Business Activity And Environmental Degradation In Mexico

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ABSTRACT

This paper contributes to the literature by investigating the relationships between business activity, carbon dioxide (CO_2) emissions, energy consumption in a developing country by taking into consideration the effects of ongoing industrialization and financial development. To do this, we introduce an innovative empirical approach based on ARDL bounds testing in the presence of structural breaks and apply it to Mexico over the period 1971-2011. We show strong evidence of cointegration between these variables. More interestingly, we find that energy is the long-run forcing variable to explain the Mexican business activity growth. This implies that energy savings policy may result in decreasing the national income or employment.

Keywords: Business Activity; Environment; ARDL Cointegration

1. INTRODUCTION

With rapid industrialization, changes in trade, financial development, the threat of climate change is increasing. Carbon dioxide (CO_2) emissions are considered as the main cause of greenhouse gases (GHGs). The Kyoto Protocol, a protocol of the United Nations Framework Convention on Climate Change (UNFCCC), aims to reduce the collective emission of GHGs. In 2009, 187 countries have signed and ratified this protocol, among them Mexico which constitutes an interesting case study.

Mexico is defined as a newly industrialized country as it is the eleventh largest economy in the world in 2011. The share of oil in the Mexico's total consumption is 37 percent and industrial production growth was the 58th highest in the world at 6 percent (EIA, 2011). The CO_2 emissions, measured in metric tons per capita, in Mexico were at 4.30 in 2008, according to the World Bank (WDI-2009). According to the U.S. Energy Information Administration, Mexico is ranked 12th among the world's top carbon-emitting countries.

In this paper, we contribute to the literature by investigating the relationship between business activity, CO_2 emissions, energy consumption, condition to the increasing industrialization and the role of financial development in the case of Mexico over the period 1971-2012. An upward movement in carbon emissions, energy consumption and industrialization has raised some questions in Mexico's perspective such as: (1) is there any long-term relationship between these variables? (2) What is the nature of short-run relationships between these variables? And (3) What are the policy implications of the findings? Our paper attempts to answer these questions by proposing an original empirical framework based on ARDL bounds testing in the presence of structural breaks. The econometric tools we use are robust to violations of statistical assumptions, especially when the sample size is small.

The remainder of this paper is structured as follow. Section 2 presents the results of previous contributions. Section 3 introduces the econometric specification and estimation methodology. Section 4 discusses our empirical results and gives some policy implications. Finally, Section 5 concludes the paper.

2. LITERATURE REVIEW

The work by Kuznets (1955) suggests that an inverted U-shaped relationship exists between business activity and environmental degradation. The empirical evidence suggests that energy consumption and income are jointly determined and that environmental Kuznets curve (EKC) exists in numerous countries and regions (Soytas et al., 2004 and references therein). More recent studies show that income is the most crucial determinant of CO_2 emissions, followed by trade (Halicioglu, 2009). Anderson et al. (2013) show that CO_2 emissions related to exports are greater than the emissions attributable to imports in the case of a developing country like China. Moreover, Tamazian et al. (2009) show that CO_2 emissions are significantly related to the level of financial development.

Working on South American countries for the period of 1980 to 2007, Sadorsky (2008) finds a short-run bi-directional feedback relationship between energy consumption and exports, output and exports and output and imports. Empirical findings also suggest that there is a one way short-run causality from energy consumption to imports. In the long-run, a causal relationship has been established between trade (exports or imports) and energy consumption. Ghani (2009) shows that trade liberalization does not affect the growth of energy consumption of developing countries, but its interaction with capital per labour reduces the growth of energy consumption as capital per labour increases. However, the effect is only significant after a certain minimum threshold level capital per labour is reached. On the other hand, business activity increases energy consumption and its effect is not conditional upon trade liberalization.

By applying co-integration and Hsiao's version of Granger causality to three Latin countries (Brazil, Mexico, and Venezuela), Cheng (1997) finds no causal linkages between energy use and economic growth for both Mexico and Venezuela. To examine different types of energy consumption for the Mexican economy a study have performed by Galindo (2005) using annual data from 1965 to 2001. The results indicate that demand for energy is fundamentally driven by income and that the effect of the relative prices is basically concentrated on the short-run with the exception of the industrial sector which also shows a long-term price impact. Working on panel unit root tests and panel cointegration analysis based on data from 11 oil-exporting countries (Iran, Kuwait, Saudi Arabia, United Arab Emirates, Bahrain, Oman, Algeria, Nigeria, Mexico, Venezuela and Ecuador), Mehrara (2007) finds that there is a unidirectional strong causality from economic growth to energy consumption. The author concludes that energy conservation policies have no damaging repercussions on economic growth for this group of countries. Recently, a research has been done by applying the wavelet analysis in Mexico to examine the relationship between energy price differential and industrial production growth using monthly data from $1978M_5$ to $2011M_{10}$ (Uddin et al., 2013). Empirical results show strong co-movements between industrial growth and energy price growth difference and changes over the time horizon.

