Dynamic Interaction between Economic Indicators, Technology and CO_2 Emissions in New Zealand

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ABSTRACT

Serious damage to the environment is an inevitable consequence of worldwide improvements in the standard of living. Consequently, unrestrained and limitless economic growth is a result of an increase in environmental pollution. In this study we therefore aim at investigating the relationship between the level of CO_2 emissions and some key economic and technology-related determinants by using ARDL econometric approach and annual data from 1971 to 2013 in New Zealand. The analysis incorporated the effects of real GDP per capita, energy consumption per capita, financial development index, trade openness index, and fossil fuel consumption ratio as a proxy for technology on per capita CO_2 emissions. The empirical findings show that there are significant positive causalities from GDP and energy consumption toward CO_2 emissions which are in line with findings in previous studies. However, the financial development and trade openness indicate notable negative influences on emission levels implying that their improvements help to decrease New Zealand's emissions. Furthermore, we observe strong positive correlation between fossil fuel consumption ratio and carbon emissions. In this regard, we argue that the technological improvements can stimulate demand for more low-carbon energy sources. This, in turn, increases economic efficiency and provide effective factors of production.

1. Introduction

Exploring the current environmental issues, economists agree that factors affecting economic growth continue to be a subject of considerable controversy. Almost all economic activities relating to the environment directly or indirectly affect the ecological system, and thus the activities can damage the environment in various stages of extraction, production, transportation, and consumption. The impact of human activities on the ecological system increases as the level of human activities progress. Economic growth requires an expansion of energy and raw materials which can lead to a higher degree of environmental degradation and the loss of environmental quality. However, human beings are not capable of engaging in economic activities if ecological system ends its run.

Since the economy is an open system, three main stages (extraction, production, and consumption) all generate end products that ultimately return the waste to the environment (air, water or earth). So macroeconomic indicators cannot be separated from the environment in which economic activities are going on and from the society that provides the public needs of its members. There is plenty of waste in the wrong place at the wrong time that can cause biological changes in the environment, which in turn can affect the animals living and plants there, as well as the structure of the entire ecosystem. Economists believe that economic pollution would occur if environmental degradation and its damaging consequences affected human health.

Economic activity can be considered as a process of energy transformation in connection with materials conversion. As materials and energy cannot be destroyed in any absolute sense, they emerged in the form of waste which will be eventually returned to the environment. Therefore, the more economic gains are achieved, the more waste will be produced. Economic growth is estimated in terms of an increase in national output, or gross national product (GNP). Along with economic growth, the amount of waste is also expected to increase compared to the limited capacity of the natural environment for storing the waste. Furthermore, serious damage to the environment is an inevitable consequence of worldwide improvements in the standard of living. Consequently, unrestrained and limitless economic growth is a result of an increase in environmental pollution.

The name and nature of sustainable development suggest that environmental quality and overall services provided by the natural resources and environment overweight expectations of economic development planning. Hence sustainable development with respect to environment offers a concise overview of natural and synthetic environments. Therefore, economic policies play a significant role in preventing pollution.

In terms of environmental sustainability index (ESI), New Zealand was ranked in 11th place among 180 countries in 2016 (Columbia University, 2016). The current study investigates the impact of the gross domestic product, energy consumption, financial development, trade openness and fossil fuel consumption ratio on New Zealand's carbon dioxide emissions. According to the current debates concerning global warming, air quality and other serious environmental issues, the analysis of the relationship between economic and environmental indicators helps New Zealand policy makers and planners to address socially and environmentally viable policy options.

2. Review of the Literature

There is a huge literature addressing the environmental quality and economic growth nexus. Various studies have been conducted to examine the validity of inverted-U relationship between environmental degradation and economic growth, known as the Environmental Kuznets curve (EKC), which was addressed by Grossman and Krueger (1991). However, the empirical findings of the existing literature vary across studies due to the diversity in economic structures across the countries and the use of different econometric models. Therefore, the literature utilises control variables such as energy consumption (Ang, 2007; Alam et al., 2007), foreign trade (Halicioglu, 2009), population growth and growth of electricity demand (Tol et al., 2009), financial development (Tamazian et al., 2009), foreign direct investment (Pao and Tsai, 2011), trade openness (Managi et al., 2009; Shahbaz et al., 2013a; Shahbaz et al., 2013b), urbanization (Dhakal, 2009; Sharma, 2011; Farhani and Ozturk, 2015) to eliminate any specification bias. Nonetheless, results differ for model components across studies.

Regarding carbon emissions in BRIC countries (Brazil, Russia, India, and China), Tamazian et al. (2009) adopted a reduced-form modelling approach with Panel data over 1992–2004 to investigate the impact of financial development on carbon emissions. The results demonstrated that both financial development and economic growth decreases environmental degradation. Furthermore, they argue that adopting financial liberalization policies could play an important role in cutting CO_2 emissions by funding R&D projects in these economies.

Similarly, by estimating the efficiency of advanced financial system and institutional quality in cutting carbon emissions in 24 transition economies, Tamazian and Rao (2010) pointed out the importance of a robust institutional framework in increasing environmental quality.

