan's industrial sector is available on different base years i.e., 1980 base year and 2000 base year. The different bases are converted into a single base year i.e., convert the 2000 base year into the 1980 base year. For a single year 2000, two values of real GDP are available on the 1980 base and 2000 base. Divide these two values and multiply the resulting value by the values from 2000-2021. The values from 1984-2000 are already on the 1980 base year. This data is available in the Pakistan Bureau of Statistics from year 1984-2021.

Labor input L:

Data on the Employed labor force in the industrial sector is available in the Pakistan Bureau of Statistics from the years 1984 to 2021. Energy input E: This data contains overall total energy consumption in the industrial sector. i.e., coal, oil, and gas in the industrial sector of Pakistan's economy, etc. Data on aggregate energy consumption in the industrial sector of Pakistan's economy is available in Pakistan energy yearbooks for the period 1984-2021.

Capital stock K:

The capital contains buildings and infrastructure such as rail networks and automobiles etc used in the production process. The capital stock is an autonomous variable in the Cobb- Douglas production functions. As the capital stock data is not accessible, it is measured as follows. Data on GFCF in the industrial sector of Pakistan is available in the Pakistan Bureau of Statistics yearbook for the years 1984-2021. Capital stock Kt is created by the (PIM) Perpetual inventory method. (Alvi & Ahmed 2014). The method is as follows:

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

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

The capital stock is Ko, GFKFo is the initial level of GFCF, and δ is the depreciation rate, presumed to be 5 % per annum. gGFCF is the average growth rate of GFCF. To estimate the data for the remaining years, we used the procedure given by the following equation. It is a capital stock in the current year, K_{t-1} is the previous year's capital stock, GFCFt is the Real Gross Fixed Capital Formation and δ is the rate of depreciation, as specified previously.

Analysis and Estimation of Rebound Effect in the Industrial Sector

Stationary of Data

Using the Augmented-Dickey Fuller (ADF) test, the logarithms of all variables were tested. At level form all the variables are non-stationary. The first difference in the data is tested by the augmented Dickey fuller test. As expected, the variables are stationary at first difference. The stationary results of the variables are as follows.

Table 1 Stationary of variables.

Variables	ADF Statistics (I)	5% Critical Value	ADF Statistics I(0)	5% Critical Value	Stationarity
ΔlnGDPi	-5.386195	-3.533083	-2.745668	-2.938987	I(1)
ΔlnEi	-4.483107	-3.533083	-0.251948	-2.938987	I(1)
ΔlnLi	-8.864736	-3.533083	0.484326	-2.938987	I(1)
ΔlnKti	-2.559530	-1.949856	-2.378823	-2.941145	I(1)

The outcomes of the unit root test, presented in the above table 1 show that all these variables are stationary at first difference and hence it may be determined that all the series are integrated of order 1. The result indicates the chances of a long-term association between the variables. Here OLS is applicable only to find the elasticity of variables if the residual from such regression is stationary and statistically significant. To confirm this indication, the OLS method is applied and reported in Table 2. Ordinary Least Square (OLS) methodology has been adopted to test the relationship between mentioned variables as follows:

$$\ln Yi_t = \ln A_o + rt + \alpha \ln Ki_t + \theta \ln Li_t + \gamma \ln Ei_t \quad \textbf{(4)}$$

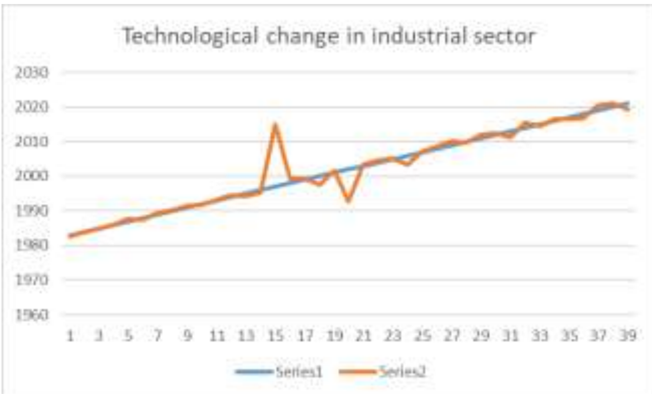
$$\ln Yi_t = 0.17+0.47\ln Ki_t+0.64\ln Li_t+0.28\ln Ei_t$$