The motivation of our paper is to reinvestigate the relationship between income, carbon emissions and energy consumption in Mexico, condition to the industrialization and the role of financial development, which is absent in the earlier literature. To do this, we introduce an innovative empirical approach based on ARDL bounds testing in the presence of structural breaks in order to take into account the effects of fundamental reforms of the Mexican economy started in 1985. Moreover, our cointegration approach based on bootstrapping critical value is robust especially when the sample size is small as in the case for Mexico.

3. DATA AND METHODOLOGY

Annual data for Mexico on CO_2 emissions (metric tons) per capita, energy use (kg of oil equivalent) per capita, domestic credit to the private sector as proxy for financial development, industrial value add per capita as proxy for industrialization and real Gross Domestic Product (GDP) (constant 2000 US$), our proxy of business activity, per capita were collected from World Development Indicators (WDI-2013), published by the World Bank. The analysis was performed on the period 1971-2012 due to data availability. This is the longest possible data set for Mexico. The data used in this study was converted to logarithmic form.

The relationship between a nation's carbon emissions, energy consumption, industrialization, financial development, and national income, can be expressed in the following basic multivariate model:

$$Ly_t = \alpha_1 + \Omega_1 le_t + \Omega_2 lc_t + \Omega_3 li_t + \Omega_4 lf_t + \varepsilon_t \quad (1)$$

where α and Ω are model parameters, ε_t is the residual term, le_t is the log of energy consumption, lc_t is the log of carbon emissions, li_t is the log of industrial value add per capita as a proxy for industrialization, lf_t is the log of the domestic credit to the private sector as proxy for financial development, and ly_t is the log of real GDP per capita.

The ARDL (Pesaran and Shin, 2009 and Pesaran et al., 2011) model we use in this study can be expressed by the following equation:

$$\Delta Ly_t = \alpha_2 + \Omega_1 le_{t-1} + \Omega_2 lc_{t-1} + \Omega_3 li_{t-1} + \Omega_4 lf_{t-1} + \sum_{i=1}^{p} \theta_i \Delta le_{t-i} + \sum_{i=1}^{p} \Phi_i \Delta lc_{t-i} + \sum_{i=1}^{p} \Theta_i \Delta li_{t-i} + \sum_{i=1}^{p} \Psi_i \Delta lu_{t-i} + u_{1t} \quad (2)$$

where p signifies the maximum lag length. The ARDL bounds test approach consists in estimating Equation (2) using the ordinary least squares (OLS) method. The F-test is used to check for the existence of long-run relationships and it tests for the joint significance of lagged level variables involved. The null hypothesis of non-existence of a long-run relationship for the equation of ($F_{Ly,}$ Ly_t/ Le_t, Lc_t, Li_t, Lf_t) is (H_0: $\Omega_1 = \Omega_2 = \Omega_3 = \Omega_4 = 0$) against the alternative hypothesis (H_1: $\Omega_1 \neq \Omega_2 \neq \Omega_3 \neq \Omega_4 \neq 0$). The Error Correction Model (ECM) is presented using Equations (2). To ensure the convergence of the dynamics to the long-run equilibrium, the sign of the lagged error correction (ECM) coefficient must be negative and significant. A general correction model is formulated as follows:

$$\Delta Ly_t = \alpha_3 + \sum_{i=1}^{p} \theta_i \Delta le_{t-i} + \sum_{i=1}^{p} \Phi_i \Delta lc_{t-i} + \sum_{i=1}^{p} \Theta_i \Delta li_{t-i} + \sum_{i=1}^{p} \Psi_i \Delta lf_{t-i} + \lambda_g ECM_{t-1} + u_{2t} \quad (3)$$

where λ is the speed of adjustment parameter and ECM_{t-1} is the residual obtained from the estimation of Equation (2).

In order to ensure that correct statistical methods are applied to the model, diagnostic and stability tests are conducted. The diagnostic tests include testing for serial correlations, function form, normality and heteroscedasticity (Pesaran et Pesaran, 1995). In addition, the stability tests (Brow et al., 1975), which are also known as the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests based on the recursive regression residuals, are employed to check the stability of parameters.