On the other hand, in other studies, including Frankel and Romer (1999), Dasgupta et al. (2001), Sadorsky (2010), Zhang (2011) and Al-Mulali et al. (2015), financial development decreases environmental quality. Zhang (2011), for instance, asserts that households have higher tendency to purchase energy-intensive items with the aid of financial intermediation.

Some studies shed doubt on whether financial development have been effective at reducing carbon dioxide emissions. Using an ARDL[1] bounds testing approach, Jalil and Feridun (2011) and Ozturk and Acaravci (2013) found no meaningful long-term causality from financial developments to CO_2 emissions and vice versa. However, they showed that economic growth and energy consumption have positive effect on emission levels and confirmed the EKC hypothesis in the case of China and Turkey.

In terms of foreign direct investment, Pao and Tsai (2011) adopted panel cointegration approach with Granger causality test to investigate the impact of FDI, GDP, and energy use on CO_2 emissions in BRIC countries. Their findings suggest that FDI has no significant long-term impact on environmental quality. Nonetheless, energy consumption and GDP are the main contributors to pollution. Moreover, the EKC hypothesis is confirmed.

Using time series data for newly industrialized countries (NIC), Hossain (2011) have indicated that there are short-run causal relationships running from urbanization to GDP and from GDP to CO_2 emissions. Similarly, Sharma (2011) analysed the key determinants of CO_2 emissions for a panel of 69 countries. The results demonstrate a negative relationship between urbanization and CO_2 emissions while GDP and energy consumption show positive impacts on pollution. Farhani and Ozturk (2015), however, claim a significant and positive long-term

[1] Auto regressive distributed lag

link between urbanization and carbon emissions in Tunisia applying ARDL bounds testing approach.

To examine the effect of trade openness on environmental quality, Managi et al. (2009) used instrumental variables technique. With a mixed results for the OECD and non-OECD countries, they found that freer trade decreases emissions in OECD countries and adds emissions in non-OECD countries. Furthermore, they concluded that in the presence of effective environmental regulatory, the quality of the environment will be improved. Shahbaz et al. (2013a) for Malaysia, Shahbaz et al. (2013b) and Kohler (2013) for South Africa, likewise, confirmed that trade openness is beneficial for environmental quality. In this regard, according to Shahbaz et al. (2013b), improvements in environmental performance is achievable by pursuing trade liberalization policies.

In contrast, other studies claim that trade openness has contributed to environmental degradation. Loi (2012) explored the relationship between trade liberalization and environmental quality for six Asian countries over the period of 1980-2006. The study found that the trade has negative environmental effect. More recently, in the same way, Farhani and Ozturk, (2015) have investigated the validity of EKC and the long-term impact of some key economic indicators including trade openness on carbon dioxide emissions in Tunisia. The results obtained from their study reveal that the long-run coefficient of trade openness variable has a positive sign, meaning that freer trade increases emissions in Tunisia. However, the t statistic for the same coefficient is negative in sign and does not match with their conclusion.

3. Methodology

3.1 Model Specification

In the light of previous literature on the impact of economic activities on fuel consumption and level of emissions, in this section, we set up a time-series econometric model to examine the long-run relationship and causality issues between the level of CO_2 emissions in New Zealand and some determinant variables. The proposed relationship between the carbon dioxide emission and its determinant variables is defined as follows;

$$CO_2 = f(GDP, EU, FD, TR, FFC)\ , \qquad (1)$$

where, CO_2 is total carbon dioxide emissions in metric tons per capita, GDP is real GDP per capita in constant 2005 US$, EU is energy use (kg of oil equivalent per capita), FD is financial development indicator measured using domestic credit to private sector as share of GDP, TR is Trade openness (measured using exports and imports as share of GDP), and FFC is fossil fuel energy consumption (as share of total energy consumption) as a proxy to technology improvements in New Zealand.

According to the literature, economic growth has a direct positive effect on energy use and emissions (Ang, 2007; Apergis and Payne, 2009; Acaravci and Ozturk, 2010). This is because countries are demanding more energy resources, especially fossil fuels to achieve their macroeconomic targets. Thus, a positive relationship between emissions and GDP is hypothesized. Moreover, it is expected that positive correlation exists between emissions and energy consumption. Whether the economies are developing, emerging or developed, the energy supply plays a very crucial role in maintaining or improving the production level.

The literature mostly uses energy consumption and economic growth as the main components in the emission model. However, in some studies, financial development is used as an important determinant of environmental performance (Shahbaz et al., 2013a,b; Tamazian et al., 2009; Tamazian and Rao, 2010). A well-designed financial sector could attract domestic and foreign investments, which would stimulate economic growth and, hence, affect the environmental quality (Frankel and Romer, 1999). Thus, a negative causation from financial developments to CO_2 emissions is expected.

Trade openness is another very important component and plays a central role in the model since New Zealand is a trade-dependent economy. The country heavily relies on open trade agreements with its trade partners. Therefore, more trade liberalization policies could lead to attracting more direct investments in trade-exposed sectors, which in turn could lead to more efficient use of resources (King and Levine, 1993; Tadesse, 2005). So, by expanding bilateral trade we expect an impact similar to financial developments in the long-term.

