HABIB UNIVERSITY
SCIENTIFIC METHODS
SEMESTER PROJECT FALL 2021

The Potential of Increasing Renewable Energy Production And Subsequent Impact on GDP and Employment in Pakistan

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December 17, 2021

1 Introduction

Pakistan's energy deficit is a considerable struggle faced by the country's industry and population on a daily basis. About 50 million people—nearly half of the population in Pakistan's rural areas—has no electricity, and blackouts of up to 10 hours were rampant in urban areas until two years ago. The availability and reliability of electricity is rated among the worst in the world according to the World Economic Forum's 2019 Global Competitiveness Report[1]. In addition, importing fossil fuels in order to meet energy demands makes up a significant number of the country's imports. According to the World Bank, oil imports account for nearly 29 percent of all imports[1]. However, Pakistan has rich geographical diversity that can be used to produce various forms of renewable energy, such as solar energy and biogas, which can be used to increase overall energy production sustainably as compared to non-renewable sources and thus promote economic growth. Therefore, the primary aim of this study is to determine the feasibility of increasing energy production through renewable means and analysing the subsequent impact on the economy of Pakistan in terms of its GDP and employment rates. The research question this study focuses on is as follows: **How would increasing RE (renewable energy) practices in Pakistan impact its economy in terms of its GDP and employment?**

The independent variable of the study is the use of renewable energy resources available in Pakistan to generate energy. The dependent variable is the amount of energy produced by these resources and their impact on the GDP and employment of Pakistan. The renewable energy parameters in this study will be limited to solar energy, hydropower, and biogas. Moreover, analysis will be drawn using data of countries that have implemented/are implementing renewable energy production methods, primarily Germany, China, and Nepal and the time period under consideration in this study is from 1991 to 2020. We hypothesize that increasing the implementation of REPG (renewable energy power generation) will lead to economic growth due to an increase in both the GDP and employment rates of Pakistan.

2 Literature Review

2.1 Current Energy Production and Consumption in Pakistan

There is little to no research on the relationship between energy consumption and economic growth focused on Pakistan. Electric power consumption per capita of Pakistan has increased from 107.3 kWh/capita in 1974 to 447.5 kWh/capita in 2014, which translates to 340.2 kWh/capita increase over the span of 40 years and still increasing[2]. One factor is that Pakistan is still a developing country, and when compared to developed countries such as the USA (12,993.9 kWh/capita)[3], UK (5,130.4 kWh/capita)[4] and France (6,939.9 kWh/capita)[5] at the same time, Pakistan's electric power consumption is negligible. Another example is of Pakistan's neighbor China. In China's case, we see a huge increase in electric power consumption from early 2000's when it stepped towards modernization and started to open up to the world. Electric power consumption per capita went from 992.9 kWh/capita in 2000 to 3,927 kWh/capita in 2014[6]. During the same time period, the GDP of China went from 1.2 Trillion USD to 10.4 Trillion USD[7]. We can see here a co-relation between power consumption and economic growth. Currently, Pakistan generates around 134,745.70 GWh of electrical power (FY 2019-20) in which 34% comes from renewable energy, 5% from Nuclear energy and the remaining 61% from non-renewable and non-sustainable resources[8].

2.2 Renewable Energy Potential in Pakistan

Pakistan is currently producing energy through renewable means including hydropower, solar energy, wind, and biogas. As of 2021, 27.02% of Pakistan's total energy production came from hydroelectric sources, which amounts to 38,800.54 GWh[8]. However, only 3.25% of total energy production comes from wind, solar and biogas[8]. Studies conducted by The World Bank[9] have determined that this number can be increased by looking at the natural resources Pakistan has for increasing REPG. The study looked into the potential of increas-

ing solar power generation by determining viable land for solar power plants. Looking at the total land of Pakistan and the average sunlight and temperatures, it calculated that even if just 0.071 percent of the country's area was used for solar PV (photovoltaic) panels, the generated energy would meet Pakistan's current electricity demand[10]. The same study looked at viable wind corridors in the country that had average wind speeds of 7.87 m/s in 10% of the windiest areas, according to the Global Wind Atlas[11] and concluded that these can be used to increase energy generation from wind in the country. Another study concluded that biogas production in Pakistan can be increased by considering the amount of poultry waste generated by major poultry farms in the country and approximated that 280 MWh energy can be generated per day[12]. Moreover, in addition to Pakistan's abundant natural resources for REPG, its existing grid infrastructure and substations have enough spare capacity to support increased energy production and support the government of Pakistan's target of raising solar and wind production to 20% of total capacity by 2025[9]. Thus, these studies show that not only is it possible for Pakistan to increase REPG due to existing natural resources like sunlight, land and wind, but also implement them without the need for immediate updates to the country's energy grid, making it economically viable as well.