4. EMPIRICAL ANALYSIS

The primary consideration is to check for the stationarity of the series. The ARDL bounds testing approach is free from pre-unit root testing but we ensure that none of the variables is integrated of order two, I(2). Indeed, the bounds testing approach assumes that variables should be stationary at I(0) or I(1) or both. In Appendix A we represent the variables we consider in level and in first differences. Figures suggest that variables in level are not stationary. So to overcome this issue, we have applied conventional approach unit root tests such as DF test by Dickey and Fuller (1979, 1981), and PP test by Philips and Perron (1998).

The results of these unit root tests are reported in Table 1. Monte Carlo simulations have shown that the power of the various DF tests can be very low (Enders, 2004). Also the DF test is less powerful than the PP test (Maddala & Kim, 1998). Table 1 shows that the log of income (ly_t), energy consumption (le_t), carbon emissions (lc_t), financial development (lf_t) and industrialization (li_t) have a unit root. This series are found to be stationary at first differences. This shows that all variables are integrated of order one, I(1).

Table 1: Unit Root Tests

Variables	ADF	Decision	PP	Decision
ly_t	-2.661(0)	I(0)	-2.661(0)	I(0)
le_t	-3.225(0)	I(1)	-3.128(1)	I(0)
lc_t	-2.318(0)	I(0)	-2.275(1)	I(0)
lf_t	-4.062(5)	I(0)	-2.099(3)	I(0)
li_t	-1.371(0)	I(0)	-1.442(0)	I(0)
Δly_t	-5.047(0)***	I(1)	-4.99(3)***	I(1)
Δle_t	-4.738(0)***	I(1)	-4.798(3)***	I(1)
Δlc_t	-7.654(0)***	I(1)	-7.575(2)***	I(1)
Δlf_t	-6.442(0)***	I(1)	-6.305(2)***	I(1)
Δli_t	-6.065(0)***	I(1)	-6.065(1)***	I(1)

Note: ***, ** and * denote the significance at 1%, 5% and 10% levels respectively. Figure in the parenthesis is the optimal lag structure for ADF and bandwidth for the PP test.

Notice however that the Mexican economy has known a series of economic reforms and crises since the 1980s. Yet traditional unit root tests are not reliable in the presence of structural breaks (Brown et al., 1975). This limitation has been covered by applying Zivot-Andrews (1992)'s structural break unit root test. The results from this test are presented in Table 2. The empirical evidence indicates that the series are non-stationary at level but found to be stationary at first differences. This confirms that all the series are I(1).

Table 2: Z-A Unit Root Test

Panel A: Series in Level			
Variable	**Level**		
	T-statistic	**Time Break**	**Decision**
Ly_t	-4.208(1)	1985	Unit Root
Le_t	-4.886(0)	1978	Unit Root
Lc_t	-3.968(0)	1978	Unit Root
Lf_t	-3.606(0)	1989	Unit Root
Li_t	-5.019(0)	1988	Unit Root
Panel B: Series in First Differences			
Variable	**1st Differences**		
	T-statistic	**Time Break**	**Decision**
Ly_t	-6.284(0)***	1982	Stationary
Le_t	-7.032(0)***	1982	Stationary
Lc_t	-9.490(0)***	1983	Stationary
Lf_t	-8.128(0)***	1995	Stationary
Li_t	-7.081(0)***	1988	Stationary

Note: ***, ** and * denote the significance at 1%, 5% and 10% levels respectively. Figure in the parenthesis is the optimal lag structure.

In the ARDL approach, lag order of the variables is important for the model specification. We rely on Schwarz information criterion (SBC) to select the appropriate lag length. According to the debate of lag length specification in ARDL model, the SBC-based ARDL model performs better than the AIC-based model (Narayan, 2004). Table 3 shows that optimal lag is 1.

Table 3: Lag Order Selection

VAR Lag Order Selection Criteria						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	311.683	NA	2.69E-15	-16.523	-16.262	-16,431
1	483.107	277.986	1.83E-18	-23.843	-22.015*	-23.199*
2	510.215	35,168	3.47E-18	-23.363	-19.967	-22.165
3	569.559	57.739*	1.56e-18*	-24.625*	-19.661	-22.875

Note: * indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

Now we present the estimation results for cointegration based on the ARDL method. If the calculated *F* statistics exceed the upper bound, the null hypothesis of no cointegration among variables can be rejected. However, if the calculated *F* statistics fall below the lower bound, the null hypothesis of no long-run relationship cannot be rejected. If the calculated *F* statistics fall within the lower and upper bounds, it is inconclusive. In addition, caution that the critical values for the bounds test are sensitive to the number of regressors (k) in the model and the critical values of the *F*-test depend on the sample size (Narayan, 2004). In order to account for the fact that we have a relatively small sample size, we have produced critical values (CVs) of the *F*-test, computed by stochastic simulations using 20 000 replications.