Moreover, in order to capture the impact of technological changes on emission levels, we include the consumption of fossil fuels as a share of total energy consumption. Although New Zealand imports the majority of energy in the form of petroleum products, introducing and maintaining renewable energy technologies has helped the country to experience a consistent growing in renewable energies while the non-renewable energy ratio decreased. Thus, the study aims to examine the impact of historical changes in technology on emission levels with an assumption that there could be a potential positive relationship between FFC (fossil fuel consumption) and CO_2. Indeed, this study is the first attempt to incorporate the ratio of fossil fuel consumption as a separate determinant of CO_2 emissions in the analysis.

The long-run relation among the variables is specified as follows (ln represents the natural logarithm):

$$lnCO_{2_t} = \alpha_1 + \alpha_2 lnGDP_t + \alpha_3 lnEU_t + \alpha_4 lnFD_t + \alpha_5 lnTR_t + \alpha_6 lnFFC_t + \varepsilon_t \quad (2)$$

with sign expectation;

$\alpha_2 > 0$, $\alpha_3 > 0$, $\alpha_4 < 0$, $\alpha_5 < 0$ and $\alpha_6 > 0$

where,

CO_{2_t}= Total carbon dioxide emissions in metric tons per capita in time ‘t’

GDP_t= Real GDP per capita in constant 2005 US$ in time ‘t’

EU_t= Energy use (kg of oil equivalent per capita) in time ‘t’

FD_t= Financial development indicator, domestic credit to private sector (% of GDP) in time ‘t’

TR_t= Trade openness indicator, measured by dividing the sum of exports and imports (volume of trade) by GDP in time ‘t’

FFC_t= Fossil fuel energy consumption (as share of total energy consumption) in time ‘t’

ε_t= The error term in time ‘t’

3.2 Data Source

To carry out this study, annual time series data for the period of 1971-2013 are considered. The data on CO_2 emissions (CO_2, in metric tons per capita), real GDP per capita (GDP, in constant 2005 US$), energy use (EU, in kg of oil equivalent per capita), financial development indicator (FD, domestic credit to private sector as share of GDP), trade openness (TR, exports and imports as share of GDP), and fossil fuel energy consumption (FFC, fossil fuel energy consumption as share of total energy consumption) are taken from the World Development Indicators (WDI) online database.

3.3 Econometrical Methodology

In this study, the bound testing approach based on the estimation of auto regressive distributed lag model (ARDL) methodology used to investigate the causal linkage between CO_2 emissions and some key determinants in the short-run, in the long-run, and overall. This method has been used as an alternative cointegration test that examines the long-run relationships and dynamic interactions among the variables. This approach has several desirable statistical features. First, the cointegrating relationship can be estimated easily using OLS after selecting the lags order of the model. Second, it allows testing simultaneously for the long and short–run relationships between the variables in a time series model. Third, in contrast to the Engle-Granger and Johansen methods, this test procedure is valid irrespective of whether the variables are I(0) or I(1) or mutually co-integrated, which means that no unit root test is required. However, this test procedure will not be applicable if an I(2) series exists in the model. Fourth, in spite of the possible presence of endogeneity, ARDL model provides unbiased coefficients of explanatory variables along with valid t-statistics. In addition, ARDL model corrects the omitted lagged variable bias (Inder, 1993). Furthermore, Ma and Jalil (2008) and Ang (2010) argue that the ARDL framework includes sufficient numbers of lags to capture the data generating process in general to specific modelling approach of Hendry (1995). Finally, this test is very efficient and consistent in small and finite sample sizes.

3.4 The ARDL Approach's Procedures

In general, the unit root test is a formal preparation test before we proceed to cointegration tests. Here, in order to tests for presence or absence of unit root we employ the Augmented Dickey Fuller (ADF). Augmented Dickey-Fuller (ADF) unit root tests are computed for each series to examine whether the variables are stationary and integrated of the same order.

The ARDL approach to co-integration involves several steps. The first step is the bounds test, which involves estimating the conditional unrestricted error correction model (UECM) to test for the existence of a long-run steady state relationship between the dependent variable and all the explanatory variables.

$$\Delta lnCO_{2_t} = \delta_0 + \sum_{i=1}^{p} \delta_1 \Delta lnCO_{2_{t-i}} + \sum_{j=0}^{q} \delta_2 \Delta lnGDP_{t-j} + \sum_{k=0}^{r} \delta_3 \Delta lnEU_{t-k} + \sum_{l=0}^{s} \delta_4 \Delta lnFD_{t-l} + \sum_{m=0}^{v} \delta_5 \Delta lnTR_{t-m} + \sum_{n=0}^{w} \delta_6 \Delta lnFFC_{t-n} + \beta_1 lnCO_{2_{t-1}} + \beta_2 lnGDP_{t-1} + \beta_3 lnEU_{t-1} + \beta_4 lnFD_{t-1} + \beta_5 lnTR_{t-1} + \beta_6 lnFFC_{t-1} + \varepsilon_t \quad (3)$$

where p, q, r, s, v, w are the maximum number of lags in the ARDL estimation, Δ is the first difference operator; and δ_0 is a drift component. The $\delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6$ parameters correspond to the short-run relations, whereas $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ correspond to the long-run relations; ε_t is random errors and assumed to have a mean value of zero and to be uncorrelated with the independent variables.

