Impact of Dependence on Renewable Energy on GDP Per-Capita Growth

A S M Shakil Haider*
Taufiq Hasan Quadria†
Darren Hudson‡§

Abstract

Increasing energy consumption behaviour around the world is causing the high dependency on the non-renewable energy sources day by day. As a result, there is rapid depletion of the non-renewable energy resources along with detrimental effects on the environment. Based on these major concerns, 29 countries of European Union (EU) signed on an agreement known as "Renewable Energy Directive 2009" to increase their dependency on renewable energy sources by increasing the share of renewable energy to 20%.Hence, this paper investigates the impact of this policy of increasing the dependence on renewable energy on GDP per-capita growth for these 29 EU countries. For the investigation, total 41 countries had been considered where 29 EU countries are in treatment group and 12 countries from North America, South America, Africa and Asia are considered in the control group. The time frame of the analysis is from 2003 to 2016 and the data are yearly data. Hence, by applying a standard difference-in-differences (DID) strategy, it can be causally attributed that, when the dependency on renewable energy had been increased in the EU countries due to the Renewable Energy Directive 2009, average per-capita GDP growth had been elevated in those countries even though there were price shocks in oil price and there was a global recession effect.

Keywords: Renewable energy, GDP per-capita growth, Difference-in-differences
JEL Classification: Q20, Q28, O40, O47

1 Introduction

The growth of energy-consumption behaviour in the developed and developing countries lead to two major concerns: emission of more greenhouse gases (i.e. CO_2) and rapid depletion of the easily accessible energy resources (i.e. fossil fuel, coal, gas). These certain major challenges give us the indication of shifting towards renewable energy resources from the non-renewable ones. Renewable energy is generally explained as energy generated from solar, wind, tide and wave, waste, biomass and geothermal. Creating more dependence on renewable energy is better as it is unlimited, clean and safe. For such reasons, the dependence on renewable energy is increasing more and

*Department of Agricultural and Applied Economics, Texas Tech University; email: asmshakil.haider@ttu.edu
†Department of Personal Financial Planning, Texas Tech University; email: taufiq-hasan.quadria@ttu.edu
‡Department of Agricultural and Applied Economics, Texas Tech University; email: darren.hudson@ttu.edu
§We would like to acknowledge Professor Muhammad Yunus (Nobel Peace Prize Laureate (2006); SDG Advocate), Dr Benaissa Chidmi, Dr Rashid Al-Hmoud, Dr Syed Osman and Dr Shaikh Rahman for their comments and continuous support.

more around the globe.

According to UN Environment Programme Report (2015), global investment in renewable energy increased to $270 billion, a 17% rise from 2013. Furthermore, IEA (2015) reported that, the most significant price drop being observed in solar, 80% over the last seven years. Therefore, it is expected that the investment on renewable energy will increase more due to its decreasing cost as well.

Energy supply shortage along with the price shocks on the non-renewable energy sources cause detrimental effect on the growth and development of any non-renewable energy dependent country. More specifically, it affects the economy by harming the per-capita income, causing higher unemployment, slows down the capital formation of the economy and increases problem regarding corruption and governance issues. Therefore, overall, the economy faces reduction in per-capita GDP growth. Moreover, the existing climate change issues along with greenhouse gas emissions are making the situation more vulnerable.

