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Effects of CO_2, Renewables and Fuel Prices on the Economic Growth in New Zealand

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ABSTRACT

This study investigates the impact of green policy initiatives on economic growth in the form of reduction in CO_2 emissions, fossil fuel consumption, and an increase in renewable energy in New Zealand for the period 1980-2019. Our study addresses two questions: First, whether New Zealand managed to achieve economic growth while simultaneously decreasing emissions and increasing renewables? and second, whether the New Zealand GDP per capita is sensitive to the changes in fuel prices at the international level. Our study provides empirical insights on green policy initiatives, which will help refine early mitigation actions and support a transparent public debate about longer-term desirable and feasible mitigation pathways. We use a range of time series estimation techniques after the pre-diagnostic's tests. The Johansen Cointegration test confirm long-term cointegration in the series. Our results from VECM suggests that the New Zealand economic growth and CO_2 emissions are sensitive to the changes in the renewables, fossil fuels, brent and Australian coal prices in the long run. While our results from the error correction term indicate that renewables have the flexibility and potential to correct the short-run inconsistencies in economic growth at a significant speed and ensures equilibrium in the long run. But the brent and the Australian coal are likely to cause discrepancies in the short term and after which the error corrections in the long-term equilibrium are unlikely to happen. We also undertake impulse response function for forecasting the effects of economic growth, CO_2 emissions, renewables, fossil fuels, brent and Australian coal on one another. Our results of economic growth on CO_2 emissions, show differential short and long-run effects. In comparison, a negative CO_2 emissions shock lasts for a brief period and triggers a very marginal short-term positive effect on economic growth and indicates that worsening or improving CO_2 emissions will play an essential role in determining the level of economic growth in New Zealand. Therefore, it is crucial to execute policies that ensure a negative shock in CO_2 emissions with long-term consequences on the economic growth with reduced emissions. Our study provides essential insights into the effectiveness of green initiatives on the economic growth of New Zealand.

Keywords: Climate Change, Carbon Emissions, Economic Growth, Renewable Energy
JEL Classifications: O56, P18, Q41, Q43, Q47, Q54

1. INTRODUCTION

New Zealand was a party to the United Nations Framework Convention on Climate Change (UNFCC) and a signatory to the Kyoto Protocol. It assumed a responsibility emissions reduction target for the first commitment period from 2008-2012 to reduce greenhouse gas emissions to their 1990 levels[1]. Further, it reiterated its commitment to the Kyoto Protocol by signing the Doha amendment agreement on November 30, 2015, described as the second commitment period. New Zealand aims to reduce emissions to 30% below 2005 levels by 2030. Therefore, it is vital to understand the green policy initiatives and their effects on CO_2 emissions, changes in the energy mix, and economic growth.

Our study addresses two questions: First, whether New Zealand achieved economic growth while simultaneously decreasing emissions and increasing renewables? Furthermore, second,

1 https://environment.govt.nz/what-government-is-doing/international-action/nz-united-nations-framework-convention-climate-change/

whether the New Zealand GDP per capita is sensitive to the changes in fuel prices at the international level. Therefore, we provide empirical insights on green policy initiatives that will help refine early mitigation actions and support a transparent public debate about longer-term desirable and feasible mitigation pathways (Sims et al., 2016).

Urban population agglomeration and industrialization describe a higher contribution to climate change and rising carbon emissions. (Raihan and Tuspekova, 2023). Global forums warn the adversaries of not reducing the greenhouse gas emissions on climate change. Therefore, urgent action by all the nations for saving the planet earth is vital. Emphasis is on setting up targets globally, at the national level for carbon emissions is one aspect of these green efforts to reduce carbon emissions. The Kyoto Protocol international treaty of 1997 came into force in 2005 as the United Nations Framework Convention on Climate Change (UNFCC). It urged the signatories to reduce the emission of six greenhouse gases in 41 countries plus the European Union to 5.2% below 1990 levels. The signatories assumed mandatory emission-reduction targets, depending on the unique circumstances of each country. At the same time, restrictions on emissions to developing countries, signatories to the UNFCC are relaxed. New Zealand has announced an unconditional target of –5% (below 1990 levels) by 2020, equivalent to a 2013-2020 QELRO (quantified emission limitation and reduction objectives) of 96.8 on 1990 emissions. New Zealand will apply the Kyoto Protocol framework of rules to its target to ensure actions are transparent and have integrity. New Zealand's conditional Copenhagen target range of reducing emissions between 10 and 20% by 2020 remains on the table, pending meeting those conditions (ETS 2012).