The Wald or F-statistic is used to test the joint significance of lagged levels of the variables in the UECM, and determine the existence of the long-run equilibrium under the null hypothesis of no co-integration ($H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$) against the alternative that a long-run relation exists ($H_1: \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$) in Equation (3). However, as discussed by Pesaran et al. (2001), both statistics have no standard distribution, irrespective of whether the regressors are purely I(0), purely I(1) or mutually co-integrated. Therefore, Pesaran et al. (2001) computed two types of asymptotic critical values for a given significance level in the case of including and excluding trend. The first type assumes that all the variables are I(1), and the other assumes that all the variables are I(0). If the computed Wald or F-statistics exceed the upper critical value, the null hypothesis is rejected and the underlying variables are cointegrated. If the Wald or F-statistics are below the lower critical value, the null cannot be rejected and the variables are not co-integrated. Finally, if the Wald or F-statistic values lies between the two bounds, the test is inconclusive, and further investigation on the integration order of all the variables is required to determine whether the variables are I(0) or I(1). The value of these critical values depends on the number of regressors and whether the ARDL model contains intercept or intercept and trend (Pesaran et al., 2001).

Once a long-run relationship has been established in the first step using the bounds test, the long-run and the associated short-run relationships can be estimated in the next stage. First, the optimal number of lags for all level variables in the ARDL model is selected using the appropriate information criteria. Then, we can proceed to estimate the ARDL (p, q, r, s, v, w) as in Equation (4).

$$lnCO_{2_t} = \gamma_0 + \sum_{i=1}^{p} \gamma_1 lnCO_{2_{t-i}} + \sum_{j=0}^{q} \gamma_2 lnGDP_{t-j} + \sum_{k=0}^{r} \gamma_3 lnEU_{t-k} + \sum_{l=0}^{s} \gamma_4 lnFD_{t-l} + \sum_{m=0}^{v} \gamma_5 lnTR_{t-m} + \sum_{n=0}^{w} \gamma_6 lnFFC_{t-n} + \rho_t \quad (4)$$

where p, q, r, s, v, w are the optimal lags of level of the regressors CO_2, GDP, EU, FD, TR, and FFC respectively, γ_0 is a drift term, and $\gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5$, and γ_6 are the long-run elasticities in the CO_2 emissions model to be estimated using the general to specific approach (Hendry, 1995).

By normalizing Equation (4) on CO_2 emission levels, the static long-run parameters can be obtained as in Equations (5).

$$lnCO_{2_t} = \tau_0 + \tau_1 lnGDP_t + \tau_2 lnEU_t + \tau_3 lnFD_t + \tau_4 lnTR_t + \tau_5 lnFFC_t + \varepsilon_t \quad (5)$$

where $\tau_0 = \frac{\gamma_0}{1-\gamma_1(L)}$, $\tau_1 = \frac{\gamma_2(L)}{1-\gamma_1(L)}$, $\tau_2 = \frac{\gamma_3(L)}{1-\gamma_1(L)}$, $\tau_3 = \frac{\gamma_4(L)}{1-\gamma_1(L)}$, $\tau_4 = \frac{\gamma_5(L)}{1-\gamma_1(L)}$, $\tau_5 = \frac{\gamma_6(L)}{1-\gamma_1(L)}$ $\tau_0, \tau_1, \tau_2, \tau_3, \tau_4, \tau_5$ are the static long-run parameters, (L) are the lag operators for the different variables.

The next step in the ARDL approach is estimating the associated error correction model including the error correction of the long-run estimation lagged one period, the first differences of all the variables and their lags as in Equation (6). This error correction model (ECM) is also performed using the Hendry general to specific approach.

$$\Delta lnCO_{2_t} = \delta_0 + \sum_{i=1}^{p-1} \delta_1 \Delta lnCO_{2_{t-i}} + \sum_{j=0}^{q-1} \delta_2 \Delta lnGDP_{t-j} + \sum_{k=0}^{r-1} \delta_3 \Delta lnEU_{t-k} + \sum_{l=0}^{s-1} \delta_4 \Delta lnFD_{t-l} + \sum_{m=0}^{v-1} \delta_5 \Delta lnTR_{t-m} + \sum_{n=0}^{w-1} \delta_6 \Delta lnFFC_{t-n} + \varphi ECT_{t-1} \tag{6}$$

where Δ is the first difference operator, $\delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6$ are the short-run parameters, and φ is the speed of adjustment toward the long-run steady state equilibrium. Finally, the models have to undergo several statistical checking in order to ascertain their statistical reliability.

