Critical Analysis of Renewable Energy in Italy

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Abstract. The study aims to examine the effect of environmental and economic variables on carbon dioxide emissions in Italy. The study used an auto-regressive distribution lag (ARDL) approach on a time series of data from 1965 to 2020 to study the long run and short run association between the variables. In the recent report published by the World Bank, Italy is ranked 50th with 5.3 metric tonnes per capita. The findings revealed that coal consumption and GDP have a positive relationship with CO2 emissions, whereas renewable energy consumption and agricultural land area have a negative relationship in both the short and long run.

Keywords. Carbon dioxide emissions, renewable energy consumption, coal consumption, gross domestic product (GDP), agricultural land area.

1. Introduction

Recent academic studies have given carbon dioxide emissions a lot of attention due to its concerns and drawbacks for the economic and ecological development of nations. In terms of reducing the effects of climate change and global warming, Italy is currently up against a tough challenge. The planet Earth is in severe danger and poses a huge threat to our future generations due to the atmosphere's rising greenhouse gas concentrations. In order to lessen the effects of climate change, we must act more responsibly in all of our actions now. There may be a worldwide discussion about shared but distinct responsibilities, but now is the moment to act. Natural resources found in the environment are used to create renewable energy. Renewable resources are readily available and cost-free sources of energy. We don't have to worry about running out of renewable energy when we use it. Other names for this energy include "green energy" and "clean energy." Solar, hydro, wind, geothermal, and biomass energy are a few types of renewable energy. We currently rely primarily on finite, non-renewable resources like coal, petroleum, etc. They hurt the ecosystem as well. So, for today and tomorrow, renewable energy is a good alternative.

Italy contributes 11.4% of the EU's overall greenhouse gas (GHG) emissions, and since 2005, it has decreased emissions more quickly than the EU as a whole. Over the period of 2005 to 2019, emissions declined across all Italian economic sectors, with the agriculture sector recording the lowest decreases. Nearly half of Italy's overall emissions come from the "other emissions" sector, which includes the building sector and transportation. Between 2005 and 2019, the emissions of the energy sector decreased by 42%, moving the industry to third place in terms of its contribution to overall emissions. Italy lowered its emissions by 13% between 2005 and 2020 as a result of EU effort-sharing regulations, and it anticipates meeting the 33% target for 2030. In 2019, Italy's percentage of renewable energy sources (RES) was 18%. The nation's 2030 30% share goal focuses primarily on wind and solar energy. The building stock and transportation sectors are at the centre of energy efficiency efforts, including support programmes for businesses and people [European Parliament: EU progress on climate action – How are the Member States doing?].

1.1. Research motivation and objective

Carbon dioxide emissions play a critical role in determining the position of renewable energy in Italy. Countries like China and the US are leading the list, whereas India is far behind. The motive behind the study is to highlight the parameters that are good for renewable energy growth so that CO2 emissions can decrease and we can live in a much more sustainable environment.

2. Review of Literature

In order to minimize the adverse impact of carbon dioxide (CO2) emissions on climate change, a large amount of research has been devoted to analyzing the factors that influence these emissions. Since fossil fuel usage accounts for 80% of global energy consumption [13], non-renewable energy consumption has been identified as one of the main drivers of CO2 emissions [14, 15, 16, 17]. The capacity of renewable energy sources worldwide is anticipated to increase by 50% between 2019 and 2024 [18], which could lessen the negative effects of GHG emissions on the environment and human health [19]. In this regard, a number of studies have discovered that the use of renewable energy reduces CO2 emissions globally [14, 20, 21].

The relationship between renewable energy and CO2 emissions is supported by a number of findings from existing research. Using the vector error correction model (VECM) and autoregressive distributed lag (ARDL) limits approach, [Chen et al. (2019)] investigates the link between RE, GDP, trade, and CO2 emissions during the period 1980–2014. The findings indicate that trade and renewable energy have a negative impact on emissions, but GDP and CO2 emissions have an inverted U-shaped relationship. Granger causality studies reveal a two-way relationship between trade, RE, and CO2 emissions. In a previous analysis, [Qi et al. (2014)] found that, compared to the No Policy scenario, renewable energy targets might result in a nearly 1.8% drop in CO2 emissions from 2010 to 2020. [Inglesi-Lotz and Dogan (2018)] evaluate the correlation between RE and CO2 emissions in the top 10 sub-Saharan African nations over the period 1980–2011. The study shows the long-term relationships between CO2 emissions, GDP, RE, and non-RE. In addition, there is a causal relationship between RE and CO2 emissions, as well as between CO2 emissions and commerce.