New Zealand Government considers Emissions Trading Scheme as a critical instrument for decreasing greenhouse gas emissions. Carbon pricing is used an instrument for reducing greenhouse gas emissions by utilizing the emissions trading system (ETS) and carbon tax methods (Rontard and Hernández, 2022). Emission units, sometimes called "carbon credits," are traded between participants in the Scheme. An emission unit can either represent one metric tonne of carbon dioxide or any other greenhouse gas equivalent. The primary unit of trade is created by the New Zealand Government and allocated to organizations and individuals participating in the Scheme. "Emissions trading" is a market-based approach for reducing emissions of greenhouse gases. The ETS puts a price on emissions by charging specific sectors of the economy for the greenhouse gases they emit. Those that emit greenhouse gases into the atmosphere have to surrender NZUs or other eligible emission units to the Government. While those that remove greenhouse gases from the atmosphere or New Zealand may earn NZUs from the Government. For example, owners of forests that absorb greenhouse gases or export products containing hydrofluorocarbons.

National emission trading programs are mixed in the Asia Pacific region. The carbon emissions trading system (ETS) is an important policy tool recognised by international community to achieve carbon-neutrality goals and promote carbon emission reduction by using a market mechanism (Tan et al., 2022).

Although the Tokyo Metropolitan Government has been operating a trading scheme for indirect CO_2 emissions since 2010, Japan has no plans to initiate a national emission trading system. Likewise, Australia abandoned its long-planned national ETS after a change in the government. While New Zealand's small ETS has been operating since 2008 and South Korea's emission policy has been in force since 2015 (WB, 2015). Extant literature identifies that the renewable energy development in New Zealand is less compared to other countries like Japan due to barriers that are specific to hydro, solar, geothermal, and wind.

In contrast, environmental and resource consent issues are significant factors in development (Kelly, 2011). A study from Suomalainen et al. (2015) provides insights on the trade-offs of developing wind power in different parts of New Zealand. This study provides valuable evidence on wind resource availability in critical periods of the year, such as dry seasons. It thereby enables identifying sites that can most optimally balance price volatility while potentially also maximizing profits to investors. While literature also shows that installing wind energy projects will support domestic energy demand and reduce the consumption of fossil fuels to produce energy (Jin et al., 2021). Prior studies on the long-term association between the GDP and CO_2 emissions (Vidyarthi, 2013, Zou, 2018; and Leitao 2014). Some studies show energy-induced growth (Leitao, 2014; Emir and Bekun, 2019; Duppati et al., 2023), while few studies show that reducing emissions by cutting down fossil fuels would restrict economic growth (Soytas and Sari, 2009), upgradation of technologies (Chang et al., 2015; Akram et al., 2020) or by increasing renewables in the energy mix (Zafar et al., 2019). Atkins et al., (2010), contributes to the literature by conducting Carbon Emissions Pinch Analysis (CEPA), which extends the standard thermal and mass pinch analysis to the realm of macro-scale (i.e. economy-wide) emissions targeting and planning. This methodology takes growing demand into consideration, as well as a carbon pinch study of the New Zealand electricity companies.

Our study adds to the literature, the experience of New Zealand on the effects of CO_2 emissions, renewables, fossil fuels, brent and Australian coal on the economic growth. We show that the crossover points in the Brent and Australian coal has implications for cleaner economic growth in New Zealand. A negative shock in Brent has a positive effect on renewables and a negative impact on fossil fuels and CO_2 emissions. These effects lead us to believe that the economic growth in New Zealand is sensitive to the changes in the oil and coal commodity prices and, therefore, can be moderated by reducing the dependencies on coal consumption and increase the renewable energies potentials. Our study provides empirical insights on green policy initiatives, which will help refine early mitigation actions and support a transparent public debate about longer-term desirable and feasible mitigation pathways.

The rest of the paper proceeds as follows: Section 2 provides a brief outline of the data and methodology used. We present our results in section 3 and we present our discussion and concluding remarks in section 4.