Based on the above-mentioned problems, attempts had been made via the Kyoto Protocol agreement of 1997. Since the Protocol, the replacement of the traditional sources for Renewable Energy Sources has appeared as a viable solution to reduce emissions, particularly in the electricity sector (Bohringer and Loschel, 2006, Neuhoff, 2005; Stocker et al., 2008) Even though many countries are trying to shift to the renewable energy sources, it has been reported that the current energy supply and use are still economically, environmentally and socially unsustainable (IEA, 2009). Furthermore, it is estimated that, the energy demand will increase by 1.5% per year between 2015 and 2030 (Apergis and Danuletiu, 2014). Therefore, it is high time to find alternative energy sources which can sustain the increasing demand of energy, sustain the economic growth and reduce the problems of environmental and climate change issues. It is already been suggested by many researchers that the renewable energy sources can be a better source of energy supply as it is sustainable, clean and helps to increase the economic growth. Tiwari (2011) reveals that, while the growth rate of non-renewable energy consumption has a negative impact, the growth rate of renewable energy consumption has a positive impact on the growth rate of GDP. Pao and Fu (2013) examined the role of renewable energy with its different components in promoting the Brazil's economic growth process. Furthermore, Bowden and Payne (2010) showed unidirectional causality from residential renewable energy consumption to real output. Kaygusuz (2007) suggested that, the expansion of the renewable energy sector may serve as the impetus for the modernization of the energy sector in meeting sustainability objectives specified by policy makers. One study found that, due to environmental awareness and simultaneous sustainable economic growth concern, European Union, China and USA are increasing their dependability on renewable energy (Canning and Pedroni, 2008). Therefore, the existence of causal relationship between economic growth and renewable energy dependency gives a positive incentive to formulate government policies that enhance the development and dependency on renewable energy.

According to the European Environment Agency (2008), the energy sector is responsible for about 80% of the Greenhouse Gas (GHG) emissions in Europe. Therefore, based on the positive effects of renewable energy on environment and the economic growth, 29 countries of the European Union (EU) came to an agreement that, 20% of the energy consumed within the European Union should be renewable (Directive 2009/28/EC). This agreement among the EU countries is known as the "Renewable Energy Directive 2009/28/EC". This target is pooled among the member states. EU leaders had already reached agreement in March 2007 that, in principle, 20% of the bloc's final

energy consumption should be produced from renewable energy sources by 2020 as a part of its drive to cut carbon dioxide emissions. The draft report on the directive was published by the European Commission in January 2008. The other key objectives of the directive are to reduce carbon dioxide emissions by 20% and to achieve energy savings of 20% or more.

Even though the Renewable Energy Directive 2009 amends and repeals amends and repeals the 2001 Directive on "Electricity Production from Renewable Energy Sources 2001/77/EC", it is very important to assess the effect of this 2009 directive on the economies who already started shifting towards renewable energy. It is because, a research based on 27 European countries showed that, a random effect model to cointegration and a panel error-correction model framework does not confirm any Granger causality direction between renewable energy and economic growth (Menegaki, 2011). Furthermore, Silva et al. (2012) in their study including EU countries showed that, increasing renewable energy sources on electricity generation share had economic costs in terms of GDP per capita. Both of these studies included data from 1960 to 2004. Hence, their studies provided certain evidences of the failure of Renewable Energy Directive of 2001. Therefore, it is very important to examine whether the 2009 Renewable Energy Directive is on the track to fulfil its targets along with contributing to the GDP growth of the countries.

This research tries to examine the effect of increasing renewable energy dependence on GDP per capita growth based on the Renewable Energy Directive 2009. For the analysis, difference-in-differences (DID) methodology had been applied here. The 29 EU countries who signed the directive of 2009 are considered in the treatment group and 12 other countries (from North America, South America, Africa and Asia) who are not a part of this directive had been taken in the control group. The results suggest that, increasing the dependence on renewable energy not only increases the average per capita GDP growth among the treatment countries but also creates resilience against price shocks in non-renewable energy resources.

The article is organized as follows: Section II describes the methodology and data. Empirical results and analysis are explained in Section III. Limitation and future research are explained in Section IV. Concluding remarks and policy implications are presented in Section V.