The correlation between RE, economic freedom, and CO2 emissions in a sample of EU member states from 2000 to 2017 is evaluated by [Shahnazi and Dehghan Shabani (2021)]. The study finds that there is a nonlinear relationship between economic freedom and CO2 emissions and that renewable energy lowers CO2, using a spatial econometric model. The impact of RE and GDP growth on CO2 emissions in the EU and prospective EU member states between 1995 and 2015 is examined by [Bilan et al. (2019)]. The authors demonstrate how adopting RE raises environmental quality using cointegration and other empirical techniques like VECM (a decrease in CO2 emissions). The role of RE in reducing CO2 emissions is examined by [Dong et al. (2018)] in the context of EKC in China from 1993 to 2016. Long- and short-term reductions in CO2 emissions are achieved using renewable energy. On the other hand, using fossil fuels increases CO2 emissions.

[Mendonça et al. (2020)] evaluate the factors that contributed to CO2 emissions in the 50 largest economies between 1990 and 2015. The authors demonstrate using hierarchies that while RE reduces CO2 emissions, GDP and population increase CO2 emissions. Using ARDL and the canonical cointegration method, [Pata (2018)] examines the relationships between GDP, financial development,

CO_2 emissions, and RE usage in Turkey from 1974 to 2014. The link between GDP per capita and emissions is inverted U-shaped, with the turning point exceeding Turkey's current GDP per capita levels. In contrast to urbanization and financial development, which worsen environmental deterioration, renewable energy has no effect on emissions. By employing worldwide panel data to examine the relationship between GDP, RE, and CO_2 emissions, [Fatima et al. (2021)] add to the body of existing research. The paper demonstrates that GDP modifies the link between RE and CO_2 emissions using several econometric techniques. Additionally, GDP has an impact on non-RE consumption, which raises CO_2 emissions. The relationship between globalization, renewable energy, rents, and CO_2 emissions in Colombia from 1970 to 2017 is examined by [Awosusi et al. (2022)]. The authors demonstrate how globalization and renewable energy reduce CO_2 emissions using FMOLS, DOLS, and ARDL. In 73 nations between 1990 and 2019, [Dou et al. (2021)] look into the connections between natural gas usage, innovation, and CO_2 emissions. The EKC hypothesis is present, and innovation globally lowers CO_2 emissions, according to the regression results.

3. Methodology

Climate change poses a greater existential threat to the world today than ever before. It has been well known that the foremost contributors to global climate change have been past increases in greenhouse gas emissions due to the increased use of fossil fuel energy and economic growth experienced during the previous century. This study examines the relationship between Italy's CO_2 emissions and economic (GDP) and environmental (RENEW, COAL, AGRI) factors. In this study, we have used secondary data downloaded from the World Bank development indicators (WDI) for testing hypotheses and achieving research objectives. Equation 1 is formulated to check the relationship of overall carbon dioxide emissions with environmental and economic factors in the context of Italy during the period 1965–2020.

$$\ln CO2 = f(\ln RENEW, \ln COAL, \ln GDP, \ln AGRI) \qquad (1)$$

In the above equation, ln is the natural log, and the descriptions of the variables are in Table 1.

$$\Delta \ln CO2_t = \alpha_0 + \sum_{i=1}^{n_1} \alpha_{1i} \Delta \ln RENEW_{t-i} + \sum_{i=1}^{n_2} \alpha_{2i} \Delta \ln COAL_{t-i} + \sum_{i=1}^{n_3} \alpha_{3i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{n_4} \alpha_{4i} \Delta \ln AGRI_{t-i} + \beta_1 \ln RENEW_{t-1} + \beta_2 \ln COAL_{t-1} + \beta_3 \ln GDP_{t-1} + \beta_4 \ln AGRI_{t-1} + \mu_t \dots\dots\dots\dots (2)$$