2. DATA AND METHODOLOGY

This paper examines the effects of climate change policy initiatives on economic growth in New Zealand for the period 1980 to 2019 following its commitment for reducing carbon emissions in international forums by using before and after method. We use time series data of New Zealand. Seven variables are selected for the model. Economic Growth is the Log of Gross domestic product (GDP) expressed as Billion $US/annum. Carbon Emissions ((×10^6 tonnes CO_2e/annum) are log transformed. Renewable energy and fossil fuels consumption are expressed as fraction of the total energy consumption. Total energy consumption is expressed in Exojoules/annum. Brent represents the price of the Brent oil benchmark in USD per barrel. Australia coal price are expressed. The natural gas is the price of the natural gas prices (US) in USD per million British Thermal Units. The Australian coal price is the price of the South African coal in USD per metric ton. The data of the brent, US-Natural gas and Australian gas is dawn from the Global Economy database. The data for the period 1980 to 2019 on the GDP, carbon emissions, renewables and non-renewables are obtained from multiple sources: the OECD (data.oecd.org), NZ Ministry of Business, Innovation, and Employment, World Bank data (data.worldbank.org) and BP Statistical Review.

2.1. Time Series Estimation Approaches

2.1.1. Pre-diagnostics tests

In order to examine the long-term association of CO_2 per capita emissions, fossil fuels, renewables, prices of brent and Australian coal on the GDP per capita of New Zealand in vector error correction model (VECM) framework, we undertake some pre-diagnostics tests like, testing the stationarity of the variables included in the VECM analysis and the cointegration of the series. This is important for drawing valid conclusions and to avoid a spurious regression phenomenon. We therefore conduct a unit root test for each variable before the analysis. This paper adopts the augmented Dickey-Fuller (ADF) tests.

The proposed null hypothesis for the series is nonstationary, or the series has a unit root. For all cases if critical value (which is based on Mackinnon, 1996) exceeds the calculated value in absolute terms (less in negative terms) null hypothesis will not be rejected implying that that series is nonstationary (Tiwari, 2012). These tests involve the testing of coefficient associated with 1 year past value of dependent variable. Differencing a series using differencing VECM is as follows: operations produce other sets of observations such as the first-differenced values, the second-differenced values and so on (Asari et al., 2011). We expect the series in the first difference to be stationary. If the variables used in this study are nonstationary and having same order of integration, we undertake cointegration analysis.

Johansen approach is one widely used method of conducting cointegration tests. Prior literature finds this approach particularly promising as it is based on the well-established likelihood ratio principle and precludes the limitations of single equation cointegration procedures (Arzie, 1996; Dickey et al., 1991) and its superiority over other single and multivariate techniques (Gonzalo, 1994). We therefore use Johansen and Juselius (1990). These procedures use two tests to determine the number of cointegration vectors: the First test is trace (λtrace) statistics and the second one is maximum eigenvalue (λtrace) statistics. The trace statistics tests the null hypothesis that the number of cointegrating relations is r against of k cointegration relations, where k is the number of endogenous variables. The maximum eigenvalue test tests the null hypothesis that there are r cointegrating vectors against an alternative of r +1 cointegrating vectors. Critical value for estimation has been obtained from Mackinnon, Haug, and Michelis (1999) which differs slightly from those provided by JJ. For both tests if the test statistic value is greater than the critical value, the null hypothesis of r cointegrating vectors is rejected in favor of the corresponding alternative hypothesis.

If the series are found to be cointegration then we apply the Vector Error Correction Model (VECM) for testing the long-term relationships and in the absence of cointegration we adopt grange causality tests to check the causal relationships between the variables. The regression structure for VECM estimation is given below:

$$\Delta\gamma_t = \alpha_1 + p_1 e_1 + \sum_{i=0}^{n} \beta i \Delta\gamma_{t-i} + \sum_{i=0}^{n} \delta i \Delta \times_{t-1} + \sum_{i=0}^{n} yiZ_{t-1} \quad (1)$$

$$\Delta \times_t = \alpha_2 + p_2 e_1 + \sum_{i=0}^{n} \beta i \gamma_{t-i} + \sum_{i=0}^{n} \delta i \Delta \times_{t-1} + \sum_{i=0}^{n} yiZ_{t-1} \quad (2)$$

The cointegration rank in the VECM indicates the number of cointegrating vectors. For instance, a rank of two indicates that two linearly independent combinations of the non-stationary variables will be stationary. A negative and significant coefficient of the ECM (i.e. et-1 in the above equations) indicates that any short term fluctuations between the independent variables and the dependent variable will give rise to a stable long run relationship between the variables (Asari et al., 2011).