As an outcome of regression, the labor β elasticity to total production is 0.64, the capital elasticity α to the total production is 0.47, and the total energy elasticity γ to total production is 0.28. This shows that for every additional 0.64, 0.47, and 0.28 percentage points of labor, capital, and energy input respectively, Pakistan's industrial sector output increases by 1 percent. If the sum of β, α, and γ is greater than 1, the output has an increasing return to scale. On the other hand, the elasticity of labor in Pakistan's industrial sector (0.6462) is higher than energy (0.2810) and capital (0.4725), indicating that the development of Pakistan's industrial sector depends on labor-led development. It means that the Commitment to work is the main motivating force. As a labor-concentrated economy, Pakistan's plentiful labor force is a positive force for the growth of Pakistan's industrial sector, so investors are sure to ignore investments in technological transformation. Many investors are not increasing their investments in technological development. Technological development is an important factor in Pakistan's economic growth and investors should be more concerned about it. Through rising investment in technological development, accelerating technological development, and encouraging new technologies and new materials can the industrial sector develop from a labor-concentrated sector to a technology-concentrated sector? ADF stats of residuals of the above regression is -3.563 at 5% degree of confidence. This shows that regression is still valid because it shows that it is stationary. So, variables are counteracted.

Depending on the above-measured outcomes of Equations (4) and using

$$T_t = \frac{gAt}{gYit} = \alpha_t \frac{gKit}{gYit} - \beta \frac{gLit}{gYit} - \gamma \frac{gEit}{gYit} \quad \textbf{(6)}$$

By using relevant statistical data, we find the technological change which is given in Table 2 and shown in Figure 1 below. We find the technological change in the industrial sector of Pakistan through eq (6). The results of technological change are given in Table 2. Technological change is required in eq 9 to find the additional energy consumption. The graph of technological improvement shows an upward trend in Pakistan. which is showing



technological improvement with time.

Figure 1 Technological change in the industrial sector

We determine the potential energy saving through eq (8) of the model and its results are given in Table 2 and shown in Figure 2 below. The graph given below shows an irregular trend of energy saving in Pakistan due to behavioral change and technological improvement. In some years energy saving is positive while in other years energy saving is negative due to technological change as shown in Figure 2 given below.

$$XEi_{t+1} = Yi_{t+1}(EIi_t - EIi_{t+1}) \quad \textbf{(8)}$$

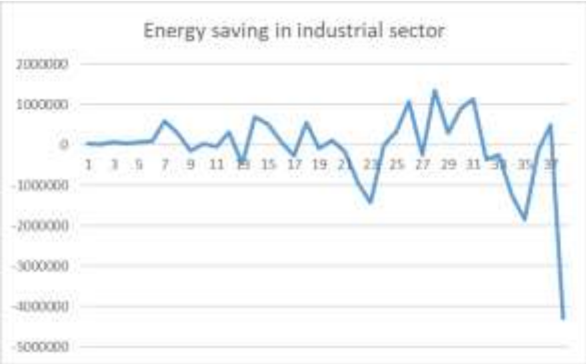


Figure 2 Energy saving in the industrial sector

We also calculated additional energy consumption through eq (9) of the model which is given in Table 2 and shown in figure 3 below. The additional energy consumption due to technological improvement is also showing irregular trends in the industrial sector of Pakistan. In some years, the additional energy consumption is positive while in other years it is negative as shown in Figure 3 given below.

