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An Econometric Study of the Long-Run Determinants of CO_2 Emissions in Cote d'Ivoire

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Abstract

This study investigates the long-run determinants of CO_2 emissions in Cote d'Ivoire. It makes use of the bounds testing approach to cointegration and data covering the period 1970 to 2010. The main variables driving CO_2 emissions are per capita income, the share of industrial sector in GDP and trade openness. The results also give support to the environmental Kuznets curve. More interestingly, the results show that the effect of trade openness on CO_2 emissions depends on the structure of the economy and increases as the country industrializes. Additionally, trade openness and industrialization are complementary in worsening environmental quality in Cote d'Ivoire.

JEL Classifications: C22, Q53, Q53

Keywords: carbon dioxide emissions, environmental Kuznets curve, Trade, GDP, cointegration

1. Introduction

Global warming is a major threat for all countries. Among its consequences are increasing desertification, rising sea levels and rising average temperatures. Today, economists and policy makers have become fearful about the environmental consequences of human activities. As carbon dioxide (CO_2) is regarded as the major cause of global warming, accounting for over 75% of total greenhouse gas emissions, it has captured more attention from researchers. Thus, a growing body of studies has been accumulated to examine the dynamics and determinants of CO_2 emissions. The empirical results from these studies are however inconclusive. Most of these studies used cross-section or panel data analysis under the implicit assumption of common coefficients of the estimated relationship. This restriction implies that the expected inverted U-shaped relationship and the turning point income are the same for every country. The absence of any clear consensus in the empirical literature may be attributed to the heterogeneity in climate conditions, energy consumption patterns, environmental policies and the structure and stages of economic development. Given this heterogeneity, different countries would show different patterns for the relationship between CO_2 emissions and its determinants. As suggested by Stern, Common, and Barbier (1996), the experience of individual countries should be analyzed when studying the relationship between CO_2 emissions and its determinants.

This study examines the long-run determinants of carbon dioxide emissions in Cote d'Ivoire. Over the 1970 to 2010, CO_2 emissions in Cote d'Ivoire have increased by 137%, causing a deterioration of air quality in urban areas. The major sources of air pollution are industries, vehicle exhaust, importations of old second hand vehicles, uncontrolled bush burning and open air waste burning activities. Recently, air pollution in Abidjan was judged high and responsible to rising rates of asthma. Experts are now warning of a dangerous and costly increase in respiratory-related diseases if actions are not taken. This concern raises the following questions: what are the key factors driving carbon dioxide emissions in Cote d'Ivoire? To what extent do urbanization and industrialization contribute to air pollution in Côte d'Ivoire? How can policymakers reduce dioxide carbon emissions without harming economic growth? Until now, there is no study addressing these questions for Cote d'Ivoire. Most empirical studies on CO_2 emissions applied a bivariate framework with the aim of examining the causal relationship between CO_2 emissions and another variable such as economic growth, energy consumption or trade. Apart from filling the gap in the empirical literature, this study uses the bounds testing approach to cointegration of Pesaran, Shin, and Smith (2001). This technique has been widely used in many empirical studies. However, our study is an advance over these works because we compute exact critical values specific to our sample size using Monte Carlo simulations. In doing so, we ensure that our inference regarding cointegration is correct.

The rest of the paper is organized as follows. Section 2 provides a brief review of the empirical literature. In section 3 we discuss the econometric methodology and data used in estimation. Section 4 presents and discusses the empirical results. Section 5 concludes the study.

2. Literature Review

The relationship between economic development and environmental pollution has been the topic of a burgeoning literature since the work of Grossman and Krugler (1991). These authors have investigated the environmental impacts of the North American Free Trade Agreement and discovered that the relationship between the total discharge of various environmental pollutants and economic growth exhibits an inverted U-shaped curve. Later, this curve has been coined as the Environmental Kuznets Curve (EKC) and many studies have tested the validity of this relationship. The basic idea of the EKC hypothesis is that environmental degradation increases with income up to a threshold income level beyond which air quality improves as income continues to grow. Subsequently researches found other variables to be closely related to CO_2 emissions. A thorough survey of theoretical and empirical studies dealing with the EKC is provided by Dinda (2004) and Stern (2004).