2 Methodology

2.1 Data and Variable

In this research, yearly data for 41 countries had been taken in to account for the time period of 2003-2016. The dataset had been collected from the World Bank data archive and the total number of observations were 539. The 29 countries of European Union who signed the 2009 directive had been taken in the treatment group. Other 12 countries of North America, South America, Africa and Asia had been taken in the control group as they were not the part of the 2009 directive. As the economic growth indicator, GDP per-capita growth had been taken as the dependent variable. The independent variables considered in this research were unemployment rate (proxy for labor), gross capital formation as a percentage of GDP (proxy for capital), oil price (due to price fluctuations of fossil fuel) and control of corruption (as a proxy for governance).

2.2 The Model

This research implements difference-in-differences (DID) model to explain the causal and measurable relation between observed outcomes and implemented policies. Difference-in-differences (DID) had been widely used for policy impact evaluation impact in different disciplines ((Duflo et al. 2007; Palmer and Walls 2015). A very important and strong assumption of this model is that, the dependent variable for both the treatment group and the control group should have followed a parallel trend, as both a necessary and sufficient condition to prove unbiasedness of the model, in the absence of treatment allowing the effect of the treatment to be calculated as the difference of the changes in the treatment and control groups over time (Meng et al., 2017). The Basic framework of the treatment and control group can be explained by Figure 1. In the figure, we can see that, "1" refers to the application of new policy on the treatment group. "0" indicates that the policy doesn't have any effect on the control group before and after the policy implementation. "0" also indicates that the treatment group doesn't have any effect before the policy is implemented.

Table 1: Difference-in-differences model

	Before Policy	After Policy
Treatment	0	1
Control	0	0

The before-after difference in the treatment group represents the sum of the policy and confounding factors, and the before-after difference in the control group represents only the confounding factors (Meng et al., 2017). Therefore, the difference of these before-after differences between treatment and control groups (the second difference) represents the isolated policy effect (Meng et al., 2017). In this case, the treatment group consists of 29 EU countries who signed the 2009 Renewable Energy directive. The control group is usually consisting of one-third number of countries compared to the treatment group. Hence, the control group consists of 12 countries from North America, South America, Africa and Asia. To check the before and after effect on the control group, data from 2003 to 2016 had been considered for all the countries in treatment and control group for all the variables considered. Here, 2003 to 2009-time periods are the before treatment period and 2010 to 2016 are the after treatment period as the directive got implemented in 2010. Therefore, to conduct the difference-differences causal study design on a panel data setup, an econometric regression approach had been used. The general form of the econometric approach is:

$$Y_{it} = \beta_0 + \beta_1 Treat_i + \beta_2 Post_t + \beta_3 (Treat * Post)_{it} + \beta_j X_{it} + \epsilon_{it} \tag{1}$$

Here, $i = country$, $t = time$, $j = coefficientnumber$ with the independent variables. "$Treat_i$" refers to country dummy (which gives "1" for the treatment group countries after the policy implementation and "0" before the policy. It gives "0" for the control group countries both before and after the policy implementation). "$Post_t$" refers to the time dummy which suggests the periods after the policy has been implemented. "$(Treat * Post)_{it}$" suggests the interaction term which is the main focus of this econometric analysis. This interaction term explains the policy effect on the treatment group countries after the policy had been implemented. "X_{it}" suggests the other independent variables. Therefore, if we elaborate the general econometric model considering our research, we can write-down the following model:

$$\begin{aligned} GDP(percapgrowth)_{it} = \beta_0 + \beta_1 Treat_i + \beta_2 Post_t + \beta_3 (Treat * Post)_{it} + \\ \beta_4 Unemprate_{it} + \beta_5 Oilprice_{it} + \beta_6 CoC_{it} + \beta_7 Capformation_{it} + \epsilon_{it} \end{aligned} \tag{2}$$