3.5 Diagnostic and Stability Tests

The last step is to conduct the goodness of fit of the ARDL model. This is done through diagnostic and stability test.

Given that the macro-economic time series data are volatile and might be correlated with each other, the OLS estimators might suffer from the autocorrelation and heteroskedasticity problems. Therefore, all estimated models include a sufficient lag augmentation in order to forestall any biased resulted from both autocorrelation and endogenity problems. Moreover, the Newey-West method has been employed to obtain robust OLS estimators with Heteroskedasticity and Autocorrelation-Consistent (HAC) standard errors.

Thereby, the inferences remain valid even in the presence of both arbitrary autocorrelation as well as heteroskedasticity problems.

Furthermore, the stability of the long-run coefficients together with the short run dynamics have been tested. We apply the cumulative sum of recursive residuals (CUSMUS) and cumulative sum of squares of recursive residuals (CUSMUSQ) stability tests for the ARDL model.

4. Empirical Results

In this chapter we investigate the effects of economic growth, energy consumption, financial development, trade openness and fossil fuel ratio on CO_2 emissions using time series econometric technique, namely, ARDL model in ECM framework. Figure 1 illustrates the historical trends of model variables.

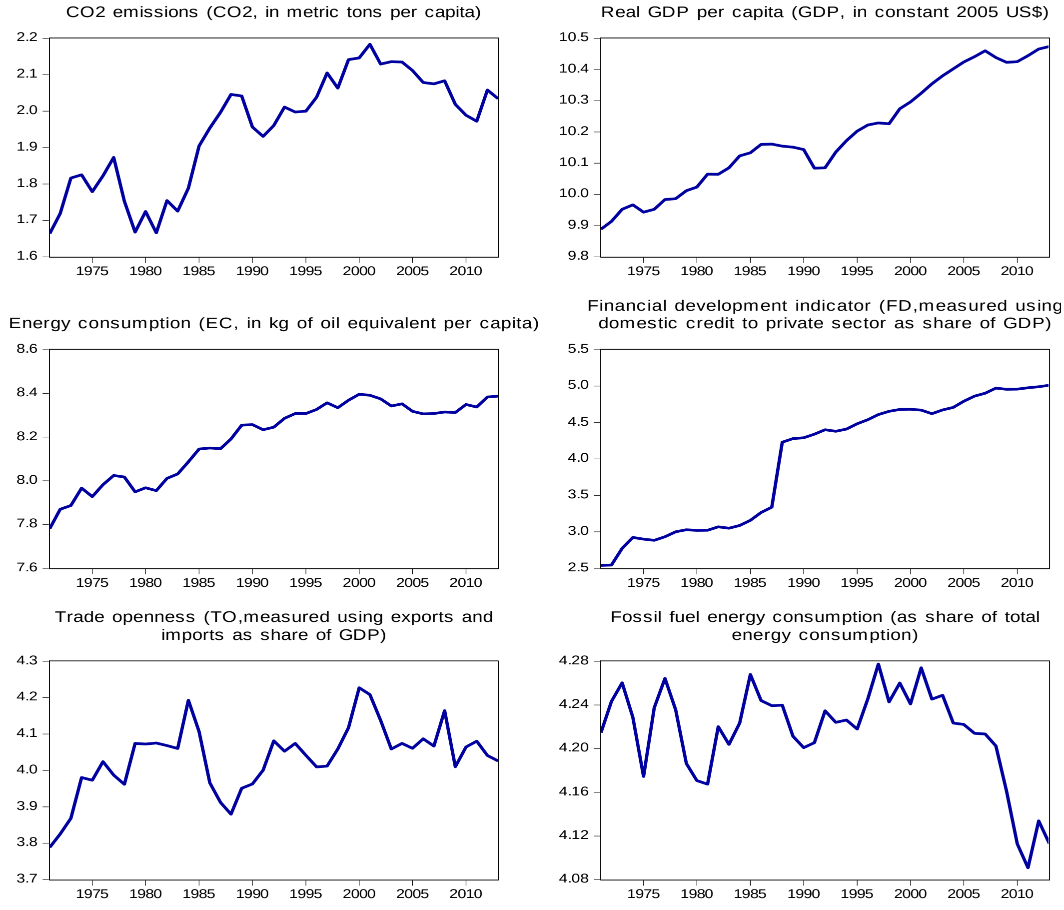

Figure 1: Plots in natural logarithm of per capita CO_2 emissions, per capita real GDP, per capita energy consumption, financial development, trade openness, and fossil fuel share for case of New Zealand, 1971−2013

4.1 Unit Root Test Results

To evaluate whether or not the variables under consideration are stationary at levels, 1st difference or mixed, we conduct the Augmented Dickey-Fuller (ADF) unit root test. Even though the ARDL framework does not require the pre-testing of variables, the unit root test could indicate whether or not the ARDL model should be used. The unit root tests investigate the stationarity of the variables at the level and then at the first difference of each series. The result of the tests are reported in Table 1, by taking into consideration with time trend and without time trend variable in the regression.

