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TRADE OPENNESS AND CO<sub>2</sub>  
EMISSIONS IN TUNISIA

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and Habib Zitouna

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## Abstract

The literature on trade often focuses on its impact on economic growth. However, more recently attention has been paid to the impact of openness on other important aspects of individual welfare, such as the environment. Because openness affects economic activity it will also affect pollution levels. But changes in economic activity also imply changes in the levels of income per capita which may lead to changes in the demand for environmental standards. Moreover, trade will affect pollution levels directly through its impact on the composition of the production bundle, as resources get reallocated across more, or less polluting sectors. All this suggests that the impact of trade openness on pollution is likely to depend on initial conditions and therefore cross-country results are likely to hide significant heterogeneity which may lead to the wrong policy conclusions. The objective of this paper is to assess the impact of Tunisia's trade reforms over the last four decades on its CO<sub>2</sub> emissions by taking into account not only the direct effect of trade on emissions, but also its indirect effect through growth. Using cointegration techniques we disentangle the long and short-run relationship between trade openness, income per capita and CO<sub>2</sub> emissions in Tunisia, and explore the extent of Granger causality among these variables. Results suggest that the direct effect of trade openness on CO<sub>2</sub> emissions is positive both in the short and the long run, but the indirect effect is negative at least in the long run.

## ملخص

كثيرا ما تركز الكتابات و الدراسات في مجال التجارة على تأثيرها على النمو الاقتصادي. ومع ذلك، فقد أعطيت أهمية كبيرة في الآونة الأخيرة لتأثير الانفتاح على جوانب هامة أخرى لرفاهية الفرد مثل البيئة. وكما أن الانفتاح يؤثر على النشاط الاقتصادي فإنه يؤثر أيضا على مستويات التلوث. ولكن التغيرات في النشاط الاقتصادي تنطوي على تغييرات في مستويات نصيب الفرد من الدخل والتي قد تؤدي إلى تغييرات في الطلب على المعايير البيئية. وعلاوة على ذلك، فالتجارة تؤثر على مستويات التلوث بشكل مباشر من خلال تأثيرها على تشكيلة عناصر الإنتاج، حيث أن الموارد يتم إعادة تخصيصها على أساس القطاعات الأكثر أو الأقل تلويثا للبيئة. كل هذا يشير إلى أن أثر الانفتاح التجاري على التلوث من المرجح أن يعتمد على ظروف أولية، وبناءا عليه فإن النتائج المتمخضة عبر قطر من الأقطار من المحتمل أن تخفي عدم تجانس كبير مما قد يؤدي إلى استنتاجات خاطئة. والهدف من هذه الورقة هو تقييم أثر الإصلاحات في قطاع التجارة في تونس على مدى العقود الأربعة الماضية على حجم انبعاثاتها من ثاني أكسيد الكربون، أخذة في الاعتبار ليس فقط التأثير المباشر للتجارة على تلك الانبعاثات، ولكن أيضا تأثيرها غير المباشر على النمو. و عندما نستخدم تقنيات التكامل المشترك فإننا نفضل بين العلاقة طويلة أو قصيرة المدى، التي تربط بين الانفتاح التجاري ودخل للفرد و بين انبعاثات ثاني أكسيد الكربون في تونس. كما تساعدنا تقنية التكامل المشترك أيضا في استكشاف مدى تأثير اختبار جرانجر للسببية على هذه المتغيرات. و تشير النتائج إلى أن الأثر المباشر للانفتاح التجاري على انبعاثات ثاني أكسيد الكربون إيجابية على المدى القصير و المدى الطويل أيضا، ولكن التأثير غير المباشر سيكون سلبيا على الأقل في المدى الطويل.

## 1. Introduction

Since the 1980s, Tunisia has adopted structural adjustment programs stipulating, among others, increased openness of the economy to foreign competition and integration into world markets. This policy choice, aims at stimulating growth and improving well-being. However, openness to trade is likely to affect the specialization and the structures of production. These structural changes may affect pollution emissions and environmental degradation.