Here, $Unemprate = Unemploymentrate$; $OilPrice = OilPrice$;
$CoC = ControlofCorruption$;
$Capformation = Grosscapitalformation(asapercentageofGDP)$.
The econometric model considered here is based on a standard structured model of output (GDP per capita growth) which is a function of labor and capital along with other variables like unemployment rate, oil price, control of corruption and gross capital formation. However, the possible signs of the variables can be expected as: the interaction term (which refers the policy impact on the treatment countries) is supposed to have a positive effect on the GDP per-capita growth; unemployment rate is expected to have a negative effect; oil price changes should have a negative sign as most of the countries in the treatment group are oil importing countries; capital formation is supposed to have a positive effect on GDP. The effect of control of corruption can be either positive or negative. Generally, when the sign is negative, it suggests that controlling the corruption is helping to increase the per-capita GDP growth. On the other hand, if the country has significant corruption and the monetary gain from the corruption is spent inside the economy (assuming minimal capital flight of the corruption money), it is highly likely that the corruption is helping the GDP per-capita growth in the economy. In this kind of scenario, if the control of corruption is increased, the GDP per capita is supposed to slow down, having a negative effect due to strict control of corruption.

3 Results and Analysis

After running the regression, it is found that the interaction term is having a positive and significant effect per-capita GDP growth (Table 1). As the expected sign of the interaction term was positive, the result of the interaction term suggests that, due to the policy implementation of Renewable energy directive 2009, GDP per-capita growth has been increased for the treatment group countries (29 countries of EU) by 1.659% on average. Even though, oil price increase has a significant negative effect on the GDP per-capita growth (decreases the growth by 0.035%), due to increase in dependence on the renewable energy resources is creating the resilience for the oil price shocks along the treatment time period and thus the economic growth has increased in the treatment group countries. Furthermore, if we examine the other variables impact, unemployment rate has a very small negative and insignificant effect on GDP per-capita growth. It is possible that, due to increasing dependency on renewable energy sources, it has created job opportunities which made the effect of unemployment variable smaller and insignificant for the treatment group countries. Furthermore, capital formation has a positive sign and the variable is significantly helping to increase the GDP per-capita growth in treatment group countries.Control of corruption is showing a negative and significant impact on GDP per-capita growth (decreasing the growth by 0.737%). It might be the case that, the countries in the treatment group has corruption effect and the monetary gain from the corruption is spent inside the economy (assuming minimal capital flight of the corruption money). Hence, it is highly likely that the corruption is helping the GDP per-capita growth to increase of the treatment group countries. In this kind of scenario, when the control of corruption is increasing, the GDP per capita is slowing down, having a negative effect due to strict control of corruption.

Table 2: Difference-in-differences model Results

Variables	**Coefficients**
Treatment	-1.047** (0.447)
Post	-0.468 (0.564)
Treat*Post (Interaction Term)	1.659** (0.655)
Unemployment Rate	-0.015 (0.037)
Oil Price	-0.035*** (0.008)
Control of Corruption	-0.737*** (0.189)
Capital Formation	0.313*** (0.030)
Constant	-1.386 (1.136)
R-squared	0.265
Observations	539

However, the correlation matrix (Table 3) suggests that, correlations among the independent variables along with the interaction term are very minimal. Hence, there is no multi-collinearity problem existing in this estimation.

Table 3: Correlation Matrix

Variables	Unemployment Rate	Oil Price	CoC	Capital Formation	Treat*Post
Unemployment Rate	1				
Oil Price	0.0153	1			
CoC	-0.3199	-0.0357	1		
Capital Formation	-0.3593	-0.0106	-0.1707	1	
Treat*Post	0.2182	0.3582	0.083	-0.3147	1

It is mentioned earlier in the methodology part that the dependent variable for both the treatment group and the control group should have followed a parallel trend before the treatment period allowing the effect of the treatment to be calculated as the difference of the changes in the treatment and control groups over time. It is evident from the graphical representation in Figure 1 that both the treatment (blue line) and control group (red line) countries' GDP per-capita growth on average were moving parallelly for about two years before the treatment started becoming effective with the policy implementation starting from 2010. According to Card and Krueger (1994), a parallel trend between the treatment and the control group is necessary immediately before the policy implication years. Hence, in our case, even though, the two groups were not following a parallel trend in the prior years before 2008, that does not cause any biasedness in the model because the global financial crisis in 2008 affected all the major economies in the world, which itself can be considered as a natural treatment, taking away the factors that were actively making the two groups of economies follow a nonparallel trend prior to 2008 and making them follow a parallel trend after 2008. When the Renewable Energy Directive became effective from 2010, which is begining of the

post-treatment period in the model, the parallel pattern started changing.