Next, we present the empirical findings. The estimation results for cointegration are presented in Table 4. The structural breaks in 1985 reveal that Mexican government signaled a fundamental change in development strategy by reorienting economic policy toward trade liberalization and export promotion. This structural break is incorporated in the ARDL equation for F-statistics. If the calculated F-statistic exceeds the upper bound, the null hypothesis of no cointegration among variables can be rejected. However, if the calculated F statistic falls below the lower bound, the null hypothesis of no long-run relationship cannot be rejected.

Table 4: ARDL Bounds Testing Analysis

Estimated Model	$F_y(Ly_t / le_t, lc_t, lf_t, li_t)$	
F-statistics	3.790*	
Structural Break	1985	
Critical values#	**Lower Critical Bound**	**Upper Critical Bound**
5% level	3.002	4.337
10% level	2.516	3.719

Note: ***, ** and * denote the significance at 1%, 5% and 10% levels respectively. The optimal lag structure is determined by SBC.

The results reported in Table 5 show that there is evidence of cointegration in the presence of structural break at 10%. This shows that there are cointegration vectors validating the existence of long-run relationship between the variables in presence of structural break.

Table 5: Long-Run Analysis

SBC_Model(0,1,0,1)	**Dependent Variable = ly_t**			
	Long-Run Results			
Variable	**Coefficient**	**Std. Error**	**t-value**	**t-prob**
Constant	0.818	0.776	1.054	0.301
Le_t	0.557 ***	0.193	2.881	0.007
Lc_t	-0.038	0.443	-0.086	0.933
Lf_t	0.067	0.105	0.667	0.510
Li_t	-0.024	0.291	-0.084	0.934

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

According to the SBC model specification, the coefficient of energy use is significant when the level of income is the dependent variable. Therefore, energy utilization is the long-run forcing variable to explain the level of income in the case for Mexico. It indicates that 1% rise in energy use per capita will raise the level of income by 0.55%. This finding implies that the energy has been considered as a main source of income predominantly since the occurrence of the oil shocks in the 1970s in Mexico.

The summary of results of the preferred models is displayed in Table 6. There is unidirectional causality between changes in energy utilization and business activity in Mexico. The long-run causality from energy consumption to income is supported by the coefficient of the lagged error–correction term, which is negative and statistically significant, as expected. This implies that energy usage leads to business activity. Thus, limitations on the amount of energy used could result in a drop in the rate of economic growth.

Table 6: Short-Run Analysis

Variable	Coefficient	Std. error	t-value	t-prob
Δle_t	0.82061***	0.138	5.948	0.00
Δlc_t	-0.007	0.077	-0.086	0.93
Δlf_t	0.012	0.018	0.6782	0.50
Δli_t	-0.005	0.049	-0.085	0.93
ECM_{t-1}	-0.175	0.105	-1.661	0.10
R^2 = .967	AIC = 112.03	Model_SBC: (0,1,0,1)		

Note: ***, ** and * denotes the significance at 1%, 5% and 10% level respectively.

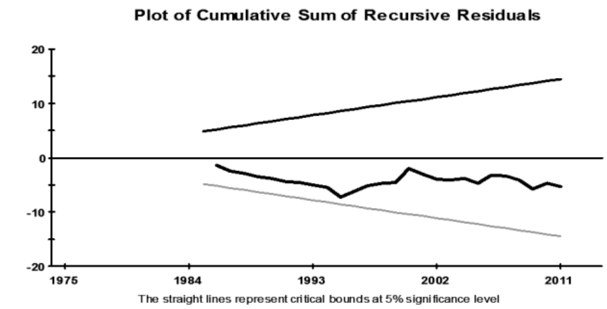
Table 7 presents diagnostic tests associated with the Equation (1). The exercise carries out four diagnostic tests: A) the Lagrange multiplier (LM) test of residual serial correlations, B) the heterosedasticity test based on the regression of squared residuals on squared fitted values, C) the normality test based on a test of skewness and kurtosis of residuals, and D) the Ramsey Regression Equation Specification Error Test (RESET) test using the square of the fitted values.