This paper aims at assessing empirically the impact of the recent trade policy reforms in Tunisia on pollution emissions. We consider CO<sub>2</sub> emissions a measure of the level of pollution and environmental degradation.

The answer to this question will help to determine whether policy makers have to be concerned with the impact that further integration of Tunisia into world markets may have on its environment quality. If the answer is positive, the policy solution does not imply a reversal in trade reforms, but rather complementary policy measures that would help firms internalize the cost of their actions on the environment. In other words, the solution will likely lie in domestic and international environmental problems, rather than in trade policy. That said, trade policy could arguably be a suitable second best in the short run.

As highlighted by the traditional theory of international trade, country specialization is driven by comparative advantages. The effects of trade on pollution will then depend on the distribution of comparative advantages across countries. When accounting for the pollution content of production in different sectors, it is intuitively clear that comparative advantages are determined by the interaction between differences in factor endowments and pollution policy (see Copeland and Taylor (2004)). We will present each component (factor endowments and pollution policy) alone before thinking about them jointly.

First, we consider the factor endowments framework. If we isolate the environmental policy's effect and assume it has no effect on trade pattern, standard forces such as differences in factor endowments or technology, determine trade. As usual in the Heckscher-Ohlin framework, capital abundant countries export capital-intensive goods and are net importers of labor-intensive ones.

As a matter of fact, countries that are relatively abundant in factors used intensively in polluting industries (sectors with relatively high pollution-content) will on average get dirtier as trade liberalizes. On the other hand, countries that are relatively abundant in sectors used intensively in clean industries will get cleaner with trade. The outcome will then depend on the pollution contents of different goods.

As for the environmental policy, the well known pollution haven hypothesis states that differences in pollution policy across countries affect trade flows or plant location decisions. All other things being equal, countries with relatively strong (weak) environmental policy will specialize in clean (dirty) industries. From a political economy point of view, this pollution haven hypothesis can lead to a race to the bottom; trade and investment liberalization puts pressure on governments to weaken environmental policy to shield firms from increased foreign competition.

Combining both effects may lead to a non trivial effect of openness on pollution especially if rich countries are relatively abundant in factors used intensively in pollution-intensive industries.

Indeed, developing countries are both labor-abundant and have weaker pollution rules than developed countries. If labor-intensive goods are relatively cleaner, the South's less-stringent pollution policy will tend to make it a clean goods importer, but its labor abundance tends to make it a clean goods exporter. The pattern of trade depends on which of these effects is

stronger. In this particular case, for example, trade will not induce dirty industry migration from rich to poor countries, and in fact can lead to the opposite conclusion and pollution haven need not emerge.

Frankel and Rose (2005) develop some other possible links between openness and environment degradation. First, a ratcheting up of environmental standards —at the product level — may be at play (see Vogel (1995) and Porter and Van der Linde (1995)). Second, foreign companies can bring technological and managerial innovations from their home countries for the benefit of host countries. These innovations may lead to the use of energy efficient techniques (see for example Eskeland and Harrison (2002) for a study comparing foreign and indigenous plants in developing countries in terms of energy efficiency). Furthermore, openness offers consumers a larger set of available varieties. This positive effect increases the welfare, which translates into a rise in the demand for environmental quality and cleaner products.

The described mechanism ignores one important channel of transmission from openness to pollution. Indeed, openness to trade is expected to positively affect per-capita income. Foreign direct investments are also expected to stimulate growth. This is one of the main arguments in favor of liberalizing policies<sup>1</sup>. On the other hand, growth is also linked to the environment. An important link between trade and the environment is then passed-through per-capita income.

Grossman and Krueger (1993) underline an inverted U-shaped relation between income and environmental quality: growth harms the environment at low levels of development and helps it at advanced stages. This inverted U relation is known as the Environmental Kuznets Curve (EKC)<sup>2</sup>. One of the main explanations of the shape of the EKC is that it reflects changes in the demand for environmental quality as income rises. At low income levels, pollution rises with growth because increased consumption is preferred to environmental quality. As income goes up, the willingness to pay for environmental quality rises and increasingly large sacrifices in consumption are made to provide greater environmental benefits.