In equation 2, the short-run relationship is represented by α_1 to α_4, whereas the long-run relationship is represented by β_1 to β_4 and the drift component is α_0. While n_i is the optimal lag and μ_t is the error term.

$$\Delta \ln CO2_t = \beta_0 + \sum_{i=1}^{n_1} \beta_{1i} \Delta \ln RENEW_{t-i} + \sum_{i=1}^{n_2} \beta_{2i} \Delta \ln COAL_{t-i} + \sum_{i=1}^{n_3} \beta_{3i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{n_4} \beta_{4i} \Delta \ln AGRI_{t-i} + \theta ECM_{t-1} + \mu_t (3)$$

The co-integration among the variables was tested, and then the error correction model was developed, where θ is the speed of adjustment of the long-run equilibrium.

Table 1: List of variables

Variables	Description
CO2	Carbon dioxide emissions (million tonnes)
RENEW	Renewable consumption (exajoules)
COAL	Coal consumption (exajoules)
GDP	GDP (constant 2015 US$)
AGRI	Agricultural land area

Source: World Bank Database, 2020

As some variables were stationary at the level and some at first difference, we found the ARDL (autoregressive distribution lag) technique to be most appropriate for our research. Table 1 shows the variable description, where GDP represents the economic factor influencing CO2 emissions on the other hand RENEW, COAL, and AGRI are the factors affecting environmental sustainability.

4. Results and Discussion

Table 2: Illustrates the result of the unit root test. The Augmented Dickey Fuller (ADF) test was employed to check the stationarity at level and the 1st difference. The results proved the stationarity of the independent variable GDP at level, whereas the independent variables (RENEW, COAL, and AGRI) and dependent

variable CO_2 were stationary at 1st difference. The ARDL model allows for a mixture of variables at level and first difference; therefore, it is most appropriate for our study. Before applying ARDL co-integration, the ARDL bound test is used to check the long-run association between the dependent and independent variables. The bound test shows two critical values: the upper bound and the lower bound, where the upper bound assumes all variables are at first difference and the lower bound assumes all variables are at level. If the value of the upper bound is less than the F statistic, the null hypothesis is rejected, showing the presence of co-integration, and vice versa.

Table 2: ADF Unit Root test

Variables	level t-statistics	level Prob.	1^{st} diff t-statistics	1^{st} diff Prob.
CO2	-2.249325	0.1919	-3.432198	0.0140
RENEW	1.294500	0.9984	-3.486633	0.0122
COAL	-0.261655	0.9234	-4.144333	0.0018
GDP	-6.307992	0.0000	-3.355107	0.0171
AGRI	-1.026719	0.7376	-8.275988	0.0000

Table 3: Shows the results of the ARDL-bound test. The results indicate that there is a significant degree of co-integration between the dependent and independent variables, as the F statistic is greater than the upper bound statistic.

Table 3: ARDL-bond test for co-integration

Variable	F statistics	Co-integration	
F(CO2,RENEW,COAL,GDP,AGRI)	5.303364***		
Critical value	1%	5%	10%
Lower bound	3.29	2.56	2.2
Upper bound	4.37	3.49	3.09

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level

Table 4: ARDL short-run results show that total coal consumption (COAL) and Italy’s gross domestic product (GDP) are significant and have a positive correlation with carbon dioxide emissions ($0.06<0.1$, $0.00<0.01$), whereas renewable energy consumption (RENEW) and agricultural land area (AGRI) have a negative correlation with carbon dioxide emissions ($0.07<0.1$, $0.002<0.01$).

Table 4: Auto Regressive Distributed Lag short-run estimates

Variables	Probability	t-statistic	Coefficient
RENEW	0.0762*	-1.530445	-0.083209
COAL	0.0646*	1.896504	0.095099
GDP	0.0000***	4.922514	0.957102
AGRI	0.0023***	-3.240917	-0.522354

Note: Adjusted $R^2 = 0.97$ *significant at 10% level, **significant at 5% level, ***significant at 1% level

Table 5: Demonstrates the long-run result of ARDL. Findings suggest that the value of the F statistic is much greater than the upper bound, implying that there is a long-run relationship between the dependent and independent variables at the 5% level of significance. Total coal consumption is statistically significant and positively correlated with carbon dioxide emissions, which is a sign of concern for human health. Italy's gross domestic product is significant and have a positive impact on carbon dioxide emissions in the long run. On the other hand, renewable energy consumption has a negative relationship with carbon dioxide emissions and is significant in the long run, which is a positive sign for environmental sustainability. Lastly, in the long run, agricultural land area has a negative relationship with carbon dioxide emissions.