Table 1: The T-Stat Results of Augmented Dickey Fuller Tests

Data Series	**At level**		**At first difference**		**Decision**
	Intercept	Intercept & trend	Intercept	Intercept & trend	
lnCO₂	-1.893668	-1.797673	-6.112546*	-6.133828*	I(1)
lnGDP	-0.594283	-2.588618	-4.652324*	-4.592859*	I(1)
lnEU	-2.504445	-2.015914	-6.750665*	-6.924776*	I(1)
lnFD	-1.236895	-1.442232	-5.913968*	-5.969850*	I(1)
lnTR	-3.349078**	-3.163907			I(0)
lnFFC	-1.582538	-1.995775	-6.629813*	-6.635244*	I(1)

Note: '*' and '**' indicate significance at the 1% and 5% levels respectively

According to Table 1, the t-test statistics for all series except for trade openness (lnTR) from ADF tests are statistically insignificant to reject the null hypothesis of non-stationarity. This result indicates that the lnTR is stationary at level at 95% significance level, whereas all other series are non-stationary at their level form. Hence, the results of the unit root test demonstrate that the ARDL model is more appropriate to analyse the data than the Johansen cointegration model.

4.2 ARDL Bounds Test

The first stage of ARDL technique involves testing the existence of the long-run relationship between CO_2 emissions and model components using bounds cointegration test by examining the lagged level variables in the error correction representation of the ARDL model using F-test. Empirical results for ARDL model and bounds cointegration test are reported in Table 2.

Table 22: ARDL Bounds Test for Cointegration

Panel A: Bounds testing to cointegration		
Estimated equation	$lnCO_2$=f(lnGDP, lnEU, lnFD, lnTR, lnFFC)	
Optimal lag structure	(1, 0, 3, 3, 4, 3)	
F-statistics (Wald-statistics)	4.858783*	
Significant level	Lower bounds, I(0)	Upper bounds, I(1)
1%	3.41	4.68
5%	2.62	3.79
10%	2.26	3.35
Panel B: Diagnostic tests	Statistics	
R^2	0.9860	
Adjusted-R^2	0.9720	
F-statistics (Prob-value)	70.5392 (0.0000)*	
Jarque–Bera normality test	0.2542 (0.8806)	
Breusch–Godfrey LM test	2.028547 (0.1622)	
Breusch-Pagan-Godfrey heteroskedasticity test	1.331914 (0.2691)	

Sources: The results are calculated by author using EViews 9.0 software.

Note: The superscripts (*) indicates statistically significant at 1% level of significance.

Results in panel (A) provide strong evidence in favour of a long-run relationship between CO_2 emissions and the explanatory variables, where the F-statistics (4.85) is higher than the upper bounds of asymptotic critical values (4.68) at 1% level of significant. Therefore, the null hypothesis of no cointegration has been rejected.

Panel B represents the diagnostics tests for normality of error term, serial correlation and heteroskedasticity. These tests have been conducted to show robustness of ARDL bound testing approach to cointegration. The diagnostic tests indicate no statistical problem.

4.3 Long-run Impact

The second step of ARDL approach involves estimating the parameters of the long-run relationships, making inferences about their significance and interpreting them according to the economic theory. Table 3 represents the long-run coefficients for the ARDL model using logarithm of per capita CO_2 emissions as dependant variable, and logarithm of per capita real GDP, per capita energy consumption, financial development, trade openness, and fossil fuel share as explanatory variable. Where, economic growth, energy consumption and the ratio of fossil fuels are correlated positively with CO_2 emissions. However, financial development, trade openness have negative effect on CO_2 emissions in the long-run.

Table 3: Long-run coefficients from ARDL model ($lnCO_2$ as dependant variable)

Variable	Coefficient	standard error	t-statistic
lnGDP	0.772836	0.161939	4.772391*
lnEU	1.540637	0.389288	3.957580*
lnFD	-0.222023	0.085140	-2.607754*
lnTR	-1.126901	0.292108	-3.857827*
lnFCC	1.490898	0.325528	4.579936*
constant	-19.410228	2.710968	-7.159889*

Sources: The results are calculated by author using EViews 9.0 software.

Note: The superscripts (*) indicates statistically significant at 1% level of significance.

As revealed by Table 3, the long-run results show that economic growth has a positive impact on CO_2 emissions and is statistically significant at the 1% level. It is noted that a 1%

increase in GDP per capita is linked with 0.772% increase in per capita CO_2 emissions in the long-run. The empirical evidences also show that a 1.540% increase in per capita carbon emissions is associated with 1% increase in per capita energy consumption. This reveals a quite elastic relationship between energy consumption and emission levels in the long-run.

Furthermore, the elasticity of CO_2 emissions with respect to the financial development is -0.222 in the long-run, suggesting that whilst the contribution of financial development to CO_2 emissions is rather minimal during the estimation period, it contributes to decreasing New Zealand's emissions. It is believed that financial reform policies, by facilitating entrance for private and foreign financial corporations, increase the number of financial institutions, promote competition in the capital markets by absorbing more direct investments on R&D platforms and offer different ways of financing low-cost environment friendly projects.