In order to better understand this curve, Grossman and Krueger (1993) and Copeland and Taylor (1994) distinguish between the scale, composition and technique effects (Copeland and Taylor (2004)).

- The scale effect measures the increase in pollution that would be generated if the economy were simply scaled up, holding constant the mix of goods produced and production techniques.
- The composition effect is captured by the change in the share of the dirty goods in national income. If we hold the scale of the economy and emission intensities constant, then an economy that devotes more of its resources to producing the polluting good will pollute more, and vice versa.
- The technique effect: all things being equal, a reduction (raise) in emission intensity reduces (increases) pollution. In this regard, Porter and Van der Linde (1995) put forward a complementary hypothesis according to which a tightening of environmental regulation stimulates technological innovation and growth and thereby has positive effects on both the economy and the environment.

However, as rightly noticed by Dinda (2004), The EKC is more likely to hold for certain types of environmental damage — pollutants with more short-term and local impacts (such as

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<sup>1</sup>A large empirical literature provides empirical evidence of this positive effect of openness (see for example Dollar (1992), Ben-David (1993), Sachs and Warner (1995), Edwards (1998), Frankel and Romer (1999) or Rodriguez and Rodrik (2003) for a critical review).

<sup>2</sup> The authors chose such a designation by analogy to the Kuznet's curve which links growth and income inequality.

SO<sub>2</sub>, CO, urban air concentrations), rather than those with more global indirect and long-term impacts (like CO<sub>2</sub>, energy consumption. . .).

It is then clear how trade liberalization can influence the environment: (i) it may affect positively the quantities produced (scale); (ii) it may change the country's specialization (composition) and (iii) it may alter the employed technologies (technique).

The empirical literature concerning studies on the links between growth and pollution as well as openness and pollution is very large. These studies were extensively reviewed by Copeland and Taylor (2004).

As for the link between growth and the environment, it is generally admitted that the validity of the EKC is sensible to the sample (countries and period considered) as well as the proxy chosen to measure pollution (see for example Grossman and Krueger (1993) or Frankel and Rose (2005)).

As for the pollution haven hypothesis (i.e. environmental regulatory gaps do affect countries' specialization and firms' location choices), it did not find a unanimous support.

Some case studies illustrate the pollution haven argument. Lepeltier (2004) cites some interesting examples: the case of the European tannery sector (one of the most polluting sectors) that relocated to southern countries; the case of the US solvents' producers that invested massively in Mexico (Mabey and Mc Nally (1999)); the case of production increase of some chemical products such as pesticides in Mexico (Leonard (1988)); or the case of the mining industry in Zimbabwe (Jha *et al* (1999)).

But, at the macro-economic level, these case studies do not seem to be significant. Indeed, developing countries are not specialized in polluting industries (World Bank (1998) and Sorsa (1994)). Moreover, according to Eskeland and Harrison (1997), there is almost no evidence that investors in developing countries are fleeing environmental costs at home. Instead, the evidence suggests that foreign-owned plants in four developing countries (Mexico, Venezuela, Cote d'Ivoire and Morocco) are less polluting than comparable domestic plants.

Also, plenty of other econometric studies were carried out but no consensus has emerged (see for example Mani and Wheeler (1997), Smarzynska and Wei (2005), Keller and Levinson (2002), Grether and de Melo (2003), Levinson and Taylor (2008) or Henderson and Millimet (2007)).

The relation between openness and pollution is also not straightforward. In a seminal work, Antweiler *et al* (2001) develop a theoretical model to divide the impact of trade on pollution into scale, technique and composition effects and then estimate it using data on SO<sub>2</sub> concentrations.

