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Economic Growth and Air Pollution Dynamics: The Case of Canada

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Abstract: The root cause of the most important issues facing humanity today could be traced back to environmental mismanagement or inequality. Thus, the aim of this paper is to examine the dynamic relationship between economic growth and air pollution in Canada using cointegration tests, vector error correction models and causality tests on annual data from 1960 to 2014. The cointegration tests reveal that there is a long-run relationship between economic growth, trade and air pollution in Canada. The results also show that in the long-run, economic growth and trade respectively have a positive and a negative impact on air pollution. The vector error correction models reveal that the coefficient associated with the error correction term is negative and significant. This means that, any shock disturbing the long-run equilibrium between economic growth, trade and air pollution will be corrected at a speed of 10 percent per year. As for the causality analyses, they show that economic growth does not cause air pollution in Canada.
Keywords: Air Pollution, CO_2 Emissions, Economic Growth, Sustainable Growth

INTRODUCTION

According to [1], the root cause of the most important issues facing humanity today could be traced back to environmental mismanagement or inequality. This is the case for food supply and water crises, increasing greenhouse gas emissions and climate change, rising volatility in food and energy prices and even terrorism. Such a finding could explain the rising importance given to the concepts of sustainability and sustainable economic growth. Talking about sustainability, [2] pays attention to three different dimensions of natural capital and the appropriate action for each of them. Thus, for economic activities dealing with non-renewable resources, he argues that the depletion of those resources requires an equivalent development of renewable substitutes. For economic activities dealing with renewable resources, he argues that they should not be harvested at a rate exceeding their rate of regeneration. Finally, for economic activities creating pollution, he argues that they should not generate wastes at a rate exceeding the assimilation capacity of the environment.

[3] argue that in spite of its importance, the assimilation capacity of the environment has often been given less attention. They add that the limits to economic growth may well arise from the limited assimilation capacity of the environment rather than from nature's finite supply of raw materials. Indeed, the environment acts like a "sink" absorbing millions of tons of human wastes every year. [3] argue that environmental quality will decline when the absorbing capacity of that "sink" will be exceeded by human activities. Thus, in an attempt to protect nature, strict environmental policies will be implemented and those policies will in turn limit economic growth.

[1] argues that the current pattern of our economic activities needs to be changed. Indeed, humanity cannot keep meeting the needs of a rising population at the expense of nature if not severe pollution, acute health issues, irreversible loss of biodiversity and extremely volatile commodity prices will become common. The complex link between economic growth and pollution inspired this paper of which the aim is to examine the dynamic relationship between those two concepts using Canadian data from 1960 to 2014. The paper is organized as follows: the next section reviews the related literature and section 3 presents the methodology. The main findings are presented and discussed in section 4 and 5 while section 6 concludes the paper.

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RELATED LITERATURE

In a seminal paper, [4] assess the environmental impacts of NAFTA and find that the SO_2 emissions increase with economic growth at low levels of GDP per capita but decrease with economic growth at higher levels of GDP per capita. Given that such an inverted U-shaped relationship is similar to the relationship between economic growth and income inequality as established by [5], the findings of [4] became known as the Environmental Kuznets Curve hypothesis. An abundant literature [6 – 12] has tested the Environmental Kuznets Curve hypothesis in different settings using a wide range of methodologies but found mixed evidence.

[7] assesses the dynamics of economic growth, carbon emissions and energy consumption for a panel of 116 countries. Using both panel VAR and system GMM models on annual data from 1990 to 2014, the paper finds that economic growth does not cause energy consumption at the global as well as at the regional levels. It also reveals that economic growth has a negative impact on pollution at the global level as well as in Latin America and the Caribbean. However, such a causal relation between economic growth and pollution does not hold in sub-Saharan Africa, Asia-Pacific and Middle-East and North Africa. The study also reveals that CO_2 emissions cause economic growth in all the regions taken into consideration. Finally, evidence supporting the Environmental Kuznets Curve is found at the global level as well as in sub-Saharan Africa.

Analyzing the relationship between economic growth and environmental pollution, [11] test the Environmental Kuznets Curve hypothesis in the case of 7 West African countries between 1970 and 2013. They use carbon dioxide emissions and combustible renewable waste as proxies for environmental pollution and GDP per capita as proxy for economic growth. The study reveals that in the short-run, economic growth significantly increases pollution in West Africa; meanwhile, in the long-run, the relationship between economic growth and environmental pollution is not significant. The authors then conclude that the Environmental Kuznets Curve hypothesis does not hold in West Africa.