Another striking feature is the negative and significant (at the 1% level) impact of trade openness on carbon dioxide emissions, where 1% increase in foreign trade to GDP ratio decreases carbon emissions per capita by about 1.127% on average. It implies that trade openness improves environmental quality by decreasing CO_2 emissions. Looking at this from a pragmatic point of view, this result shows that trade liberalization policies, trade opening (along with facilitating foreign direct investment in trade-exposed sectors), and growing online shopping experience could potentially cut the country's carbon emissions.

These results are consistent with findings of Managi et al. (2009), Shahbaz et al. (2013a), and Shahbaz et al. (2013b) which allege that freer trade appears to be good for the environment. Moreover, the long-run elasticity estimate of carbon emissions per capita with respect to the ratio of fossil fuel energy consumption is expected to be positive. In more details, a 1% increase in fossil fuel ratio may increase per capita carbon dioxide emissions by 1.490% (significant at the 1% level). This means that carbon emissions are relatively elastic to changes in fossil fuel consumption ratio in the long-run as continues percentage decrease in fossil fuel consumption causes higher percentage decrease in per capita carbon emissions. In other words, the technological improvements could stimulate demand for more efficient and low-carbon energy sources, and if more investments and subsidies are provided to trigger more demand for greener energies, the economy will be able to reduce the emissions much faster. This in turn could enhance efficiency of the economy and provide effective factors of production.

4.4 Short-run Impact

As a final step in the ARDL co-integration approach, the associated error correction model (Equation 6) has been constructed to obtain the short-run dynamic relationships between carbon emissions and its important determinants over the period 1971-2013.

Looking at the short run estimates in table 4, the important coefficient is that of the error correction term (ECT), which is -0.682 approximately, the sign is negative and it is statistically significant at 1% level of significance.

Table 4: Short-run results (ARDL co-integration approach); dependent variable is D(lnCO_2)

Error Correction:	**Coefficient**	**standard error**	**t-statistic**
D(lnGDP)	0.527674	0.136192	3.874478*
D(lnEU)	1.141899	0.209364	5.454125*
D(lnEU(-1))	-0.072350	0.247082	-0.292818
D(lnEU(-2))	-0.283982	0.194327	-1.461362
D(lnFD)	-0.022310	0.047732	-0.467406
D(lnFD(-1))	0.115103	0.047549	2.420747**
D(lnFD(-2))	-0.061723	0.040698	-1.516609
D(lnTR)	-0.207495	0.090342	-2.296769**
D(lnTR(-1))	0.205820	0.108737	1.892828***
D(lnTR(-2))	0.092405	0.105486	0.875988

D(lnTR(-3))	0.280906	0.100028	2.808273**
D(lnFFC)	0.700024	0.217798	3.214105*
D(lnFFC(-1))	-0.386540	0.257174	-1.503026
D(lnFFC(-2))	-0.254393	0.236599	-1.075204
ECT(-1)	-0.682776	0.162216	-4.209058*

Sources: The results are calculated by author using EViews 9.0 software.

Note: '*', '**' and '***' indicate significance at the 1%, 5% and 10% levels respectively.

The negative coefficient of the ECT indicates the speed of adjustment from any disequilibrium in the previous year toward the long run equilibrium, the speed is quite high as it is 68%, and it is also statistically significant. In other word, 68% of any disequilibrium in the previous year is corrected in the current year. The statistical significance of the ECT also shows that the relationship between these variables is also statistically significant in the short-run.

4.5 Stability Test

Hansen (1992) argues that estimated coefficients may be different in time series data due to misspecification of model. Hence the stability tests including cumulative sum of recursive residuals (CUSUM) and CUSUM of square (CUSUMSQ) developed by Brown et al. (1975) have also been applied. These tests are very crucial since the short-run dynamics seems to be very important in investigating the long-run coefficients stability. CUSUM test identifies any systematic changes in the model coefficients, whereas CUSUMSQ test reports any unexpected departure of the model's coefficients from the stability. The tests applied to the residuals of the ECM model.

Figure 2 plots the CUSUM and CUSUMSQ statistics for the model which indicate no systematic or stochastic changes in the coefficients of the ECM model as they are stable and remained within the critical bounds at 5% level of significance. Therefore, the ARDL model adopted in this study is robust and precisely estimating and depicting both short and long-run relationship between CO_2 emissions and the explanatory variables.