$$QEi_{t+1} = T_{t+1}(Yi_{t+1} - Yi_t)EIi_{t+1} \quad \textbf{(9)}$$

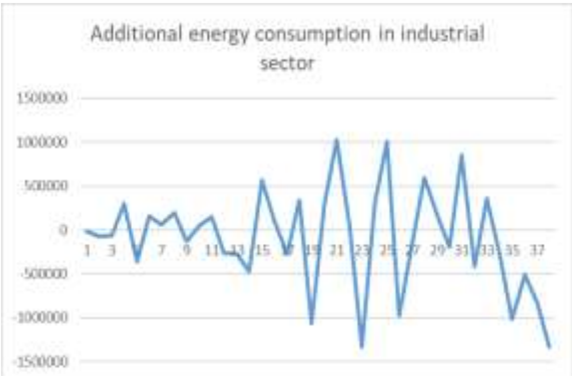


Figure 3 Additional consumption of energy in the industrial sector

In the end, we have calculated the rebound effect of the Pakistan industrial sector through eq (11) of the model which is given in Table 2 and shown in figure 4 below. The energy rebound effect is also showing an irregular trend in Pakistan. In some years the energy rebound effect is positive while in other years, the energy rebound effect is negative as shown in Figure 4 given below. We calculated the average of this trend which gives the result -104.38% energy rebound effect in the industrial sector of Pakistan.

$$REi_{t+1} = \frac{T_{t+1}(yi_{t+1} - yi_t)EIi_{t+1}}{Yi_{t+1}(EIi_t - EIi_{t+1})} * 100 \quad \textbf{(11)}$$

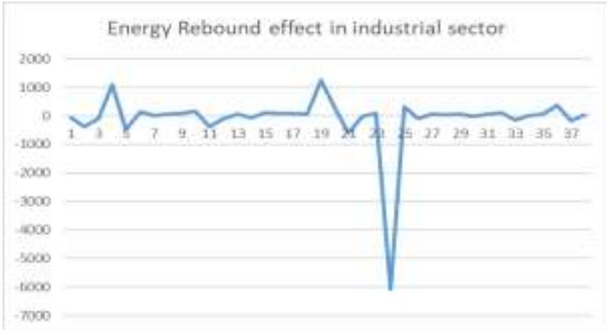


Figure 4. Energy rebound effect in the industrial sector

YEARS	TECHNOLOGICAL CHANGE RATE = T	ENERGY INTENSITY Ei=E/Y	ENERGY SAVING =XE	ADDITIONAL ENERGY CONSUMPTION = QE	REBOUND EFFECT = RE
1984	-0.058170001	69.39950924	34946.82701	-18557.94883	-53.1033870
1985	-0.194882692	69.14305295	19271.92095	-73558.84755	-381.689234
1986	-0.145107472	68.22568136	74521.7633	-60261.64192	-80.8644874
1987	0.624971563	67.91644855	27291.96023	298097.1974	1092.252792
1988	-0.615409225	67.15507867	73795.77606	-358229.8464	-485.434079
1989	0.515862898	66.13007601	103969.0946	153786.1495	147.9152531
1990	0.165407985	60.64593581	592040.3557	65424.2822	11.05064571
1991	0.620318903	58.2510705	271812.4222	200292.0931	73.6876157
1992	-0.268026607	59.50678309	-152727.298	-129636.7329	84.88117956
1993	0.149179765	59.24353769	33586.42721	52674.1048	156.8315215
1994	0.502659531	59.54885658	-40467.2707	148317.0256	-366.511066
1995	-0.830275638	57.2187826	321624.7715	-260862.9204	-81.1078447
1996	-0.698209434	60.45872766	-468340.537	-275227.8083	58.76659958
1997	18.04939443	55.6996155	685702.398	-472511.8349	-68.9091705
1998	1.223604939	52.32982543	515217.3121	564177.4303	109.5028092
1999	0.271270754	51.68209728	103906.6066	105485.2873	101.5193266
2000	-2.480834027	53.29391778	-261851.521	-269715.2639	103.0031303
2001	0.716243788	50.04964629	557668.7352	338272.3524	60.65829606
2002	-9.121848646	50.53779003	-85037.2377	-1065808.936	1253.343786
2003	0.49090961	49.97326215	105208.3633	298310.9258	283.5429773
2004	0.625347378	50.73790019	-167260.447	1027359.484	-614.227392
2005	0.055732485	54.76762713	-938860.146	43462.08503	-4.62923952
2006	-2.596973134	60.69623903	-1431390.38	-1332594.86	93.09793263
2007	0.263462265	60.71513733	-4915.46000	298536.0049	-6073.40929
2008	0.768856309	59.56058999	325741.6224	1009164.314	309.8051475
2009	1.201911339	55.50874893	1083654.315	-980104.4338	-90.4443806