3. EMPIRICAL ANALYSIS AND DISCUSSION

3.1. Unit Root Tests

The results presented in the Table 1 tests the null hypothesis that there is a unit root. The unit root ADF Test support the

Table 1: Results of the augmented Dickey-Fuller unit root test

Variables	T-statistics	Probability	Result
GDP per capita	2.0265	0.9884	Nonstationary
D.GDP per capita	−3.5331***	0.0008	Stationary
CO_2 per capita	0.6503	0.8524	Nonstationary
D.CO_2 per capita	−9.9324***	0.0001	Stationary
Fossil Fuels per capita	1.037	0.9184	Nonstationary
D.Fossil fuels per capita	−9.0834***	0.0001	Stationary
Renewables per capita	−0.2063	0.6052	Nonstationary
D.Renewables per capita	−9.7748***	0.0001	Stationary
Brent	0.1353	0.7195	Nonstationary
D.Brent	−5.8388***	0.0001	Stationary
Australia coal	0.2322	0.7454	Nonstationary
D.Australia coal	−6.7801***	0.0001	Stationary

***Significant at 1% using t-stat approach. GDP: Gross domestic product null hypothesis in the levels where the test statistics for all the variables is less than the 5% Critical values, suggesting the data as non-stationary. Therefore, the null hypothesis that there is a unit root should be accepted. While the results obtained from the first difference tests, indicate that the Test statistics is higher than the critical values at 5% level and therefore do not support the null hypothesis and accept the alternate hypothesis that there is no unit root in the data series and therefore the data is stationary. The Table 1 shows all the variables non-stationary at levels and are stationary in first differences.

We then perform the optimal vector autoregressive (VAR) lag order selection criteria and obtain in this paper is two. To proceed for cointegration first step is selection of appropriate lag length. Therefore, we have carried out a joint test of lag length selection for exports and import function separately, which suggests (basing upon SIC) we should take one lag of each variable[2].

3.2. Co-integration Tests

It is important to test the long-run relationships between the economic growth and the explanatory variables. Co-integration is therefore an important tool for modelling the long-run relationships in time series data. We perform Johansen co-integration test, because the variables are all stationary in the first-order differential sequence and co-integration relationship is likely to exist. The null hypothesis is no co-integrating equation among the variables and the alternate hypothesis implies that at least one co-integrating relationship exists. In other words, the test begins from r = 0 where there is no co-integration amongst the variables and accepts the first null hypothesis that is not rejected.

In the Table 2 below, the trace statistics at r = 0 of 125.12 exceeds its critical value of 95.75, we reject the null hypothesis of no co-integrating equation. Likewise, the trace statistics at r = 1 of 79.20 exceeds the critical value of 69.81 and the same is the case with the r = 2. We reject the null hypothesis that there is one co-integration relationship between GDP per capita and the climate change adaptation initiatives at 5% level of significance. While the trace statistics at r = 3, r = 4 and r = 5 are less than their critical values so we cannot reject the null hypotheses at these ranks. We, therefore, the Johansen Co-integration test results shows a long-term association among the GDP, energy consumption renewables and fossil fuels, commodity prices and carbon emissions.

Further, analysing the normalized co-integration coefficients in the VECM allows us to understand how the long-term relationship holds for the CO_2 emissions, renewables, fossil fuels and fuel prices on the GDP per capita. The results are displayed in the Table 3. We anticipate a stable equilibrium relationship to exist as we identified 2 co-integrating equations. In the first equation the results are normalized on the GDP per capita. The CO_2 emissions and renewables have negative association with the GDP per capita at 1% and 5% levels of significance. While the fossil fuels and Brent have a positive association with GDP per capita at 1% level of significance. The second panel of Table 3 presents the long run cointegration of the second equation showing long run association of fossil fuels, renewables, and fuel commodity prices with CO_2 emissions. These long run equilibrium relationships are examined by normalising the CO_2 emissions. Our results indicate that the fossil fuels, renewables and Brent oil prices have negative association with CO_2 emissions, at 1% level of significance, while the Australian coal has negative association at 1% level. It is evident that the changes in the carbon emissions are substantially associated to fossil fuels, renewables, brent and the Australian coal prices in the long run and can predict the changes in the CO_2 emissions in New Zealand.

It is evident from Table 3 that in all cases, there is strong evidence for the presence of one cointegration vector i.e., stable long run relationship exists among the variables in two equations. We now present long run cointegrating equation in Table 4. It is evident from Table 4 that there exists cointegration between the endogenous and dependent variables as shown under cointegration equation one and two.