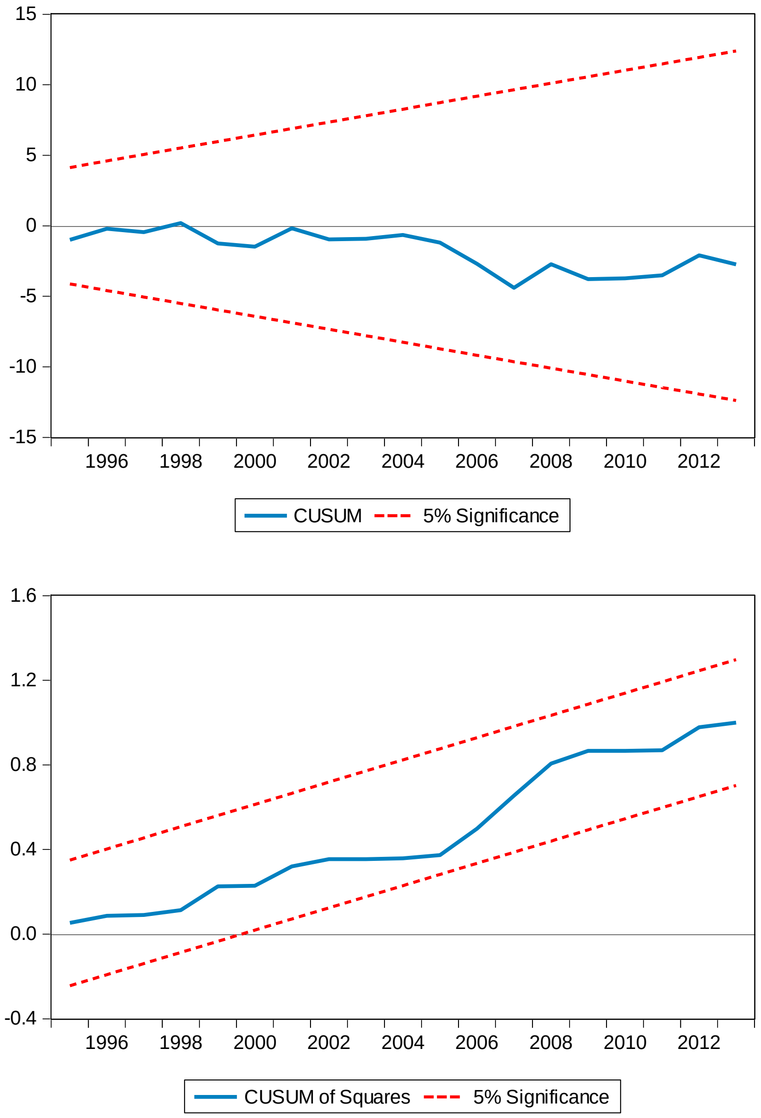

Figure 2: Plots of CUSUM and CUSUMSQ of recursive residuals

5. Conclusion

This essay is an attempt to investigate the long-run as well as the short-run linkage between the level of CO_2 emissions and some key determinants using econometric models and annual data from 1971 to 2013 in New Zealand. The analysis incorporates the effects of real GDP per capita, energy consumption per capita, financial development, trade openness, and fossil fuel consumption ratio as a proxy for technology on per capita CO_2 emissions. For this purpose, we applied the bound testing approach based on the estimation of auto regressive distributed lag model (ARDL) methodology to examine the cointegration among the variables. The results of the ARDL model in ECM framework indicate the existence of the cointegration between variables. Therefore, the model components have a long-run equilibrium relationship between them; despite there may be disequilibrium in the short-run.

On the basis of the empirical findings, in the long-run model, significant positive causalities from per capita real GDP and per capita energy consumption toward per capita CO_2 emissions are found which are in line with findings in previous studies. The model coefficients suggest that one percent increase in GDP and energy use growth rates will lead an increase of CO_2 emissions by 0.772 and 1.540 percent respectively. On the other hand, the financial development shows a significant negative (-0.222) influence on emission levels. This implies that whilst the contribution of financial development to CO_2 emissions is rather minimal during the estimation period, it rather helps to decrease New Zealand's emissions. It is believed that financial reform policies by facilitating entrance for private and foreign financial corporations, increase the number of financial institutions, promote competition in the capital markets by absorbing more direct investments on R&D platforms and offer different ways of financing low-cost environment friendly projects.

Likewise, a significant and negative (-1.127) relationship between trade openness and New Zealand's CO_2 emissions is found in the long-run. This adverse impact is consistent with my hypothesis which states that trade liberalization policies along with facilitating foreign direct investment in trade-exposed sectors and growing online shopping experience could potentially reduce environmental degradation in New Zealand. These findings are in line with those of Managi et al. (2009) in OECD countries, Shahbaz et al. (2013a) in Malaysia, and Shahbaz et al. (2013b) in South Africa.

In addition, another striking observation of study finding is that carbon emissions is relatively elastic (1.490) to changes in fossil fuel consumption ratio. As a result of this, continues percentage decrease in fossil fuel consumption ratio to total energy consumptions causes higher percentage decrease in per capita carbon emissions. In this regard, we argue that the technological improvements could stimulate demand for more efficient and low-carbon energy sources, and if more investments and subsidies are provided to trigger more demand for greener energies, the economy will be able to reduce the emissions much faster. This, in turn, could increase economic efficiency and provide effective factors of production.

These results suggest, nevertheless, that New Zealand as a trade-dependent economy is favourably affected by trade agreements and financial system developments. Hence, from a policy perspective, it is useful to explore financial reforms further with a view to aiding the technological innovations and energy efficient R&D investments, given that the impact of financial development on the latter is positive and significant.

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