Following the environmental sustainability approach according to which environmental degradation is measured where production and extraction take place and not where the good produced from those activities is consumed, [13] studies the impact of economic growth on environmental degradation in 213 countries for the period between 1970 and 2008. In this study, environmental degradation is proxied by the pressure on nature, a composite variable taking into consideration CO_2 damages, energy, mineral and forest depletions. The scholar uses fixed-effects and fixed effects instrumental-variables regressions and finds that a rising GNI leads to an increased pressure on nature. He also finds that compared to low and high-income countries, such an effect is much pervasive in middle-income countries. Finally, the findings do not support the Environmental Kuznets Curve hypothesis.

[12] explore the relationship between economic growth and CO_2 emissions in Azerbaijan. They use five different cointegration approaches (Johansen, ARDLBT, DOLS, FMOLS and CCR) and three different model specifications (quadratic, cubic and linear) on annual data spanning from 1992 to 2013. They find that the linear specification adequately models the impact that economic growth has on CO_2 emissions in Azerbaijan. They also find that in the long-run, economic growth is positively and significantly associated with CO_2 emissions revealing that the Environmental Kuznets Curve hypothesis is not valid in the case of Azerbaijan. The authors estimate the income elasticity of CO_2 between 0.7 and 0.8 and reveal that any short-term deviation from the long-term equilibrium path can be corrected in less than a year.

[14] study the relation between economic growth and environmental pollution in 111 Chinese prefectural-level cities from 2004 to 2012. They measure environmental pollution using an industrial pollution index constructed as the weighting average of industrial dust, SO_2 emissions and industrial water waste discharge. They then classify the cities into five different clusters taking into consideration the level of income, the growth potential and the industrial composition of each city. Thus, a city like Shanghai with high income, high growth rate and well developed tertiary industry falls into the first cluster. The study reveals that the relation between economic growth and pollution dynamics varies across clusters as the relationship is negative in the first cluster and positive in the third. It even takes the form of an inverted U-sharpe in the second cluster. In the case of the fourth cluster, economic growth does not affect environmental pollution as the latter remains constant no matter the level of income. Finally, in the last cluster, an increase in the level of income initially leads to a rapid fall in environmental

pollution; however, the level of pollution then seems to remain constant after income had reached a threshold (above 50,000 yuan).

In a study analyzing the determinants of industrial pollution in selected (14) Mediterranean countries, [15] run a fixed-effects model on data from 1971 to 2010. They prove the existence of an inverted U-shaped relation between economic growth and industrial pollution and conclude that the Environmental Kuznets Curve hypothesis holds in the case of the Mediterranean region. Furthermore, the study reveals that urbanization, population density, the level of industrialization and energy consumption all have a significant impact on industrial emissions in the Mediterranean region.

[16] studies the relationship between economic growth and environmental degradation in 100 metropolitan areas in the United States between 2001 and 2005. He measures environmental degradation with carbon monoxide, sulfur dioxide, nitrogen dioxide, ground level ozone and particulate matter. After controlling for both socioeconomic (population) and meteorological (temperature, precipitation, etc) parameters, the fixed-effects models reveal the existence of a U-shaped relationship between economic growth and carbon monoxide, sulfur dioxide, nitrogen dioxide as well as ground level ozone. However, the evidence found is only strong in the latter case and weak in all the others. Furthermore, the evidence does not support the Environmental Kuznets Curve hypothesis.

[6] analyze the relationship between economic growth and pollution in 30 Chinese provinces over the period 1996-2000. Chemical oxygen demand in industrial water pollution, industrial water pollution, industrial dust, industrial smoke and industrial solid waste all account for environmental pollution while income per capita accounts for economic growth. The authors also control for environmental regulation policies, the number of environmental standards issues as well as trade openness. They find an inverted U-shape relationship between income and all pollution proxies but one (Chemical oxygen demand in industrial water pollution). Thus, they confirm the validity of the Environmental Kuznets Curve hypothesis in Chinese provinces and estimate the turning point of the curve above 30,000 yuan. The authors then argue that the income level in those 30 Chinese provinces is still well below the turning point of the EKC.