After controlling for variables capturing scale and technical effects, they reach the conclusion that openness has very little impact on pollution concentrations. In fact, trade openness is good for the environment through its effect on growth. However, this is done in a cross section of mainly developed countries. Taking into account the endogeneity of trade and growth, Frankel and Rose (2005) use appropriate techniques to isolate the effects of openness on the environment. They find little evidence that trade has the detrimental effect on the environment that the race to the bottom theory would lead one to expect. On the other hand, they find that openness harms the environment through its impact on growth.

Estimating the impact of trade on water quality in China, Dean (2002) finds that a fall in trade restrictions raises pollution directly (via the terms of trade). But since the fall in trade restrictions also raises income, the overall impact on emissions in China is positive.

This brief review of the theoretical and empirical studies linking openness to the environment suggests some comments:

1. At the macroeconomic level, the marginal effect of liberalization policies on pollution levels is not predictable since they depend on two factors: the pollution content of goods in which each country has a comparative advantage and environmental policy. The interaction between both arguments may lead to unexpected result; developing countries can benefit from trade liberalization.
2. If the environmental regulation and pollution levels are closely linked, the previous remark suggests that the causality between openness and pollution is not predetermined. On the one hand, environmental policies do affect the country's specialization (through the pollution haven hypothesis) but openness affects also pollution emissions. Then, a two-way link between pollution and international transactions may appear.
3. There are clear endogeneity problems when dealing with this question: (i) openness does affect growth which is linked to pollution. (ii) environmental regulations may impact growth through innovation and (iii) growth may also affect openness (see for example Rodrik (1995), Helpman (1988) or Harrison (1995)). For example, investments increases in a country disadvantaged in capital goods necessitates an increase in imports of such goods (Levine and Renelt (1992)).

See Figure 1. All these conclusions inspired our empirical methodology.

The rest of the paper is organized as follows. In Section 2 we present some stylized facts regarding trade openness, income per capita and emission of CO<sub>2</sub> in Tunisia. Section 3 concentrates on the long-run cointegration analysis and Section 4 focuses on the short and long-run causality among these three variables. Section 5 concludes.

## **2. Trade Openness and CO<sub>2</sub> Emissions in Tunisia: Some Stylized Facts**

In this empirical study, we use the following variables: Tunisian per capita real gross domestic product (PGDP), per capita of carbon dioxide emissions (PCO<sub>2</sub>) as a proxy for the level of pollution and environmental degradation, and finally the trade openness measure (exports+imports)/GDP (OPEN). All these variables are collected from the World Development Indicators (World Bank, 2008). The sample period covers data from 1961 to 2004, and series are transformed in logarithms so that they can be interpreted in growth terms after taking first difference.

Since the signature of the Structural Adjustment Program in 1986, Tunisia has changed its development strategy by adopting liberalization policies in different points. For its trade policy, a switching from a substitution to imports to an export promotion policy was adopted.<sup>3</sup>

At the multilateral level, Tunisia adhered to the rules and provisions of the multilateral trading system since it participated in the Uruguay Round of the GATT and was a founder of the WTO.

At the regional level, Tunisia was the first Mediterranean country to sign an association agreement with the European Union. This agreement, which came into force in 1996, stipulates a gradual fall in trade barriers in the industrial sectors. Tunisia is also member of

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<sup>3</sup> Moreover, attracting foreign direct investments (FDI) is one of the components of the development strategy.

The liberalization of investments since 1994 and the adoption of a proactive policy to attract FDI have enabled Tunisia to record a nine percent annual average rate of increase in FDI. Note that more than one third of inward FDI is earmarked for the manufacturing industry (see WTO (2005) for a review of the Tunisian trade policy).



the Greater Arab Free Trade Area (GAFTA) since 1998 and the Arab Mediterranean Free Trade Agreement (Agadir Agreement) since 2004.<sup>4</sup>

All these liberalization policies enabled Tunisian international trade to progress rapidly. Figures 2 and 3 illustrate the consequences of these policies. First, a clear increasing trend in the openness ratio (imports and exports of goods and services over GDP) is shown. This ratio went from less than 70% in the mid eighties to more than 100% in 2005. It is worth noting that the European Union is Tunisia's main partner. Second, we notice an important fall in the imports revenues since the 1990s. Regarding import levels, taxes on imports of goods and services regularly reached 15% in the eighties but they strongly fell to five percent in the last years.