Discussions

The observed outcomes show that the rebound effect is negative in Pakistan's industrial sector. The average rebound effect is -104.388% from 1984-2021. Which is opposite to other studies in the literature. Energy rebound effect in 1980s, 1990s, 2000s and 2010s decade is 35.73%, 17.16%, -472.01% and 39.63% respectively. Observed outcomes in this sector show that the rebound effects for Pakistan's industrial sector are very low as compared to the rebound effect of other countries in the world. The energy rebound effect is 24% for the industrial sector in the US Bentzen, J. et al (2004). Pakistan's industrial growth is still in the beginning of its growing phases, but the outcome is rational. Moreover, the average rebound effect measured in China's aggregate industry was 34.85% during the period 1997–2017 Zhang (2019).

The rebound effect is also shown to change during diverse periods in Pakistan. From Table 5.6, it is revealed that the effect of technological improvement on energy intensity and energy savings is a vibrant process. In 1992, 1994 1996,2000 2002, 2004-07,2010, 2015-19 2020, and 2021, the value of energy savings is negative. This is associated with the growth background of Pakistan's industrial sector in diverse periods. For the last ten years i.e., from 2010-2021, the average rebound effect of Pakistan's industrial sector is 39.63%. Energy consumption increased in this decade. New industries have been created that cause an increase in energy consumption and thus promote economic growth. The variation of the rebound effects in Pakistan's economy (2000-2009) is low. The rebound effect for this decade is -472.01%. This is due to low energy consumption in the industrial sector. From 1990-2000, the energy rebound effect of Pakistan's industrial sector experienced 17.16% on average this decade. The energy rebound effect for the 1984-1990 decade is 35.73%. The high rebound effect is showing high energy consumption in Pakistan's industrial sector. The average rebound effect in Pakistan's industrial sector is -104.388%, but it is showing an inclining trend. Thus, the additional energy consumption in the industrial sector is very low in Pakistan.

Conclusion

Technological improvement can conserve energy by decreasing the consumption of energy, but the energy rebound effect causes an increase in energy consumption. Technical inventions are essential for economic development, and technological progress causes energy efficiency developments, which is a significant policy means for attaining the objectives of energy saving. However, the energy rebound effect has reduced the impacts of this policy. The average rebound effect in the industrial sector of Pakistan is -104.38%. Hence it is proving in the industrial sector that there is no overutilization of energy due to technological improvement in Pakistan's economy. There may be other reasons for the shortage of energy in Pakistan i.e., shortage of supply of energy, increase in population, high economic growth, mismanagement of energy use, etc. This study helps us to focus on energy where its use is high and thus proper energy consumption structure is required to be built. Proper tax structure, proper import, and proper market mechanism are required for energy consumption in Pakistan.

Recommendations

Given below are some recommendations for decreasing the rebound effect of energy in the industrial sector of Pakistan's economy.

- New inventions can promote energy savings.
- Technological improvement is important which causes energy efficiency and can benefit saving energy as well as tackling climate change and saving resources.
- Shift from non-renewable resources to renewable resources to save energy.

- The Pricing mechanism of energy and taxation should be improved.

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