METHODOLOGY

The relationship between economic growth and air pollution in Canada is examined using annual data obtained from the World Bank. The data covers the period from 1960 to 2014 and include three main variables: Growth stands for GDP per capita in constant 2010 U.S. dollar and it is used as a proxy for economic growth; pollution stands for CO_2 emissions in metric tons per capita and it is used as a proxy for air pollution; and trade stands for trade expressed as percentage of GDP plays the role of a control variable. Following the findings of [16, 13, 12], economic growth is expected to have a positive impact on air pollution. As for the impact of trade on air pollution, it is quite ambiguous. Indeed, [11] argue that free trade increases the probability of a country to suffer from higher pollution levels while [13] argues that free trade and the strict anti-pollution policies implemented in high-income countries – like Canada – incite polluting industries to relocate in low and middle-income countries and export their production back to the developed world. Through this process, trade could be associated to less pollution in rich countries.

The analytical framework of this paper is made up of five successive steps: in the first step, the stationarity of the series is checked using the augmented Dickey-Fuller test [17], the Phillips-Perron test [18] and the Ng-Perron test [19]. Secondly, the correlation coefficients between the variables are computed. In the third step, the long-run relationship between the variables is checked using Johansen cointegration test [20]. In the next step, the short-run relationship between economic growth and air pollution is examined using a full information maximum likelihood model also known as vector error correction model or VECM [21]. Finally, the causal relationship between the variables is checked using Granger causality test [22].

At the end of those five steps, robustness check is done using GDP in constant 2010 U.S. dollar as proxy for economic growth and CO_2 emissions in kg per 2010 U.S. dollar of GDP as proxy of air pollution. As for trade, it is still used as control variable in the framework.

RESULTS

The outputs of the augmented Dickey-Fuller, Phillips-Perron and Ng-Perron unit root tests are reported in Table 1. Those results reveal that the series are not stationary at level; however, the results also reveal that the variables are all stationary at first difference. Since the series are not stationary at level but are stationary at first difference, the long-run relationship between economic growth and air pollution can be examined using Johansen cointegration test.

Table 1. Unit root tests

Variables	k	ADF		PP		Ng-Perron	
		I	TI	I	TI	I	TI
Level							
Pollution	0	-3.316**	-2.116	-3.257**	-2.116	34.888	47.930
Growth	0	-3.154	-2.875	-2.947**	-2.123	58.757	19.339
Trade	1	-1.546	-1.963	-1.537	-1.199	19.528	9.497
Air_Pollution	0	0.765	-2.315	1.085	-2.176	85.549	18.304
GDP	0	-4.197**	-2.955	-3.840**	-2.319	45.811	26.527
First difference							
Pollution	0	-5.916**	-6.850**	-5.980**	-6.854**	1.044**	3.670**
Growth	0	-5.045**	-5.654**	-5.075**	-5.588**	1.063**	3.783**
Trade	0	-5.274**	-5.302**	-5.191**	-5.185**	1.030**	3.799**
Air_Pollution	0	-8.008**	-8.375**	-8.011**	-8.494**	1.017**	3.601**
GDP	0	-4.642**	-5.620**	-4.642**	-5.586**	1.110**	3.777**

Notes: ** denotes significance at the 5 percent level; k stands for the lag order, I stands for intercept and IT stands for trend and intercept.

Table 2. Correlation matrix

	Pollution	Growth	Trade
Pollution	1		
Growth	0.649**	1	
Trade	0.601**	0.901**	1

Notes: ** denotes significance at the 5 percent level.

After analyzing the correlation between the series and before examining the long-run relationship between them, a vector autoregression (VAR) model is run in order to determine the number of lags to be included in the cointegration analysis. Paying attention to the lag length of the VAR model, both the sequential modified LR test statistic and the final prediction error recommend the inclusion of 8 lags while the Akaike information criterion and the Hannan-Quinn information criterion recommend 12 lags.