Table 5: Auto Regressive Distributed Lag long-run estimates

Variables	Probability	t-statistic	Coefficient
RENEW	0.0773*	-1.489613	-0.084290
COAL	0.0550*	1.969275	0.101011
GDP	0.0268**	2.293414	1.091812
AGRI	0.0532*	-1.984572	-0.653859

Note: Adjusted $R^2 = 0.97$ *significant at 10% level, **significant at 5% level, ***significant at 1% level

Table 6: Correlation matrix

	CO2	RENEW	COAL	GDP	AGRI
CO2	1	-0.21665	0.620388	0.625088	-0.43622
RENEW	-0.21665	1	-0.14697	0.528806	-0.74754
COAL	0.620388	-0.14697	1	0.480527	-0.25092
GDP	0.625088	0.528806	0.480527	1	-0.91995
AGRI	-0.43622	-0.74754	-0.25092	-0.91995	1

Table 6: The correlation matrix with correlation coefficients of the variables used is presented in table 6.

Table 7: Illustrates the results of diagnostics test. We used the Jarque Bera test, and the results show that residuals are normally distributed. In addition, heteroscedasticity Breusch-Pagan Godfrey test has been deployed to check whether the data are homoscedastic or heteroskedastic. The results indicate that the dataset is homoscedastic. Further Ramsey RESET test was performed, and the results shows that the model is free from specification error. Lastly, the Breusch Godfrey serial correlation LM test revealed that there is no serial correlation among the error terms in our model.

Table 7: Diagnostic tests

Jarque-Bera Normality Test, JB stat	0.112689	0.945214
Ramsey RESET test, Log likelihood ratio	0.366638	0.5481
Breusch-Godfery serial Correlation, LM test	0.908214	0.6350
Heteroskedasticity Breusch-Pagan-Godfery test, Obs R-squared	9.275179	0.5062

Table 8: Shows the results of the Granger causality test. The test is used with time series data to assess whether there is any potential predictability power from one variable to the other. The result indicates that there exists a unidirectional causality between RENEW-CO2, AGRI-CO2, RENEW-COAL, and AGRI-COAL.

Table 8: Granger causality test

Direction of causality	F-statistics	Probability
RENEW-CO2	4.57679	0.0151**
AGRI-CO2	7.20779	0.0018***
RENEW-COAL	3.84058	0.0282**
AGRI-COAL	3.24530	0.0475**

Note: **significance at 5% level, ***significance at 1% level

The model's stability was checked by the cumulative sum of the recursive residuals stability test; Figure 1 suggests that the model is stable. The findings show that GDP and total coal consumption are positively related to carbon dioxide emissions, whereas renewable energy consumption and agricultural land area are negatively related.