The impact of per capita GDP on CO_2 emissions is theoretically ambiguous. This impact is decomposed into three effects: scale effect, technique effect and composition effect (see Copeland & Taylor, 2004). The scale effect refers to the fact that increases in GDP require more inputs and therefore more emissions. The technique effect refers to the invention of new environmental friendly technologies in production which in turn leads to the reduction of pollutants. The composition effect stems from changes in production of an economy caused by specialization as well as the transition from agriculture or basic industries to high-tech services. The overall impact of GDP on the environment depends on which effect is stronger and dominates the others.

International trade is another driving factor of CO_2 emissions. The impact of trade on pollution depends on differences in factor endowments and environmental policies. Trade may reduce or increase energy consumption depending upon whether the country has comparative advantage in cleaner or dirty industries. Trade liberalization may be viewed as a way to transfer dirty industries to countries where environmental regulations are laxer. On the other hand, trade may allow access to energy-efficient technologies and better environmental management practices and thus contribute to significant reduction in CO_2 emissions (Grossman & Krueger, 1991; Goldemberg, 1998; Keller, 2004).

Urbanization is also a factor that drives CO_2 emissions. It is believed that growing urbanization leads to higher demands for energy and hence to higher pollution levels in urban areas. However, the theories of ecological modernization and urban environmental transition contend that urbanization can have both positive and negative impacts on the environment with the net effect being ambiguous (Poumanyvoung & Kaneko; 2010; Sadorsky, 2014). Higher urbanization is associated with higher economic growth which induces higher per capita income. Wealthier consumers demand more energy intensive products (automobiles, air conditioning, refrigerators, washing machines, etc.) which can increase CO_2 emissions. On the other hand, wealthier people are likely to care more about the environment. This calls for environmental regulations and technological innovation in the economy.

The empirical literature on the determinants of carbon dioxide has yielded mixed and inconclusive results. For instance, Dinda and Coondoo (2006) applied panel data from 88 countries and confirmed the existence of the EKC. Similarly, Apergis and Payne (2009) reached the same finding for a panel of six Central American economies. Shi (2003) used panel data set of 93 countries over the period 1975 to 1996 and found a direct relationship between population changes and CO_2 emissions. Cole and Neumayer (2004) considered 86 countries during the period from 1975 to 1998 and found a positive link between CO_2 emissions and a set of explanatory variables including population, urbanization rate, energy intensity and smaller household sizes. Chen (2009) studied the relationship between industrial sector's growth and CO_2 emissions using Chinese provincial data, and found that industrial development increases CO_2 emissions. Lean and Smyth (2010) reached a similar conclusion in their study of the ASEAN countries and Commonwealth of Independent States.

Akin (2014) investigated the determinants of CO_2 emissions in 85 countries over the period 1990-2011. Using panel cointegration analysis, He found that there is a positive relationship between CO_2 emissions and energy consumption and per capita income. On the other hand, the increase of trade openness affects CO_2 emissions positively in short run, and then the increase of trade openness will decrease the CO_2 emissions after a threshold level. Jalil (2014) explored the key determinants of CO_2 emissions for MENA region over the period 1971-2009 using alternative GMM methods. He found that per capita GDP, energy consumption, foreign direct investment, and agriculture production have significant impact on the growth of CO_2 emissions in the region. Managi, Hibiki, and Tsurumi (2009) used the technique of instrumental variables to depict the relationships between trade openness and the environment quality in OECD and non-OECD countries. They found that beneficial effect of trade on the environment varies depending on the pollutant and the country. Trade has improved the environment quality in OECD countries. However, it has had a detrimental effect on sulfur dioxide and carbon dioxide emissions in non-OECD countries. Aka (2008) examined the impacts of trade openness and economic growth on air pollution for Sub-Saharan Africa considered as a whole during the period 1961-2003. He used the bounds test approach and found that economic growth contributes to the degradation of air quality, while trade intensity is beneficial to the environment. Antweiler, Copeland, and Taylor (2001) used a panel data analysis for 44 countries and reached the conclusion that free trade is good for the environment.