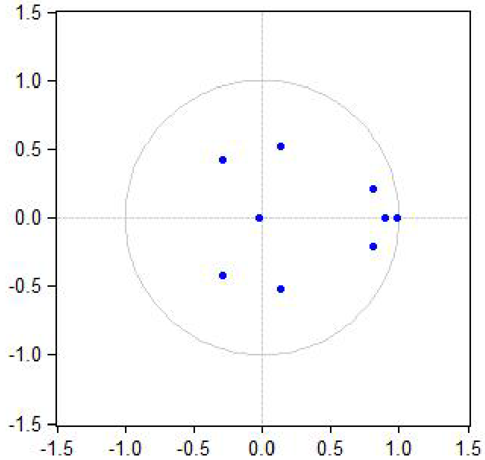

Figure 1. Inverse roots of AR characteristic polynomial

However, given that VAR models are densely parameterized, the number of estimated parameters has to be limited in order to save some degrees of freedom. So, only three lags of each endogenous variable is included in the analysis. The stability of the VAR model is then tested and as depicted in Figure 1, all the inverse roots of the AR characteristic polynomial lie within the unit circle. Therefore, it is concluded that the model is stable.

Johansen cointegration test is implemented with three lags and the results are reported in Table 3. For the first null hypothesis (no cointegration vector between the series), the trace and maximum Eigenvalue statistics show are superior to their respective critical values leading to the rejection of the null hypothesis. It is therefore concluded that there is a long-run relationship between economic growth, trade and air pollution. The cointegration vector is given by the following equation:

$$\text{Pollution} = 0.865\text{Growth} - 0.687\text{Trade} \qquad \text{(Equation 1)}$$

The cointegration equation shows that in the long-run, there is a positive correlation between economic growth and air pollution in Canada. The equation also shows that in the long-run, trade has a negative impact on air pollution in Canada.

Table 3. Johansen cointegration test

Null Hypothesis	**None**	**At most 1**	**At most 2**
Trace	31.988**	7.507	2.310
Critical value	29.797	15.494	3.841
Maximum Eigenvalue	24.391**	5.197	2.310
Critical value	21.131	24.264	3.841

Notes: ** denotes significance at the 5 percent level.

After analyzing the long-run relationship between the series, the short-run dynamics are examined using a VECM. The model is run with two lags and the results are reported in Table 4. Those results reveal that the coefficient associated with the error correction term is negative and significant. It can therefore be concluded that any shock disturbing the long-run equilibrium between the variables will be corrected at a speed of 10 percent per year.

Table 4. Vector error correction model

Variables	Coefficients
Error correction term	-0.106 (0.024)***
$Pollution_{-1}$	-0.083 (0.146)
$Pollution_{-2}$	-0.098 (0.148)
$Growth_{-1}$	-0.001 (0.320)
$Growth_{-2}$	0.152 (0.296)
$Trade_{-1}$	0.058 (0.117)
$Trade_{-2}$	-0.232 (0.117)*
Cons	0.006 (0.007)
Obs	52
Adjusted R^2	26.33%
F-stat	3.603***

Notes: Standard errors are in parentheses; *** denotes significance at the 1 percent level; ** denotes significance at the 5 percent level; * denotes significance at the 10 percent level.

After analyzing the short-term dynamics of the series, pairwise Granger causality test is implemented based on the VECM and the results reported in Table 5.

Table 5. Granger causality test

Null Hypothesis	Chi-sq	df	Prob
Growth does not Granger cause pollution	0.280	2	0.869
Trade does not Granger cause pollution	4.038	2	0.132
Pollution does not Granger cause Growth	3.492	2	0.174
Trade does not Granger cause Growth	0.994	2	0.608
Pollution does not Granger cause Trade	1.244	2	0.536
Growth does not Granger cause Trade	8.959**	2	0.011

Notes: ** denotes significance at the 5 percent level.

The results show that there is no causal relation between economic growth and air pollution and also between trade and air pollution. The table also shows that economic growth causes trade in Canada. The robustness of the above findings is tested with different proxies for economic growth and air pollution. As reported in Table 6, the trace and maximum Eigenvalue statistics are superior to their respective critical values leading to the rejection of the null hypothesis. It is therefore concluded that there is a long-run relationship between economic growth, trade and air pollution. The cointegration vector is given by the following equation:

$$\text{Air\_Pollution} = 0.979\text{Growth} - 0.481\text{Trade} \qquad \text{(Equation 2)}$$

The cointegration equation shows that in the long-run, there is a positive correlation between economic growth and air pollution in Canada. The equation also shows that in the long-run, trade has a negative impact on air pollution in Canada.

Table 6. Cointegration test (robustness)

Null Hypothesis	None	At most 1	At most 2
Trace	30.413**	7.340	3.228
Critical value	29.797	15.494	3.841
Maximum Eigenvalue	23.072**	4.111	3.228
Critical value	21.131	14.264	3.841

Notes: ** denotes significance at the 5 percent level.