For the first cointegration equation our interpretation of the coefficients is that a 1% increase in fossil fuels and Australian coal will lead to 57.73% and 48.57% decrease in the GDP per capita, and a 1% increase in renewables and brent will increase the GDP per capita by 217.51% and 21.02% in the long run. These results

2 Results of lag length selection can be obtained by request to the authors.

Table 2: Results of the Johansen co-integration test

Maximum rank	Number of CE (s)	Eigen value	Trace statistics	5% critical value	Probability**
Panel A: Unrestricted cointegration rank test (trace)					
R=0	None*	0.7109	125.1229	95.7537	0.0001
R=1	At most 1*	0.6762	79.2028	69.8189	0.007
R=2	At most 2	0.3348	37.4798	47.8561	0.3253
R=3	At most 3	0.3093	22.3912	29.7971	0.2773
R=4	At most 4	0.1434	8.6956	15.4947	0.3943
R=5	At most 5	0.0771	2.9701	3.8415	0.0848
Panel B: Unrestricted cointegration rank test (maximum Eigen value)					
R=0	None*	0.7109	45.9200	40.0776	0.0098
R=1	At most 1*	0.6762	41.7231	33.8769	0.0047
R=2	At most 2	0.3349	15.0886	27.5843	0.7412
R=3	At most 3	0.3094	13.6955	21.1316	0.3905
R=4	At most 4	0.1434	5.7255	14.2646	0.6487
R=5	At most 5	0.0771	2.9701	3.8415	0.0848

Trace test indicates, and maximum-Eigen value test indicates supports the rejection of the hypothesis at 5% level of significance suggests that the GDP per capita is sensitive to the changes in the renewables, fossil fuels, brent and Australian coal prices. While for the second cointegration equation coefficients suggest that a 1% increase in fossil fuels, renewables and brent will lead to 71.73%, 67.72% and 16.25% decrease in the CO_2 emissions, and a 1% increase in Australian coal will increase the CO_2 emissions per capita by 19.45% in the long run. These results suggests that the GDP per capita in the first equation and CO_2 emissions in the second cointegration equation are sensitive to the changes in the renewables, fossil fuels, brent and Australian coal prices.

It is evident from Table 5 that cointegration coefficient i.e., error correction term of renewables is negative and significant at 1% level, while brent and Australian coal are positive and significant at 1% levels for equation 1. Further the equation 2, indicates the error correction term of CO_2 emissions as negative and significant at 1% level while brent and Australian coal are positive and significant at 1% levels. A negative and significant value of error correction term indicates that in the next period any disturbance in the corresponding dependent variable will get corrected by the amount of the coefficient value. Conversely, a positive and significant value of the error correction term indicates that any disturbance in the dependent variable will diverge from the equilibrium by the amount of the coefficient value.

For example, when dependent variable is renewables corresponding to it value of error correction term is –0.5618, it implies that any previous periods deviations from the long run equilibrium is corrected in the current period at an adjustment speed of 5.61% in the next year. Further, our results also show that one year lag value of GDP per capita has positively significant impact on the GDP per capita itself at 5% level. While two year lag value of Australian coal has positive and significant impact on the CO_2 emissions at 5% level 9although results are not displayed, they may be obtained from the authors).

3.3. Post-Diagnostics Tests

To determine the robustness of the model, diagnostic tests are implemented in Table 6. We examine whether there are any issues associated with normality, autocorrelation, serial correlation, and heteroscedasticity, we perform post diagnostics test. we have carried out diagnostic checks analysis employing LM test for serial correlation, and J-B test of normality of residuals (Tiwari, 2012). Results of diagnostic checks are reported in the following Table 6.

Impulse response functions summarize the impact of one variable on another as shown in the Figure 1. In essence, they assume a theoretical/hypothetical shock to one variable and display how this shock propagates throughout the other variables. The Figure 1

Table 3: Cointegrating equation of climate change initiatives on economic growth (gross domestic product per capita)