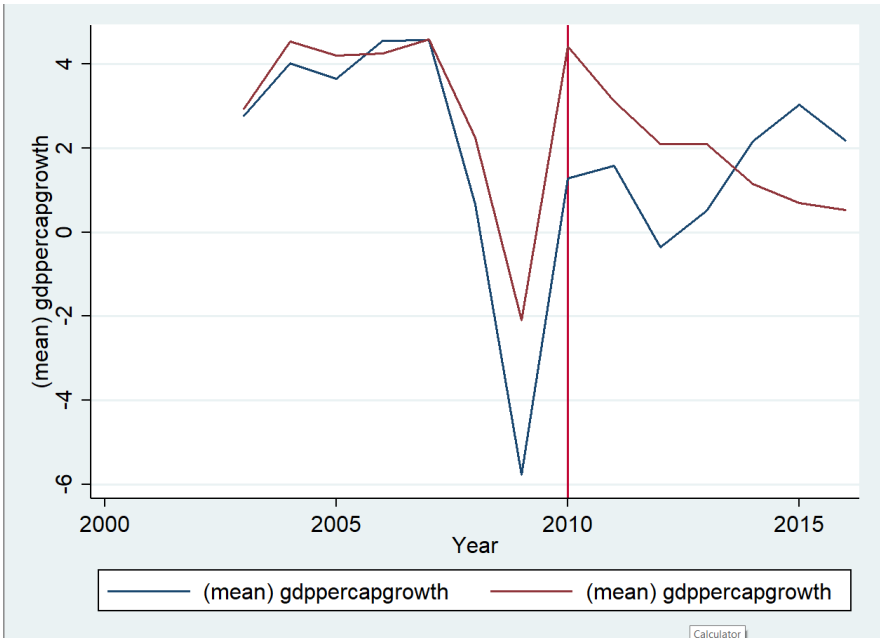

Figure 1: *Graphical Verification of Parallel Trend Assumption immediately before the Policy Treatment*

It is due to the policy treatment of 2009 Renewable Energy Directive on the treatment countries in EU that their average GDP per-capita growth started increasing whereas the GDP per-capita growth in the control group countries was following a decreasing trend as there was no certain policy treatment implemented in those countries.

4 Limitations and Future Research

One of the limitations of the research is the limitation of available data after the 2009 policy directive. As the policy had been implemented in the year of 2010, only seven years of data after the policy implementation had been considered in this research. Therefore, more data availability in the future years can provide better results considering the impact of the policy on GDP per-capita growth. Another limitation of this research is that, the actual value of renewable energy production by the countries could not be considered as it could cause multi-collinearity problem with the interaction term. The final problem of the research is, the countries in the control group had been taken based on per-capita GDP equal $4000 or above only. Hence, a future research could be implying synthetic control method where the problem of selecting control group countries is eliminated. Furthermore, estimating a panel regression including the renewable energy production in all the considered countries can provide some more insight about the impact of dependency on renewable energy on GDP per-capita growth. Furthermore, the panel estimation can also provide the insight whether the countries are keeping their track on producing renewable energy to fulfil the target of producing 20% renewable energy according to the 2009 Renewable Energy Directive.