2.3 Impact of REPG

2.3.1 GDP

Taichen Chiena and Jin-LiHu[13] (2008) published their research on the effects of renewable resources on the GDP of 116 countries using Structural Equation Modelling. Their result indicated a positive overall contribution of deployment of renewable resources as there is no import factor burdening the GDP. Pakistan currently imports oil and natural gas for electricity production, spending more than 20% of foreign exchange earnings[14]. An analysis conducted for 2005-2050 using MARKet ALlocation (MARKAL) in Pakistan indicated that by using renewable energy resources, energy import dependency would reduce by 3%[15]. The two main ways the implementation of renewable resources impacts GDP is that it lowers the cost of imports of non-renewable resources and promotes the limitless production of energy. An analysis will be made on the impact on GDP after eliminating the cost used to maintain renewable resources.

2.3.2 Employment

The literature analyzing the impact of REPG on the employment rate is limited. A study conducted by Lambert and Simba[16] analyzed the previous studies conducted in this area. It concluded that various factors such as job quality and skills, model assumptions and sources of information play a vital role in determining a relationship between REPG and employment rate. However, they also concluded that no prominent directional correlation had been found between these two variables. But the promotion can impact job scales nationally or internationally. Moreover, most of the literature is country-specific, such as Indonesia, Morroco[17], China[18], and Germany[19]. Hancheng Dai et al[18]. presented a projection of China's economy and employment due to REPG till 2050. They stated that if REPG increases to 56% by 2050, it will create 4.12 million jobs. There is no clear trend being presented by any of the states indicating a relationship between REPG and employment. This study would primarily focus on this relationship.

3 Methodology

In order to test our hypothesis, we used the following data-sets from The World Bank:

- Renewable electricity output (% of total energy output)[20]
- Electricity produced from oil, gas and coal sources (% of total)[21]
- GDP per capita (current US$)[7]
- Unemployment, total (% of total labor force)(modeled ILO)[22]
- Employment in industry (% of total employment)(modeled ILO)[23]

These were used to determine if a relationship exists between REPG and GDP, as well as REPG and employment, and if they can be modelled using linear regression as the model may then be used to predict the impact of increased REPG in Pakistan. The existing data sets were fine-tuned for 2014 before being used for cross-sectional analysis i.e. entries were removed for countries for which data was unavailable or contained data for groups of countries such as the European Union. After removing such entries, the 102 countries listed in Table 3.1 were used in the data analysis.
Moreover, we conducted case studies for Nepal, Germany, and China over 29 years (1991 - 2020) to determine a trend in REPG and economic indicators, including GDP and employment over time. These countries were chosen as they produce a significant portion of their energy using renewable means and belong to different income groups. The time period was chosen based on the availability of data.

Table 3.1: Countries part of cross-sectional data analysis

Countries	
Albania	Algeria
Angola	Argentina
Armenia	Australia
Austria	Azerbaijan
Belarus	Belgium
Bolivia	Bosnia and Herzegovina
Brazil	Brunei Darussalam
Bulgaria	Cambodia
Cameroon	Canada
Chile	China
Colombia	Costa Rica
Croatia	Cuba
Cyprus	Czech Republic
Denmark	Dominican Republic
Ecuador	Egypt, Arab Rep.
El Salvador	Estonia
Finland	France
Georgia	Germany
Greece	Guatemala
Honduras	Hungary
Iceland	Indonesia
Iran, Islamic Rep.	Iraq
Ireland	Israel
Italy	Jamaica
Japan	Jordan
Kazakhstan	Korea, Rep.
Kyrgyz Republic	Latvia
Lithuania	Luxembourg
Malaysia	Malta
Mauritius	Mexico
Moldova	Mongolia
Montenegro	Morocco
Namibia	Netherlands
New Zealand	Nicaragua
Niger	Nigeria
North Macedonia	Norway
Pakistan	Panama
Paraguay	Peru
Philippines	Poland
Portugal	Romania
Russian Federation	Saudi Arabia
Serbia	Singapore
Slovak Republic	Slovenia
South Africa	Spain
Sri Lanka Suriname	Sweden
Switzerland	Tanzania
Thailand	Turkey
Ukraine	United Kingdom
United States	Uruguay
Uzbekistan	Vietnam
Zimbabwe	

4 Results and Discussion

4.1 Factors affecting REPG

Pakistan aims to fulfil 10% of its energy requirements through renewable sources but has failed to achieve this objective (Renewable energy technologies in Pakistan: prospects and challenges). Below are the factors essential for Renewable Energy Power Generation.