GDP per capita	CO_2	Fossil	Renewables	Brent	Aus-Coal
1. Cointegrating equation					
1	−2.4954 (0.2936) 8.49903***	−2.3671 (0.2384) 9.9282***	−0.4851 (0.2321) 2.090**	0.1954 (0.0435) 4.4936***	0.0003 (0.0559) 0.0049
2. Cointegrating equation					
1	0	0.5772 (0.1345) [4.2901]***	−2.1752 (0.4281) [5.0808]***	−0.2103 (0.0868) [2.4211]**	0.4858 (0.1118) [4.1203]***
0	1	0.7173 (0.0569) [12.5912]***	0.6772 (0.1813) [3.7358]***	0.1626 (0.0368) [4.4201]***	−0.1946 (0.0473) [4.1098]***

***Rejection of the hypothesis at the 0.01, **At 0.05 level. Z-statistics are provided in square brackets. Normalized cointegrating coefficients (SE in parentheses). Null hypothesis is no cointegration among the variables. Source: Author's calculation. SE: Standard error

Table 4: Long run results of cointegration equation analysis

Dependent variables			Endogenous variables			
			Fossil	Renewables	Brent	Aus-Coal
Cointegration equation 1 GDP per capita	1	0	−0.5772*** [−4.1957]	2.1751*** [4.969]	0.2102** [2.3677]	−0.4857*** [−4.2501]
Cointegration equation 1 CO_2	0	1	−0.7173*** [−12.3137]	−0.6772*** [−3.6537]	−0.1625*** [−4.3225]	0.1945*** [4.0197]

***,** and *Significant at 1%, 5%, and 10% level respectively. Source: Author's calculations. T-values are given in the squared brackets [ ] and coefficients are presented in the top row

Table 5: Vector error correction model Engle-Granger causality analysis

Error correction	D (GDP per capita)	D (CO_2)	D (fossil)	D (renewables)	D (brent)	D (Aus-coal)
Cointegration equation 1	−0.0779 [−1.1118]	−0.2549 [−1.4963]	−0.3149 [−1.3203]	−0.5618*** [−3.1322]	1.9083** [2.1657]	2.6744*** [3.0922]
Cointegration equation 2	−0.0637 [−0.3887]	−1.0549** [−2.6453]	−0.9187 [−1.6455]	−0.4815 [−1.1471]	5.2051** [2.5241]	5.8565** [2.8933]
C	0.0069 [1.5898]	0.0073 [0.6912]	0.0110 [0.7403]	0.0043 [0.3848]	0.0329 [0.5989]	0.0538 [0.9983]
R^2	0.5316	0.6331	0.4686	0.7254	0.5769	0.5722
Adjusted R^2	0.2336	0.3996	0.1304	0.5507	0.3077	0.3000
F-statistic	1.7840	2.7115	1.3858	4.1517	2.1433	2.1022

***,** and *Significant at 1%, 5%, and 10% level respectively, "d" denotes first difference, In "[ ]" T-values. Source: Authors calculation presents 10 years forecasts of error correction impulse responses. It is evident from Figure 1a that any innovation in the GDP will have negative impact/response of nearly 0.0 to –0.1 on the CO_2 emissions, fossil fuels and –0.1 to < –0.2 for renewables. However, the impact lasts for only one and a half year and then turn towards positive direction for CO_2 emissions and Fossil fuels to above 0.00, while the negative impact on renewables continues to drop further for a period of four years and then become persistent for six years period. Figure 1b presents responses of the GDP per capita, fossil fuels, renewables, brent and Australian coal to one S.D. shock/innovation in the CO_2 Per Capita emissions. A one S.D. shock (innovation) causes CO_2 emissions to drop from 0.04 to.02 in one and half year and with some fluctuations between third and fifth year, it then rises upwards and goes beyond 0.04 in the tenth year. The fossil fuels follow similar pattern of the CO_2 emissions while the have marginal effects with minimum drops around fifth year but moves upwards and remains on –0.2 level. While the GDP per capita drops below -0.02 towards the end of the 10th year.