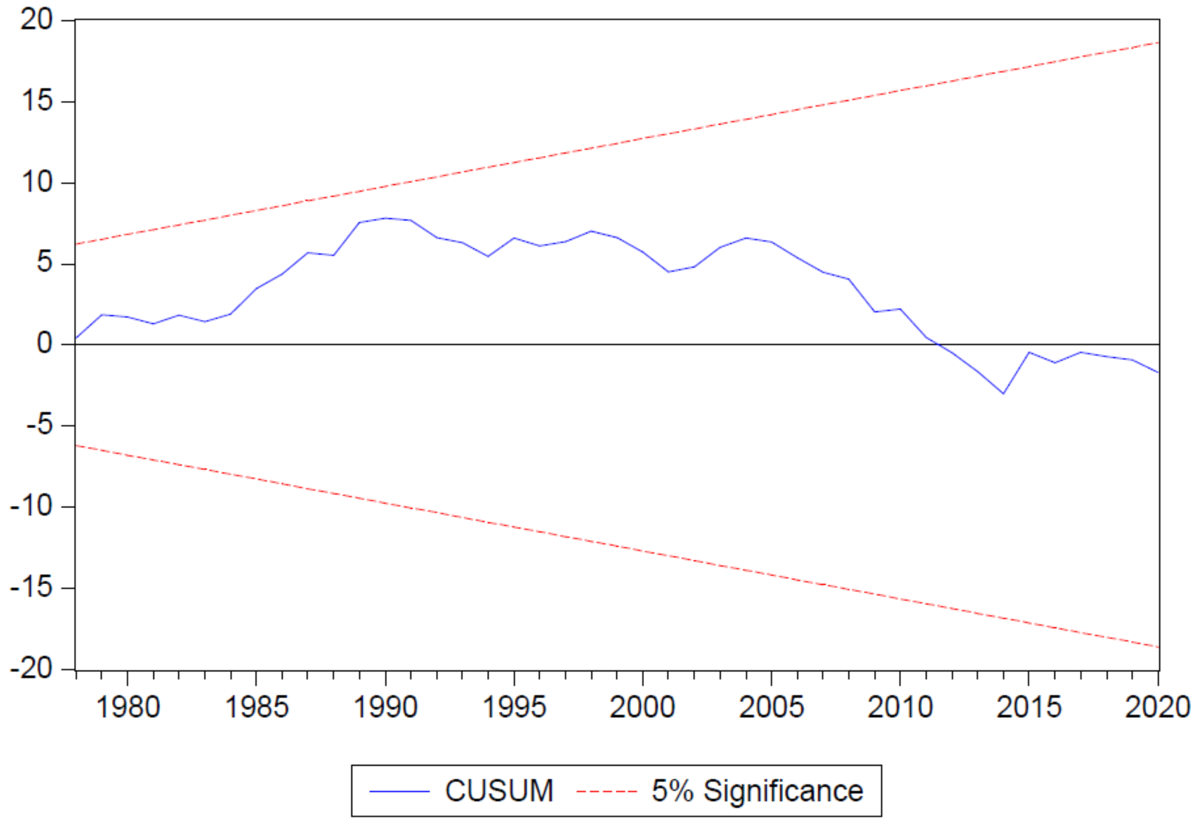

Figure 1: Cumulative sum of Square of recursive residuals

5. Conclusion

One of the key contributors to global climate warming has been CO2 emissions, and as a result, there has been extensive literature examining its factors. The findings revealed that coal consumption and GDP have a positive relationship with CO2 emissions, whereas renewable energy consumption and agricultural land area have a negative relationship in both the short and long run.

Recent years have witnessed a number of legislative and strategic policy modifications in Italy related to climate action. The June 2019 action plan for improving air quality contains various actions with the dual goals of controlling air pollutants and assisting with decarbonization initiatives. Air pollution standards are frequently surpassed in Italian urban areas. Additionally, the adoption of the Climate Decree into law in 2019 will further connect a number of Italian climate action initiatives with the EU Green Deal.

On February 13, 2021, Mario Draghi, the new prime minister of Italy, took the oath of office and immediately began rearranging the cabinet. Environment, ecosystems, and energy infrastructures, which were previously split between two ministries, have been reorganised under the Ministry of Ecological Transition in the new system. The renaming of the ministry in charge of transportation and other infrastructure as the Ministry of Sustainable Infrastructures and Mobility (MIMS) and the appointment of Enrico Giovannini, the co-founder and former spokesperson of the Italian Alliance for Sustainable Development, as minister are additional indications of the new administration's emphasis on sustainability.

A total of €62 billion (of which €41 billion comes from the Recovery and Resilience Facility) is set aside in Italy's national recovery and resilience plan for infrastructure projects that will be supervised by MIMS, including investments in housing, digitalization, and low-emission public transportation. Italy will co-chair the COP26 climate change conference in 2021 and serve as the host country for the pre-COP discussions in Milan in September before the conference's final gathering in Glasgow in November. The Italian Minister for Ecology Transition, Roberto Cingolani, stated in a conversation with US Special Envoy on Climate Change John Kerry that Italy was raising its 2030 emission reduction target to 60%.

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