4.1.1 Factor endowment and government policies

Pakistan currently lack the skilled labour required to operate renewable sources. For instance, Pakistan imports the mechanics of wind turbines from abroad, which takes a toll on its trade balance and import expenditure (Renewable energy technologies in Pakistan: prospects and challenges). Resorting to imports also reflects that the Pakistan government has spent less on labour training and improvements in technology; therefore, factor endowment for renewable sources is low in Pakistan. On the other hand, the establishment of dams such as the Kalabagh dam indicates the shift n mindset regard-

ing renewable energy sources. Indeed, some regions of Pakistan receive extensive rains, which are suitable for producing hydroelectric power. Such initiatives can enable Pakistan to resolve its energy crisis and boost its economy.

4.1.2 Economic benefits of REPG projects

Shift to renewable energy sources builds Pakistan's image as an eco-friendly nation that cares about environmental protection. Recently, the PM of Pakistan commenced a tree-planting campaign therein; 1 million trees were planted in Pakistan. Pakistan's efforts to revive climate awareness were acknowledged worldwide, and a healthy precedent was set for other countries to follow[pakistan] . Despite the recent positives, limited efforts have been made to operationalize all renewable energy sources, demanding policymakers' attention. It needs to be realized that the ecofriendly image of Pakistan can increase tourism and foreign direct investment in Pakistan, which will benefit the entire economy. Furthermore, accepting environmental responsibility can uplift Pakistan's status in international politics and make it a more prominent and respectable country on the international front.

4.1.3 Environmental prospects

Shift to renewable energy sources can provide environmental benefits to Pakistan. Lahore is an industrial city with factories that emit fumes that cause the degradation of the environment and are hazardous for people's health. Lahore currently ranks high in smoggy air, and the government needs to change production methods to save its environment and its people[samaa] . Renewable energy sources are the most viable and effective solution to the current depredatory factory practices, making people vulnerable to different diseases and environments to destruction and decline.

4.1.4 Research and Development

To develop and benefit from its renewable energy sources, Pakistan needs to spend more on its Research and Development sector[24]. The current spending is less than 1%, which exceeds the total requirement[24]. The idea should be to develop techniques that allow the complete utilization of renewable resources and shorten the duration required for the renewing process. This investment will make energy production faster in Pakistan and help tackle today's energy crisis.

4.2 Analysis

As of 2015, Pakistan was producing 31.4% of its electricity through renewable means[20], and 68.1% was produced primarily using fossil fuels such as coal, oil and gas[21]. However, Pakistan has often had to import fuel in order to meet energy demands, and fuel imports accounted for 22.9% of total imports in 2015, a number that only decreased to 22.5% by 2020[25]. A possible solution to cater to the energy deficit is producing energy by renewable means, the potential of which was explored in the literature review. However, it is worth mentioning that while Pakistan may have the physical resources to increase its REPG, there are many other factors that currently hinder it, including a lack of skilled labor to operate resources, government policies to support RE projects, as well as research and development[24].

4.3 Effect of REPG on GDP and Employment

4.3.1 Cross-Sectional Data Analysis (2014)

We used linear regression on data for the GDP per capita against the percentage of renewable energy produced compared to the total energy generated by a country. Figure 4.1 displays the result, and the value of R^2 calculated tells us that the renewable electricity output affects the GDP per capita by 0.3%. Since this number is not large enough for us to determine the direct effect of REPG on GDP, we decided to determine the effect of REPG on other variables that, in turn, have a more significant impact on the GDP of a country.