Some studies have been conducted at country level. Opoku, Amoako, and Amankwa (2014) used the Johansen cointegration test for cointegration and reported evidence supporting the EKC in Ghana. He also found that free trade is detrimental to the environment. Owoye and Onafowora (2013) investigated the determinants of per capita CO_2 emissions in Brazil, China, Egypt, Japan, South Korea, Mexico, Nigeria and South Africa over the period 1970-2010. They carried out the empirical analysis using the bounds test to cointegration. Their results provide evidence that income growth and energy consumption are main factors in increasing CO_2 emission in the long-run in all the countries. Energy consumption has a positive and significant effect on CO_2 emissions. Results also indicated an inverted U-shaped for only Japan and Korea. In all the other countries, the long run relationship between economic growth and CO_2 emissions follows an N-shaped trajectory and the estimated tuning points are out of the sample data size. With respect to trade openness and population density, the results are mixed. Increased trade openness contributes to worsening environmental conditions in Mexico, Nigeria and South Africa. For Brazil, China, Egypt, Japan and Mexico, increasing population density leads to more environmental degradation in the long run. In the cases of South Korea, Nigeria, and South Africa, population density has a positive but statistically insignificant impact on CO_2 emissions. He and Richard (2010) investigated the relationship between per capita CO_2 emissions and per capita GDP for Canada between 1948 and 2004. They found little evidence in favor of the EKC.

Iwata, Okada, and Samreth (2010), Jalil and Mahmud (2009) and Ang (2007) found evidence supporting the EKC for CO_2 emissions in France and China. A positive link between trade and carbon dioxide emissions was found by Halicioglu (2009) for Turkey. Akbostanci, Türüt-Asik and Tunç (2009) tested for the existence of EKC in Turkey using cointegration techniques and both time series and provincial panel data for the periods 1968 to 2003 and 1992 to 2001. They found a monotonically increasing relationship between CO_2 emissions and income in the times series analysis, which suggests that the EKC hypothesis does not hold for CO_2 emissions. Lantz and Feng (2006) examined the EKC relationship in Canada using a region-level panel dataset of 5 regions for the period 1970-2000.Their results show that CO2 emissions are not related to GDP. Interestingly, they found an inverted U-shaped relationship between CO_2 and population. Friedl and Getzner (2003) explored the determinants of CO_2 emissions in Australia over the period 1960-1999. They found a cubic relationship between GDP and CO_2 emissions and positive effects of imports share and the share of the tertiary sector to GDP on CO_2 emissions.

Given the restrictiveness of the polynomial specification, some authors have proposed alternative functional forms. For instance, Schmalensee, Stoker, and Judson (1998) used a spline function with 10 segments and found evidence of an EKC for CO_2 for a dataset of 141 countries over the period 1950-1990. Martinez-Zarzoso and Bengochea-Morancho (2004) used the pool mean group estimator to analyze CO_2 emissions in 22 OECD countries over the period 1975-1998. This technique allows for slope heterogeneity across countries in the short-run while imposing restrictions in the long-run. The results show a great deal of heterogeneity across countries, and in most cases an N-shaped relationship exists. Galeotti, Lanza, and Pauli (2006) used a Weibull functional form to examine the EKC hypothesis for 125 countries and found mixed results. There is evidence of an EKC for OECD countries while a concave pattern with no turning point is obtained for non-OECD countries. Aslanidis and Iranzo (2009) applied a two-regime smooth transition model for 77 non-OECD countries over the period 1971-1997. They found no evidence of EKC. They found two regimes, namely a low-income regime where CO_2 emissions accelerate with economic growth and a middle to high-income regime associated with a deceleration in environmental degradation. Poumanyvoung and Kaneko (2010) analyzed the impact of urbanization on CO_2 emissions in a panel of 99 countries over the period 1975 to 2005. Using different models, they found that urbanization increases CO_2 emissions in all income groups but its impact is greatest for the middle income group of countries. Sharma (2011) investigated the determinants of CO_2 emissions for a global panel of 69 countries using a dynamic panel data model. He found that trade openness, per capita GDP and energy consumption have positive effects on CO_2 emissions. Urbanisation is found to have a negative impact on CO_2 emissions in high income, middle income and low income panels. For the global panel, only per capita GDP and per capita total primary energy consumption are found to be statistically significant determinants of CO_2 emissions, while urbanisation, trade openness and per capita electric power consumption have negative effects on the CO_2 emissions. Martinez-Zarzoso and Maruotti (2011) analyzed the impact of urbanization on CO2 emissions for a panel of 88 developing countries over the period 1975 to 2003. They found differential impact of urbanization on CO_2 emissions. The elasticity of urbanization with respect to