Table 7: Robustness of the Model

	Version	Dependent Variable (Ly_t)
Serial Correlation	LM Version	$\chi2$ (1) = 1.701(0.192)
	F Version	F(1.28) = 1.351(0.225)
Functional Form	LM Version	$\chi2$ (1) = 0.592(0.442)
	F Version	F(1.28) = 0.455(0.505)
Normality	LM Version	$\chi2$ (2) = 4.554(0.103)
	F Version	Not Applicable
Heterosedasticity	LM Version	$\chi2$ (1) = 0.504(0.478)
	F Version	F(1.35) = 0.484(0.491)

Notes: p-values are shown in the parentheses under each coefficient and ***, ** and * denotes the significance at 1%, 5% and 10% level respectively.

The diagnostic tests suggest that the estimations of the long-run coefficients and the ECM are free from serial correlations, heterosedasticity and functional-form misspecification at the 5 percent level. The value of the adjusted R-squared in the vicinity of 50 percent signifies a relative good fit of the models. To check the stability of model parameters, we apply CUSUM and CUSUMQ techniques based on ECM. The plots of CUSUM and CUSUMSQ statistics (Figure 1) are well within the critical bounds, implying that all coefficients in the ECM model are stable. In addition, the results present the plot of cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) test statistics that fall inside the critical bounds of 5% significance. This implies that the estimated parameters are stable over the sample period 1971-2012.



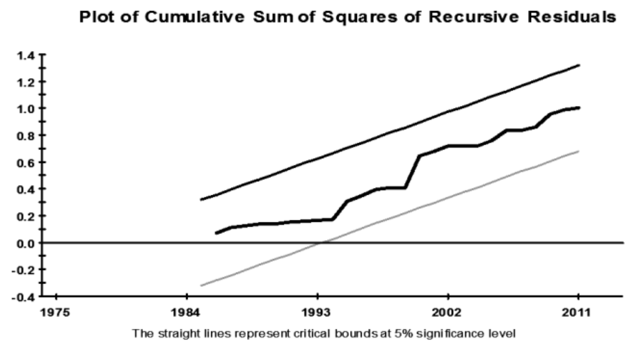


Figure 1: Cumulative Sum and Cumulative Sum of Square of the Recursive Residuals

5. CONCLUSION

The aim of this paper is to examine the relationships between carbon dioxide (CO_2) emissions, energy consumption, industrialization, financial sector development and business activity in Mexico over the period 1971-2012. All the variables are integrated of order one based on both conventional and break unit root tests. The findings claim that energy is the long-run forcing variable to explain the national income for Mexico. The short-run result also reflected the long-run coefficients: there is a unidirectional causality running from changes in energy utilization to business activity. Mexican government should be careful to implementation of energy saving policies in order to promote business activity growth. The findings are consistent in the context of industrialized economics: the limitation or shortage of energy may lead to reduction in business activity.

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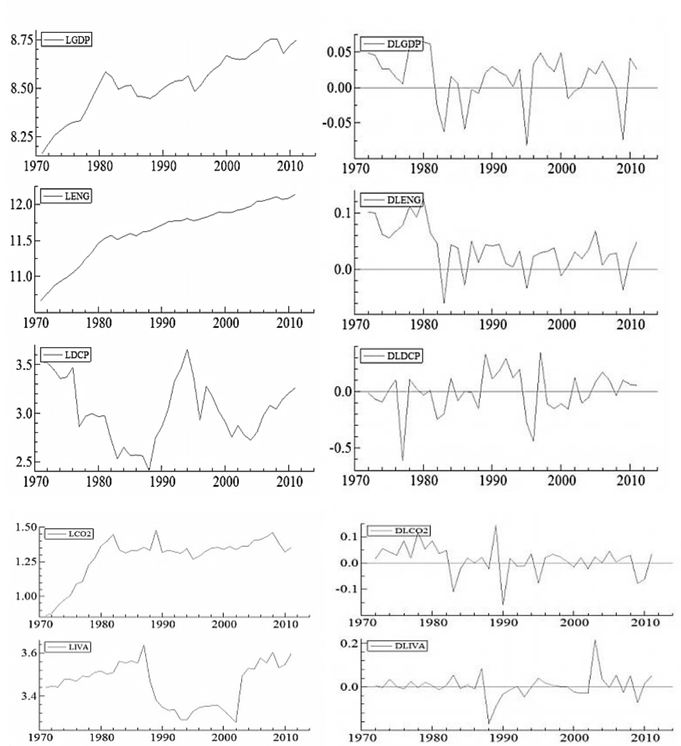
APPENDIX A



Log and First Difference of the Series

Note: The left side represent the log series and right hand side explained the first difference of the log series.