According to Investopedia, the most significant contribution to the GDP of a country is through consumer spending[26]. This comes from a higher buying power of

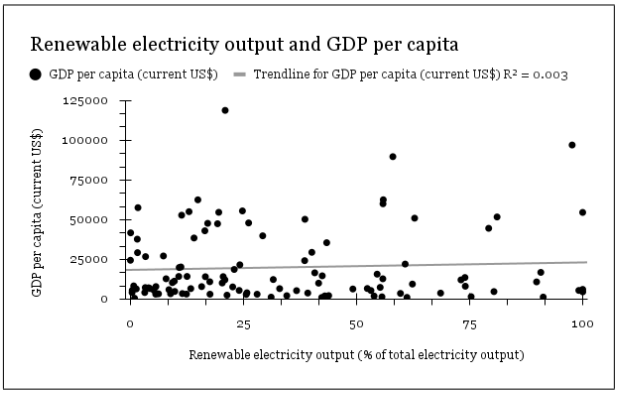

Figure 4.1: Renewable Energy Output (% of total energy output)[20] and GDP per capita[7] of 102 countries

individuals in an economy, which in turn stems from a high employment rate. In other words, the impact of REPG on the employment rates of a country may give an insight into its impact on the GDP.

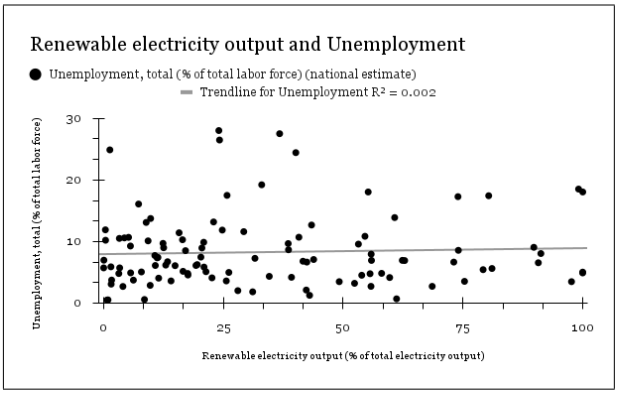

Figure 4.2: Renewable Energy Output (% of total energy output)[20] and Unemployment (% of total labor force)[27] of 102 countries.

Linear regression was performed to model the relationship, if any, between the renewable energy produced as compared to the total energy generated and the unemployment as a percentage of the total labor force (Figure 4.2). The resultant value of R^2 obtained was 0.002. This implies that there is a 0.2% impact of REPG on the unemployment of a country, with a coefficient value of 0.0097, which shows that as REPG increases, unemployment in a country also increases. While this goes against our hypothesis, both the coefficient and R^2 values are too small to disprove the hypothesis entirely.

The GDP of a country is also significantly affected by its foreign balance of trade[26]. For countries where the import of fossil fuels forms a significant portion of imports and hence significantly affect foreign balance, renewable energy may help reduce the need for fossil fuels and thus may have a positive impact on the foreign balance of trade and, by extension, the GDP. Therefore, we analysed the impact of REPG on demand for fossil fuels by considering the amount of energy produced using fossil fuels.

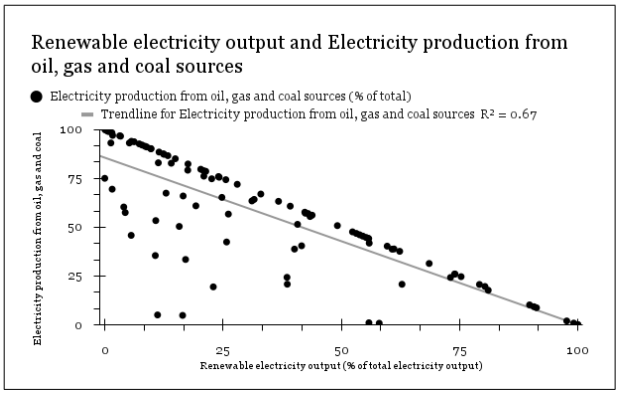

Figure 4.3: Renewable Energy Output (% of total energy output)[20] and Electricity production from oil, gas and coal sources (% of total)[21] of 102 countries.

Figure 4.3 displays a much clearer linear relationship between the percentage of energy produced using renewable means versus energy produced using coal, oil and gas, and shows that as percentage REPG increases, the percentage energy produced by coal, oil and gas decreases. The value of R^2 computed using linear regression between these variables is 0.67, which indicates a 67% impact of REPG on energy produced using coal, oil and gas. Since a significant impact is made by REPG on reducing the energy produced using fossil fuels, it is possible that that may lead to a better balance of payments due to a decrease in fuel imports, which in turn would lead to a higher GDP. An assumption in this comparison is that energy is produced by other means, i.e.

RE, coal, oil and gas are not used to produce all energy in a country. A better analysis may have been made using the amount of energy produced in kiloWatts per hour (kWh) instead of percentages, if not for the lack of relevant data.