CO_2 emissions is positive for low urbanization levels. Sadorsky (2014) used recently developed heterogeneous panel regression techniques to explore the impact of energy use, income and urbanization on CO_2 emissions in emerging economies. He found that GDP per capita, population and energy intensity have positive impact on carbon dioxide emissions while urbanization is found to have no statistically significant impact.

From the review of the literature, we see that evidence regarding the determinants of CO_2 emissions is diverse and the studies on single countries especially on Sub-Saharan African countries are rather rare.

3. Econometric Methodology and Data

3.1. Empirical Model

Based on the review of literature discussed earlier, we specify the empirical model as follows:

$$CO_{2t} = \theta_0 + \theta_1 GDP_t + \theta_2 GDP_t^2 + \theta_3 TR_t + \theta_4 Ind_t + \theta_5 TR_t \times Ind_t + \theta_6 Urb_t + \mu_t \quad (1)$$

where CO_2 stands for per capita carbon dioxide emissions as the proxy for the level of air pollution, *GDP* is the per capita real GDP in constant 2005 US dollars, *TR* is trade openness measured as ratio of exports plus imports of goods and services to GDP, *Ind* is the share of the industrial sector in GDP, and *Urb* is the share of the urban population in total population. The square of GDP is included to test for the Environmental Kuznets Curve hypothesis. The share of industrial sector in GDP controls for the composition effect. We include the interaction term TR*IND to test whether the environmental impact of trade depends on the share of the industrial sector in the economy. The data for CO_2 and real GDP were converted into natural logarithms for estimation purposes so that they can be interpreted in growth terms after taking first difference.

3.2. Estimation Method

To estimate Eq.1, we employ the bounds testing approach to cointegration developed by Pesaran *et al*. (2001). The main advantage of this approach is that it can be applied irrespective of whether the regressors are purely I(0) or I(1). Hence, it rules out the uncertainties present when pre-testing the order of integration of the series. The bounds test generally provides unbiased estimates of the long-run coefficients even when some of the regressors are endogenous (Banerjee, Dolado,Galbraith, & Hendry, 1993; Inder, 1993).

To implement the bounds test, Eq.(1) is modeled as a conditional autoregressive distributed lag model (ARDL) as follows:

$$\begin{aligned}\Delta CO_{2t} &= \phi_0 + \phi_1 CO_{2t-1} + \phi_2 GDP_{t-1} + \phi_3 GDP_{t-1}^2 + \phi_4 TR_{t-1} + \phi_5 Ind_{t-1} + \phi_6 TR_{t-1} \times Ind_{t-1} + \\ &\phi_7 Urb_{t-1} + \sum_{i=1}^{m_1} \gamma_{1i} \Delta CO_{2t-i} + \sum_{i=0}^{m_2} \gamma_{2i} \Delta GDP_{t-i} + \sum_{i=0}^{m_3} \gamma_{3i} \Delta GDP_{t-i}^2 + \sum_{i=0}^{m_4} \gamma_{4i} \Delta TR_{t-i} + \\ &\sum_{i=0}^{m_5} \gamma_{5i} \Delta Ind_{t-i} + \sum_{i=0}^{m_6} \gamma_{6i} \Delta TR_{t-i} \times Ind_{t-i} + \sum_{i=0}^{m_7} \gamma_{7i} \Delta Urb_{t-i} + e_t\end{aligned} \quad (2)$$

The bounds test for cointegration involves estimating Eq.(2) by least square and testing the null hypothesis $\phi_1 = \phi_2 = \phi_3 = \phi_4 = \phi_5 = \phi_6 = \phi_7 = 0$. This hypothesis is tested by the mean of the *F-statistic*. However, its asymptotic distribution is non-standard under the null hypothesis. The critical values are provided by Pesaran *et al*. (2001) for large samples. Given the relatively small sample size of our study (T=41), we calculate exact critical values using stochastic simulations based on 40 000 replications.