Figure 3 shows a clear increasing tendency of CO<sub>2</sub> emissions. From 1960, these emissions increased by a factor of thirteen, growing from 1700 to 22000 kilo ton. This figure shows a clear environmental degradation in Tunisia in the last three decades.

### **2.1 Stationary properties of openness, GDP per capita and CO<sub>2</sub> emissions**

In Figure 4, we plot the selected variables and include the export ratio (exports/GDP). Apart from FDI, which have an erratic evolution, they tend to move together over time and a long-run or cointegrating relationship is likely to be present in this case<sup>5</sup>. In addition, this figure reveals that PCO<sub>2</sub> and PGDP have a linear relationship so that a quadratic specification is not required. As noticed previously, it is due to the global nature of CO<sub>2</sub>, which are pure global externalities. Hence, there is no reason to expect individual countries to address it on their own, no matter what their level of income is (Frankel and Rose (2005)).

Taking into account the methodological approach followed in this paper, the first step in our analysis has been to explore univariate properties and test the order of integration of each series (PGDP, PCO<sub>2</sub> and OPEN). When the number of observations is low, unit root tests have little power. For this reason we have examined the results from two different tests: the Augmented Dickey-Fuller (ADF) (Dickey and Fuller (1979 and 1981)), which tests the null of unit root, and KPSS (Kwiatkowski *et al* (1992)), which tests the null of stationarity. The results of both tests for the individual time series and their first differences are shown in Table 1.

The ADF statistics suggests that all variables in levels are non-stationary and are I(1) (integrated of order one), but stationary in the first difference I(0) (integrated of order zero). The KPSS test rejects the null hypothesis of level and trend stationarity for both lag truncation parameters. The KPSS statistics does not reject the I(0) hypothesis for the first-differenced series at conventional levels of statistical significance.

Therefore, the combination of the unit root tests results (see Table 1) suggests that the series involved in the estimation procedure are integrated of order one (i.e., I(1)). This implies the possibility of cointegrating relationships.

### **3. Long-Run Relationship between Openness, Emissions and GDP Per Capita**

The next step is investigating whether the series are cointegrated since the three variables were I(1). In this work, cointegration analysis was conducted using the general technique developed by Johansen (1988 and 1995) and Johansen and Juselius (1990, 1992 and 1994). They provide a methodology that allows the researcher to distinguish between the short and the long-run. These authors proposed a maximum likelihood estimation procedure which allows researchers to estimate simultaneously the system involving two or more variables to

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<sup>4</sup> GAFTA members are: Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates (UAE) and Yemen. Agadir agreement involves Morocco, Egypt, Tunisia and Jordan.

<sup>5</sup> The variables in levels were indexed (basis 100=2000) in order to present the data series in the same scale.

circumvent the problems associated with the traditional regression methods. Further, this procedure is independent of the choice of endogenous variable and allows researchers to estimate and test for the presence of more than one long-run structural relationship(s) in the multivariate system and how variables in the system adjust to deviations from such long-run equilibrium relationship(s).

The baseline econometric specification for multivariate cointegration is a VAR(p) representation of a k-dimensional time series vector  $Y_t$  reparameterized as a Vector Error Correction Model (VECM):

$$\Delta Y_t = \mu D_t + \Gamma_1 \Delta Y_{t-1} + \dots + \Gamma_{p-1} \Delta Y_{t-p+1} + \Pi Y_{t-1} + e_t \quad (1)$$

where  $Y_t$  is a  $(k \times 1)$  column vector of endogenous variables;  $D_t$  is a vector of deterministic variables (intercepts, trend...);  $\mu$  is the matrix of parameters associated with  $D_t$ ;  $\Gamma_i$  are  $(k \times k)$  matrices of short-run parameters ( $i=1, \dots, p-1$ ), where  $p$  is the number of lags;  $\Pi$  is a  $(k \times k)$  matrix of long run parameters and  $e_t$  is the vector of disturbances  $niid(0, \Sigma)$ .