The robustness of the short-run dynamics is also tested. As reported in Table 7, the coefficient associated with the error correction term is negative and significant. It can therefore be concluded that any shock disturbing the long-run equilibrium between the variables will be corrected at a speed of 10 percent per year.

Table 7. VECM (robustness)

Variables	Coefficients
Error correction term	-0.101 (0.031)***
$Air\_pollution_{-1}$	-0.233 (0.135)*
$Air\_pollution_{-2}$	-0.122 (0.138)
GDP_{-1}	-0.510 (0.299)*
GDP_{-2}	0.198 (0.273)
$Trade_{-1}$	0.143 (0.108)
$Trade_{-2}$	-0.224 (0.107)
Cons	-0.006 (0.011)
Obs	52
Adjusted R^2	14.95
F-stat	2.281**

Notes: Standard errors are in parentheses; *** denotes significance at the 1 percent level; ** denotes significance at the 5 percent level; * denotes significance at the 10 percent level.

Pairwise Granger causality test is implemented based on the second VECM and the results reported in Table 8. The results show that there is no causal relation between economic growth and air pollution and between trade and air pollution. The table also shows that economic growth causes trade in Canada.

Table 8. Causality test (robustness)

Null Hypothesis	Chi-sq	df	Prob
GDP does not Granger cause air_pollution	2.911	2	0.233
Trade does not Granger cause air_pollution	4.556	2	0.102
Air_pollution does not Granger cause GDP	4.712	2	0.094
Trade does not Granger cause GDP	0.786	2	0.094
Air_pollution does not Granger cause Trade	1.576	2	0.454
GDP does not Granger cause Trade	6.354**	2	0.004

Notes: ** denotes significance at the 5 percent level.

DISCUSSION

The cointegration tests reveal that there is a long-run relationship between economic growth, trade and air pollution in Canada. In line with what [12] found in Azerbaijan, the results also show that in the long-run, economic growth has a positive impact on air pollution. Moreover, the results show that the income elasticity of CO_2 emissions is between 0.8 and 0.9 for Canada while [12] estimate it between 0.7 and 0.8 for Azerbaijan. Finally, the cointegration analyses reveal that in the long-run, trade has a negative impact on air pollution in Canada. Such a finding is consistent with the argument made by [13] and could be explained by the fact that free trade and the strict anti-pollution policies implemented in high-income countries incite polluting industries to relocate in low and middle-income countries and export their production back to the developed world rather than producing and polluting there.

The vector error correction models reveal that the coefficient associated with the error correction term is negative and significant. It can therefore be concluded that any shock disturbing the long-run equilibrium between economic growth, trade and air pollution will be corrected at a speed of 10 percent per year.

As for the causality analyses, they show that economic growth does not cause air pollution in Canada. Such a finding is in line with what [7] found in the cases of Middle East and North Africa, Asia-Pacific and sub-Saharan Africa. The results also show that pollution does not cause growth, trade does not cause pollution and pollution does not cause trade in Canada. However, it is found that economic growth causes trade.

CONCLUSION

Examining economic growth and air pollution dynamics in Canada, it is found that in the long-run, the two concepts are linked and economic growth has a negative impact on the quality of air. However, notwithstanding their long-run relationship, it is also found that economic growth does not cause air pollution in Canada. This is consistent with [3] who argue that in advanced industrial countries like Canada, policies have been implemented to mitigate the impact of economic growth on the environment. They add that over the past decades, those developed countries have experienced a fall in the level of emissions for regulated pollutants and a substantial improvement in the quality of air. The problem is that the improvements experienced in advanced economies often come at the expense of the developing world.

The cointegration analyses reveal that in the long-run, trade has a negative impact on air pollution in Canada supporting the argument that free trade and the strict anti-pollution policies implemented in high-income countries incite polluting industries to relocate in low and middle-income countries and export their production back to the developed world rather than producing and polluting there [13]. Building upon the seminal work of [23], it can be argued that the marginal costs and benefits of sustainable growth in advanced economies are divergent from their counterparts in the developing world. Consequently, advanced economies should internalize the externalities of their "green" policies rather that leaving them in the hands of market forces. As argued by [24], the imperative of sustainability should not be left to market forces because the market does not adequately represent the future.

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