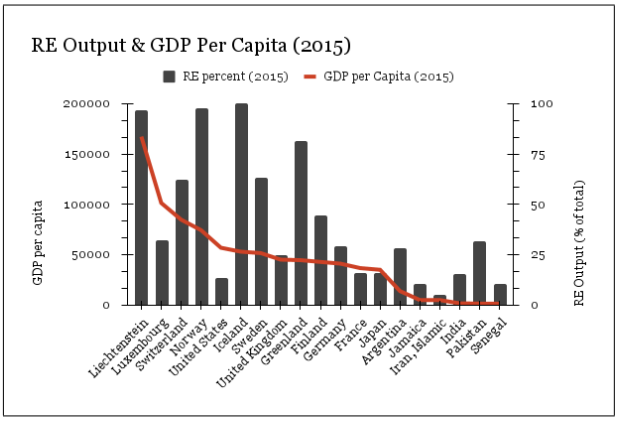

Figure 4.4: Renewable Energy Output (% of total energy output)[20] and GDP per capita[7] of 19 countries.

Linear regression proved to be an ineffective method to model the relationship between REPG and GDP/employment directly, which is likely due to a large number of factors that impact employment rates in an economy as well as its GDP. Decreasing the sample size of countries from 102 to 19 as seen in Figure 4.4 shows a clearer relationship between REPG and GDP, and the visible trend lends to our hypothesis. However, in order to be able to model this relationship, further research is required to identify these factors and include them in the subsequent analysis. While a model could not be constructed, we can not conclude that the relationship we wish to determine does not exist. Therefore, we conducted several case studies to explore this further.

4.3.2 Case Study: Nepal

In order to determine a relationship between REPG and economic growth, we looked at the same data sets as before but in relation to time for Nepal, Germany, Brazil, and China. These countries were chosen as they are all economies that produce a significant portion of their energy through renewable means.

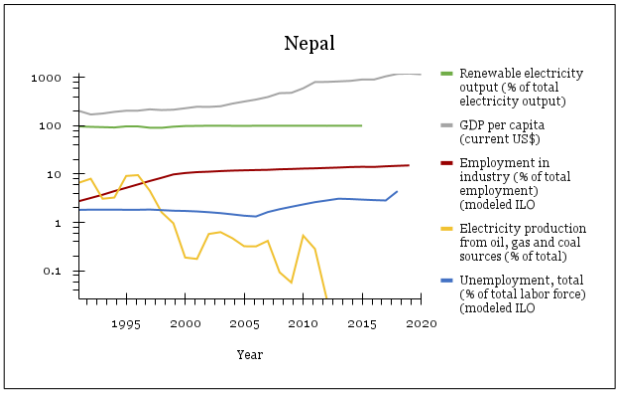

Figure 4.5: between Renewable Electricity Output (% of total energy output)[20] , Electricity production from oil, gas and coal sources (% of total)[21], GDP per capita (Current US$)[7], Unemployment total (% of total labor force)[22], and Employment in industry (% of total employment)[23] for the years 1991 to 2020. A logarithmic scale was used for the y-axis for better comparison.

According to Figure 4.5, more than 90% of Nepal's electricity output has been contributed to renewable means, and this increased to 100% by 2015. We also see the electricity produced by coal, oil and gas decrease across the years, becoming 0% by 2013. While total unemployment can be seen to increase, employment in the industry can also be seen to increase. This data gives us insight into how REPG may be affecting the economy of Nepal, as an increase in REPG may have reduced the need to generate energy using fossil fuels, which would reduce expenditure on fuel imports and improve the foreign balance of trade. This, paired with the increased percentage of employment in industry (possibly in the growing REPG industry), may have positively affected the GDP, which can be seen to have steadily increased since the 1990s. Thus, a positive relationship may be drawn between REPG and GDP/employment in Nepal.

4.3.3 Case Study: Germany

Comparing data for Germany as shown in Figure 4.7 we see that percentage REPG and GDP show an increasing trend. In contrast, total unemployment shows a clear