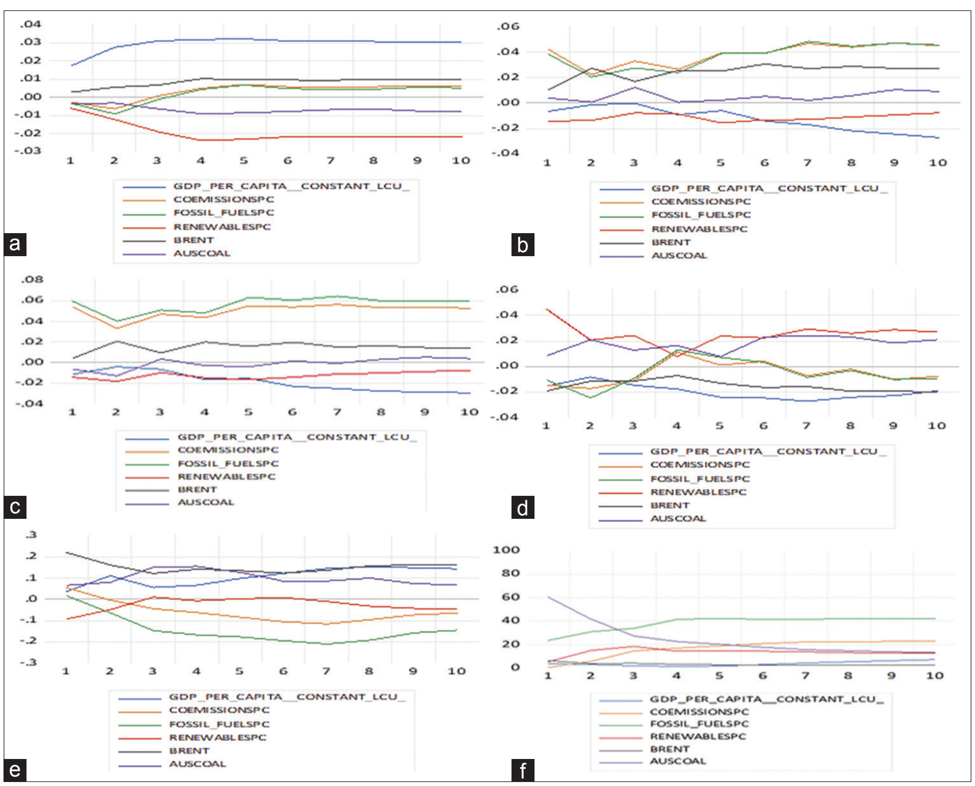
Table 6: Diagnostic checks for analysing the effectiveness of NZ climate change policy initiatives

Tests	Df	Rao F-Statistics	P
VEC residual serial correlation LM tests			
Lag 1	36	0.6702	0.8955
Lag 2	36	1.7622	0.0310
Lag 3	36	0.7589	0.8067
VEC residual JB normality tests	**Df**	**Jarque-Bera**	**Probability**
Component 1	2	0.4369	0.8038
Component 2	2	2.7372	0.2545
Component 3	2	8.1084	0.0173
Component 4	2	0.7945	0.6721
Component 5	2	0.6748	0.7137
Component 6	2	4.9114	0.0858
Joint	182	173.9868	0.6522

Source: Authors calculation. VEC: Vector error correction

Figure 1c presents responses of the GDP per capita, CO_2 emissions, renewables, brent and Australian coal to one S.D. shock/innovation in the fossil fuels. A one S.D. shock (innovation) causes fossil fuels to drop from 0.6 to.04 in one and half year and with some fluctuations between third and fifth year, it then rises upwards and goes beyond 0.06 and plateaus there from fifth year until the tenth year. The CO_2 emissions follow similar pattern of the fossil fuels. While the GDP per capita drops from 0.02 to below -0.02 in fifth year and continues to drop further nearly to nearly -0.03 towards the end of seventh year and reaches nearly −0.04. Figure 1d presents responses of the GDP per capita, fossil fuels, CO_2 emissions, brent and Australian coal to one S.D. shock/innovation in the Renewables. A one S.D. shock (innovation) causes renewables to drop from 0.04 to.02 in one and half year and with some fluctuations between third and fifth year, it then rises upwards and goes beyond 0.04 in the tenth year. The fossil fuels follow similar pattern of the CO_2 emissions drops around fifth year but moves upwards and remains on −0.2 level. While the GDP per capita drops below -0.02 towards the end of seventh year and

Figure 1: VECM forecast error-correction impulse responses. (a) Response of GDP per capita to innovations. (b) Response of CO_2 emissions to innovations. (c) Response of fossil fuels to innovations. (d) Response of renewables to innovations. (e) Response of brent to innovations. (f) Response of Australian coal to innovations. Note: (a) Response of NZ GDP per capita to generalised one SD innovations; (b) Response of NZ CO_2 emissions per capita to generalised one SD innovations; (c) Response of NZ fossil fuels per capita to generalised one SD innovations; (d) Response of NZ renewables per capita to generalised one SD innovations and (e) Response of brent to generalised one SD innovations.



gradually rises upwards towards the tenth year and reaches −0.02. Figure 1e presents a one S.D. shock (innovation) causes brent to drop from 0.2 to 0.1 in three years' time and but then gradually recovers and increases and settles above 0.1 towards the end of the 10 year. The Australian coal shows inverse response to one SD shock in brent. When the Australian coal drops the fossil fuels and CO_2 emissions rises and GDP per capita rises, while renewables drop to nearly −0.01.