5 Conclusion

The increase in energy consumption behaviour around the world is causing the dependency on the non-renewable energy sources which is causing harm to the climate and faster depletion of the non-renewable resources. In this situation, increasing dependency on the renewable energy sources is very important as they are clean, environment friendly and non-exhaustible. Furthermore, shifting to renewable energy sources also help to increase the growth of the economy along with creating resilience for different non-renewable energy price shocks (i.e. oil price shock). In this research, it is found that, when the dependency on renewable energy had been increased in the EU countries due to the Renewable Energy Directive 2009, average per-capita GDP growth had been elevated in those countries even though there were price shocks in oil price and there was a global recession effect. Furthermore, the effect of unemployment had been reduced due to new employment opportunity openings in the renewable energy sectors. Hence, it can be concluded that, global increase in GDP per capita growth can be expected if global dependence on renewable energy is mandated on a larger scale. Furthermore, the impact of oil price fluctuations on GDP per capita growth can be mitigated. Hence, the countries who are still heavily dependent on non-renewable energy sources should start formulating policies to shift towards renewable energy resources and implementing the policies soon for a sustainable economic growth along with a sustainable environment.

References

Apergis, N., Danuletiu, D.C. (2014). Renewable Energy and Economic Growth: Evidence from the Sign of Panel Long-Run Causality, International Journal of Energy Economics and Policy, 4, 578-587.

Bohringer, C., and Loschel, A. (2006). Promoting Renewable Energy in Europe: A Hybrid Computable General Equilibrium Approach. The Energy Journal, Hybrid Modelling, special issue , 135-150.

Bowden, N., Payne, J.E. (2010). Sectoral analysis of the causal relationship between renewable and non-renewable energy consumption and real output in the U.S., Energy Sources, Part B: Economics, Planning, and Policy, 5, 400-408.

Card, D., Krueger, A.B. (1994). Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania, The American Review, 84, 772-793.

Canning, D., Pedroni, P. (2008). Infrastructure, long-run economic growth and causality tests for cointegrated panels, The Manchester School, 76, 504-527.

Duflo, E., R. Glennerster, and M. Kremer (2007). Using Randomization in Development Economics Research: A Toolkit, In T. P. S. and J. A. Strauss, ed. Handbook of Development Economics, Elsevier, 3895–3962.

EurActiv (2007).EU renewable energy policy.

EurActiv (2008). Deal secured on ambitious EU renewables law.

European Council (2009). Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Brussels, Belgium.

European Environment Agency (2008). Greenhouse gas emission trends and projections in Europe 2008: Tracking progress towards Kyoto targets. EEA report: N^{o} 5/2008.

IEA (2009). World Energy Outlook. International Energy Agency. Paris, France.

IEA (2015). World Energy Outlook. International Energy Agency. Paris, France.

Kaygusuz, K. (2007). Energy for sustainable development: Key issues and challenges, Energy Sources, Part B: Economics, Planning, and Policy, 2, 73-83.

Menegaki, A.N. (2011). Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis, Energy Economics, 33, 257-263.

Meng, T., Hsu, D. and Han, A. (2017). Estimating energy savings from benchmarking policies in New York City. Energy, 133, 415-423.

Neuhoff, K. (2005). Large-Scale Deployment of Renewables for electricity generation. Oxford Review of Economic Policy, 21, 88-110.

Palmer, K.L. and M. Walls (2015). Can Benchmarking and Disclosure Laws Provide Incentives for Energy Efficiency Improvements in Buildings?, Resources for the Future Discussion Paper (15-09).
Pao, H.T., Fu, H.C. (2013). The causal relationship between energy resources and economic growth in Brazil, Energy Policy, 61, 793-801.

Stocker, A., Grobmann, A., Madlener, R., and Wolter, M. I. (2008). Renewable energy in Austria: Modeling possible development trends until 2020. International Input Output Meeting on Managing the Environment.

Tiwari, A.K. (2011). Comparative performance of renewable and nonrenewable energy sources on economic growth and CO2 emissions of Europe and Eurasian countries: A PVAR approach, Economics Bulletin, 31, 2356-2372.