In the I(1) system  $Y_t$  is said to be cointegrated if the following rank conditions are satisfied:

$H_r : \Pi = \alpha \beta'$  of rank  $0 < r < k$ , where  $\alpha$  and  $\beta$  are matrices of dimension  $(k \times r)$ .  $\beta$  is a matrix representing the cointegrating vectors which are commonly interpreted as meaningful long-run equilibrium relations between the  $Y_t$  variables, while  $\alpha$  gives the weights of the cointegration relationships in the ECM equations.

The general procedure outlined above has been applied to the system including the three selected variables (PGDP, PCO<sub>2</sub> and OPEN).

However, in empirical applications, the choice of  $r$  is frequently sensitive to: i) the deterministic terms included in the system (such as a constant and/or a trend) and on the way in which such components interact with the error-correction term; and ii) the appropriate lag length to ensure that the residuals are Gaussian.

In the present work the model has been estimated including two lags and an unrestricted constant and a trend component in the cointegration space<sup>6</sup>. In this case, the underlying VAR model contains both intercepts and deterministic linear trends, with the intercept and the trend coefficients being unrestricted. Multivariate tests for autocorrelation (Godfrey (1988)) and normality (Doornik and Hansen (1994)) have been carried out to check for model statistical adequacy before applying the reduced rank tests. Diagnostic tests on the residuals support the VAR model with three lags as a sufficient description of the data<sup>7</sup>.

Table 2 shows the results of Johansen's likelihood ratio tests for cointegration rank. As can be observed, the trace statistics do not reject the null hypothesis that there is one cointegrating relation between the variables ( $r=1$ ).

In all the following analysis we assume the presence of one cointegrating or stationary relations and two common stochastic trends in the system. The presence of one cointegrating vectors in our system suggests an inherent movement in the system to revert towards long-run equilibrium path of the Tunisian economy subsequent to a short-run shock.

<sup>6</sup>The optimal number of lags has been determined by the Akaike's information criterion, the Final Prediction Error and the Hannan-Quinn Criterion. The maximum number of lags is set to be four, given the reduced sample size.

<sup>7</sup>With respect to the deterministic components, and following Harris (1995), several tests have been conducted to empirically select such components. Results indicated that a model with an unrestricted constant and a trend component in the cointegration space. Also, our model was estimated including a dummy variable in 1972, to consider the Tunisian 1972 law for export promotion.

The estimated  $\beta$  and  $\alpha$  parameters are presented in Table 3 (Panel A), where  $\beta$  is presented in the normalized form. The cointegrating vector was normalized by LOPEN. As can be observed, all the parameters of the long-run equilibrium relationships have the expected signs.

The cointegration vector reveals a positive linkage between trade openness and per capita emissions and a negative linkage between economic growth and per capita pollution emissions in the long-run<sup>8</sup>. These results may provide some evidence of the environmental degradation coming from trade openness in Tunisia.

On the other hand, in this type of analysis, it is also convenient to consider the estimated  $\alpha$  parameters as they provide valuable information about the speed of adjustment of each variable towards the long-run equilibrium (pulling and pushing forces).

The results for the adjustment coefficients towards equilibrium show that:

1. CO<sub>2</sub> adjusts 32.5% to the long-run equilibrium in one year: it takes more than 3 years to correct long-run equilibrium.
2. GDP adjusts 12.0% to the long-run equilibrium in one year: it takes more than 8 years to correct long-run equilibrium.
3. Openness adjusts 31.6% to the long-run equilibrium in one year: it takes more than 3 years to correct long-run equilibrium.

#### 4. Short and Long-Run Causality

Since cointegration is a sufficient but not a necessary condition for Granger-causality, we next investigate the direction of causality by estimating VECM derived from the long-run cointegrating relationship (Engle and Granger (1987) and Granger (1988)). The VECM contains the cointegration relation built into the specification so that it restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics.