4. DISCUSSION AND CONCLUSIONS

Our impulse response functions show the impact of one variable on another graphically. We find that a positive shock to GDP per capita causes an initial decrease in CO_2 emissions for a short period of fewer than two years and rebounds and increases in the longer term for nearly eight years. These responses imply that the impact of economic growth on CO_2 emissions in New Zealand is multifaceted, with differentiated short and long-run effects. In the short run (approximately up to 2 years after the GDP per capita shock), higher levels of economic growth will result in decreased CO_2 emissions. However, the effect is positive in the long run. These impulse response effects suggest that economic growth is clean with reduced emissions in the short run, but economic growth leads to increased CO_2 emissions over time. We observe some exciting findings when we consider the impact of a negative CO_2 shock in Figure 1b. A negative shock in CO_2 emissions lasts for a brief period of two years and has a very marginal short-term positive impact on the economic growth (GDP per capita). Subsequently, a positive shock in CO_2 emissions causes economic growth to drop moderately (nearly two years). These responses lead us to believe that worsening or improving CO_2 emissions will play an essential role in determining the level of economic growth in New Zealand. Therefore, it is crucial to execute policies that ensure a negative shock in CO_2 emissions and are long-lasting and aligns with prior evidence (Dong et al., 2018). Thus, they have positive longer-term consequences on economic growth in a clean environment with reduced emissions. These responses pose a vital insight and challenge for policymakers.

We observe some thought-provoking findings when we consider the impact of a negative shock on renewables in Figure 1d. A negative shock in renewables lasts for a brief period of two years and causes a positive impact on economic growth (GDP per capita). Subsequently, a positive shock in renewables triggers economic growth to drop moderately. This effect on the economic expansion continues even after a bounce in renewables following a positive shock. These responses lead us to believe that the impact of renewables on the economic growth in New Zealand is complicated with differentiated in the short run but has positive effects in the long run. Therefore, it is essential to note that the positive outcome from renewable sources involves more extended gestation periods. These findings address the first question raised in this paper, i.e., whether New Zealand achieved economic growth while simultaneously decreasing emissions and increasing renewables? Revisiting the current policies and desirable actions by policymakers are of vital importance. When we consider the impact of a negative shock on Brent in Figure 1e we observe some challenging findings. A negative shock in Brent lasts for nearly three years and causes a positive effect on the economic growth (GDP per capita) for 2 years, and then it declines in the third year but rebounds when the negative shock remains persistent.

Further, it is essential to note that a small shock in Brent makes Australian coal stretch substantially. The crossover points in the Brent and Australian coal has implications for economic growth. Further, negative shock in Brent has a positive effect on renewables and a negative impact on fossil fuels and CO_2 emissions. These effects lead us to believe that the economic growth in New Zealand is sensitive to the changes in the oil and coal commodity prices and, therefore, can be moderated by reducing the dependencies on coal consumption and increase the renewable energies potentials.

We find a stable equilibrium association (negative) between economic growth and CO_2 emissions, economic growth, and renewables at 1% and 5% significance levels. At the same time, fossil fuels and Brent have a positive association with economic growth at a 1% level of significance. We also find a long-run association (negative) between CO_2 emissions and fossil fuels, renewables, and Brent at a 1% level of significance and a positive association between CO_2 emissions and Australian coal in the long run. Further, the error correction term suggests that renewables have the flexibility and potential to correct the short-run inconsistencies in economic growth at a significant speed that adjusts deviation from the equilibrium in the long run. At the same time, Brent and Australian coal are likely to cause discrepancies in the economic growth in the short term. After that, the error corrections in the long-term equilibrium are unlikely to happen. Our results inform policymakers to develop policies that increase investment in the renewable energy sector by giving investors tax relief and financial incentives. Renewable energy consumption helps in attaining a cleaner environment by decreasing carbon emissions. Therefore, our study provides important insights into the effectiveness of green initiatives on the economic growth of New Zealand. Policymakers must now consider how to achieve cleaner economic growth in New Zealand.

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