3.3. Data

Data cover the period 1970 to 2010 and are obtained from the World Bank's World Development Indicators. As illustrated in the Figures 1 & 2, Cote d'Ivoire experienced an overall increase in CO_2 emissions over the period 1970 to 1988. From 1989 to 2010, CO_2 emissions fluctuate around a stable trend. We also observe that GDP shows an overall increase. The relationship between the two variables changes after 1989. Indeed, while GDP continues to rise, CO_2 emissions stagnate and show a decreasing trend from 2005 to 2010.

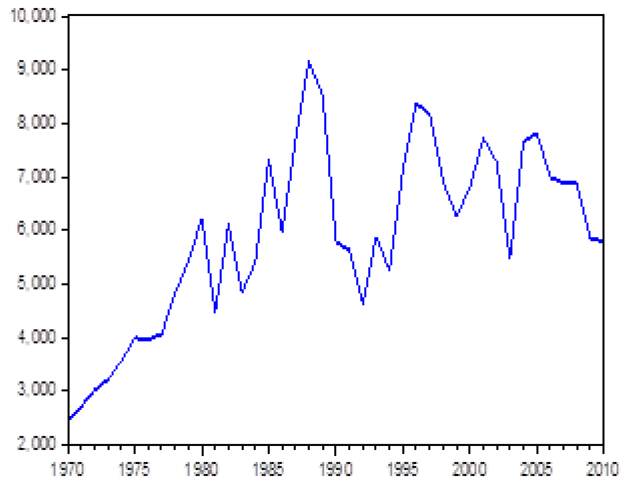

Figure 1. CO_2 emissions, 1970-2010

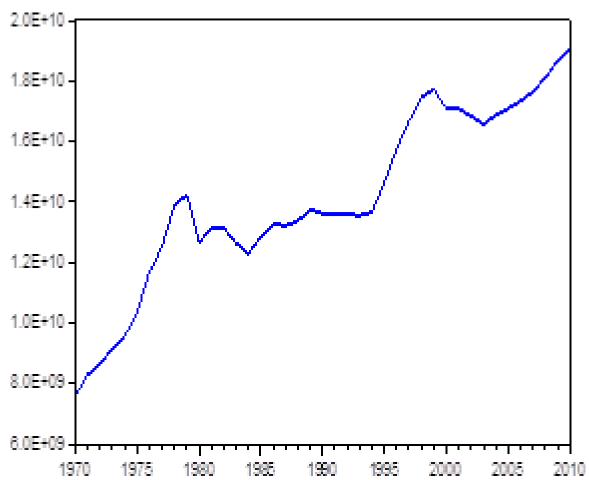

Figure 2. Real GDP, 1970-2010

4. Empirical Results

Before proceeding with the bounds test for cointegration, we test for unit roots in the variables. This step is necessary to ensure that none of the variables are I(2) so as to avoid spurious inference in cointegration tests. To test for unit-roots in the series, we apply the well-known Augmented Dickey-Fuller and Phillips-Perron unit root tests and the KPSS test. These tests have been performed under the models with constant and trend for the level series and with constant for series in first difference. The results reported in Table 1 reveal that CO_2 contains unit root in level and all variables become stationary after taking the first difference. This provides a good rationale for using the bounds test approach.

Table 1. Results of unit root tests

Series	Level			First difference		
	ADF	PP	KPSS	ADF	PP	KPSS
CO2	-3.568*	-3.508	0.154*	-8.028*	-8.910*	0.339
GDP	-2.385	-2.490	0.114	-4.315*	-4.312*	0.178
GDP^2	-2.251	-2.410	0.111	-4.348*	-4.348*	0.160
Trade	-1.717	-1.717	0.148*	-6.459*	-6.460*	0.130
Industry	-2.701	-2.696	0.113	-6.989*	-6.992*	0.089
Urbanization	-2.678	-1.990	0.102	-2.097	-2.140	0.174

Notes: * and ** indicate that the null hypothesis is rejected at the 5% and 10% levels, respectively.