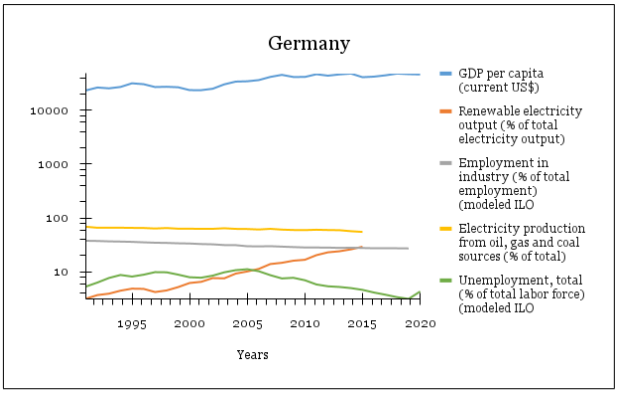

Figure 4.6: Comparison for Germany between Renewable Electricity Output (% of total energy output)[20] , Electricity production from oil, gas and coal sources (% of total)[21], GDP per capita (Current US$)[7], Unemployment total (% of total labor force)[22], and Employment in industry (% of total employment)[23] for the years 1991 to 2020. A logarithmic scale was used for the y-axis for better comparison.

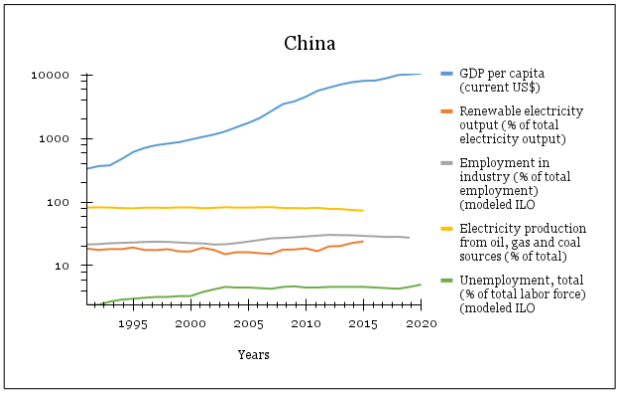

Figure 4.7: Comparison for China between Renewable Electricity Output (% of total energy output)[20] , Electricity production from oil, gas and coal sources (% of total)[21], GDP per capita (Current US$)[7], Unemployment total (% of total labor force)[22], and Employment in industry (% of total employment)[23] for the years 1991 to 2020. A logarithmic scale was used for the y-axis for better comparison.

decreasing trend, particularly since 2005. While the percentage of employed people seem to be decreasing in industry, that may be attributed to factors outside the scope of this study, particularly as the rate of decrease does not appear to be high. Moreover, the percentage of electricity produced by fossil fuels is also seen to be decreasing. As in the case of Nepal, we can conclude that a possibility exists that REPG does impact economic growth positively.

4.3.4 Case Study: China

The data for China tells a similar narrative as Germany and Nepal; the GDP per capita has increased steadily over time as percentage REPG also increases while employment in industry increases and the percentage of electricity produced from fossil fuels decreases. While each of these changes may be attributed to other factors as well, it is possible that they may be influencing the GDP and employment in China to some extent. Moreover, while the unemployment levels are seen to increase, we must also keep in mind that this data pertains to the number of unemployed people as a percentage of the total labor force and that the increasing population of China may also be impacting these numbers.

4.3.5 Case Studies: Comparison

The three case studies all show an increase in GDP as total REPG output increases. The extent of this increase cannot be determined by these graphs alone as the variables plotted do not have the same units. However, they provide a baseline for further investigation as a trend is visible and further models for calculating the exact impact of REPG on GDP (and employment) must be explored.

5 Conclusion: Implications for Pakistan

This study aimed to determine the potential impact of increasing REPG in Pakistan on its economy. In order to do so, a model needed to be determined that would allow us to predict economic growth given REPG output. Linear regression was used to model the behaviour of REPG and GDP and employment in an economy, which may then have been used to predict the impact

of increased REPG for Pakistan. However, this study brought to light that due to the various factors that affect GDP and employment in an economy, a clear relationship cannot be determined between these variables without considering them. Thus, a definite conclusion cannot be drawn to prove or disprove our hypothesis using linear regression. Although linear regression showed a weak correlation, other methods such as Pearson or Spearman correlation can be used to test the hypothesis further. Moreover, Nepal is a country quite similar to Pakistan in terms of economy and relies on REPG for most of its energy needs[20] and has also seen a rise in economic growth as seen in Figure 4.5. This indicates that Pakistan may experience similar growth if it increased its REPG. The case studies of Germany and China also paint a hopeful picture of an economy with high REPG, as do trends observed in the cross-sectional data analysis which lends to the hypothesis that increased REPG may lead to an increase in GDP and employment in an economy. Further research can be done to model this relationship, and case studies can be done with countries that have a similar topological landscape and economic standing as Pakistan to determine the impact on Pakistan's economy specifically of increased REPG.

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