Table 2 displays the results of the bounds test along with the long-run estimates. From this Table, we can see that the computed F-statistic is higher than the upper bound of the 5% critical values. Accordingly, we reject the null hypothesis of no cointegration among the variables and conclude that there is a long-run relationship among CO_2 emissions and its determinants. This implies that carbon dioxide emissions and its determinants do not move to far away from each other in the long-run.

Table 2. Long-run estimates

Variable	Coef.	t-Stat.
GDP	14.11*	3.426
GDP^2	-1.044*	-3.440
Trade	-0.266*	-3.071
Industry	-0.876*	-3.274
Urbanization	-0.059**	-1.843
Trade*Industry	0.012*	3.037
Bounds Test		
F-stat: 4.757		
5% Upper critical value: 4.192		

Notes: Figures in parenthesis are t-statistics. * and ** indicate significance at the 5% and 10% levels, respectively.

The positive sign for per capita real GDP and the negative sign for per capita real GDP squared are supporting the EKC hypothesis that pollution initially increases with income and then decreases after income reaches a certain level. The turning point is 860 US dollars. Up to this level, economic expansion harms to the environment.

Unexpectedly, the coefficient on urbanization is negative and significant at the 10% level, meaning that urbanization contributes to reduce per capita carbon dioxide emissions in Cote d'Ivoire. The message of this finding is that although urbanization embodies environmental degradation, it has potential benefits to achieve sustainable development. The experience of developed countries shows that no country in the industrialized world has ever achieved economic growth without urbanization. Cities give opportunity to people to access to advanced technologies and better knowledge that can help improving energy efficiency.

The effect of trade on CO2 emissions depends on the share of industrial sector in the economy and increases as the country industrializes. Increased trade openness contributes to worsening environmental conditions as the share of industrial sector in the economy exceeds 22.2% of GDP. Up to this threshold, trade does not harm to the environment. It is worth noting that over the period 2000 to 2009, industrial sector accounts for 23.6% of GDP and shows an upward trend, while the share of agricultural sector in GDP shows a downward trend, declining from 24.2% in 2000 to 21.2% in 2009. This finding suggests that the trade-pollution relationship depends greatly on the structure of the economy. Although theoretically openness to international trade may either reduce environmental pollution by providing industries an incentive to advance technology, or increase CO2 emissions by promoting migration of dirty industries, our finding supports the negative impact of trade, which is dependent on the size of the industrial sector. This finding is in line with the pollution haven hypothesis and the works of Opoku *et al*. (2014) for Ghana, and Owoye and Onafowora (2013) for Nigeria and South Africa, but contradicts with those of Akin (2014) for 85 African countries and Aka (2008) for Sub-Saharan Africa. Finally, a nonlinear relationship between per capita CO2 emissions and the size of the industrial sector is also found. Growing industrialization is a serious threat to environment as trade openness exceeds 73% of GDP. The results suggest that trade openness and industrialization are complementary in worsening environmental quality in Cote d'Ivoire.

5. Conclusion

In this study we examined the key variables explaining the long-run trend of CO2 emissions in Cote d'Ivoire. We used the bounds testing approach to cointegration and data covering the period 1970-2010. The results indicate that per capita GDP, the share of industrial sector in GDP and trade openness play a leading role in explaining CO2 emissions in Cote d'Ivoire. The results support the environmental Kuznets curve, that is CO2 emissions increase with income and then decrease after income reaches a threshold level. Another interesting finding is that the effect of trade openness on CO2 emissions depends on the share of industrial sector in the economy and increases as the country industrializes. Trade openness and industrialization are complementary in worsening air quality. This finding implies that the design of economic policies directed at fostering economic growth through industrialization should include considerations of its impact on the environment. Building a sustainable economic and a cleaner environment is a shared responsibility between population, the private sector and the government. Government should adopt environmental policies that induce industries to adopt new technologies which help mitigate environmental pollution. Moreover, population may embark on massive tree planting since this will help reduce the amount of CO2 in the atmosphere thereby reducing its harmful effect on the environment and human health.

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