In this empirical study, the estimated VECM can be written as follow:

$$\Delta LOPEN_t = \mu_1 + \alpha_1 ECT_{t-1} + \sum_{i=1}^k \delta_{1i} \Delta LOPEN_{t-i} + \sum_{i=1}^k \gamma_{1i} \Delta LPCO2_{t-i} + \sum_{i=1}^k \lambda_{1i} \Delta LPGDP_{t-i} + \varepsilon_{1t} \quad (2)$$

$$\Delta LPCO2_t = \mu_2 + \alpha_2 ECT_{t-1} + \sum_{i=1}^k \delta_{2i} \Delta LOPEN_{t-i} + \sum_{i=1}^k \gamma_{2i} \Delta LPCO2_{t-i} + \sum_{i=1}^k \lambda_{2i} \Delta LPGDP_{t-i} + \varepsilon_{2t} \quad (3)$$

$$\Delta LPGDP_t = \mu_3 + \alpha_3 ECT_{t-1} + \sum_{i=1}^k \delta_{3i} \Delta LOPEN_{t-i} + \sum_{i=1}^k \gamma_{3i} \Delta LPCO2_{t-i} + \sum_{i=1}^k \lambda_{3i} \Delta LPGDP_{t-i} + \varepsilon_{3t} \quad (4)$$

In addition to the variables defined above,  $ECT_{t-1}$  is the lagged error-correction term derived from the long-run cointegrating vectors (see Table 3) and  $\varepsilon_{1t}$ ,  $\varepsilon_{2t}$  and  $\varepsilon_{3t}$  are serially independent random errors with mean zero and finite covariance matrix.

<sup>8</sup>In this paper, we do not interpret the normalized cointegration relation as long-run elasticities (as in conventional regression context), since such an interpretation ignores the dynamic interactions among the variables (Juselius (1999) and Ltkepohl (2005)). For example, a 1% increase in OPEN may not result in a 0.945% increase in PCO<sub>2</sub>, since a change in the OPEN ratio is likely to have an effect on other variables as well that may interact in the long-run.

There are two sources of causation (through the error-correction term, if  $\alpha \neq 0$ , or through the lagged dynamic terms). The error-correction term measures the long-run equilibrium relationships while the coefficients on lagged difference terms indicate the short-run dynamics.

The statistical significance of the coefficients associated with  $ECT_{t-1}$  provides evidence of an error-correction mechanism that drives the variables back to their long-run relationship.

As mentioned in the econometric literature, three different causality tests can be performed, (short-run Granger non-causality, long-run weak exogeneity and overall strong exogeneity tests).

For example, in equation (2) to test that  $\Delta LPCO2$  does not cause  $\Delta LOPEN$  in the short-run, we examine the statistical significance of the lagged dynamic terms by testing the null  $H_0$ : all  $\gamma_{1i} = 0$  using the Wald test. Non rejection of the null implies that  $\Delta LPCO2$  does not Granger-cause  $\Delta LOPEN$  in the short-run. Rejection of the null implies  $\Delta LPCO2$  Granger causes  $\Delta LOPEN$  in the short-run.

The long-run weak exogeneity test, which is a notion of long-run non-causality test, requires satisfying the null  $H_0$ :  $\alpha_1 = 0$  for non-causality from long-run equilibrium deviation to  $\Delta LOPEN$ . It is based on a likelihood ratio test which follows a  $\chi^2$  distribution.

Finally, following Charemza and Deadman (1992), overall strong exogeneity can be performed.

The overall strong exogeneity test implies satisfying both short-run Granger non-causality and weak exogeneity and indicates the overall causality within the variables. For example, in equation (2),  $\Delta LPCO2$  does not cause  $\Delta LOPEN$  requires satisfying the null  $H_0$ : all  $\gamma_{1i} = \alpha_1 = 0$ .

Table 4 shows the findings of non-causality tests.

When examining the linkage between the degradation of the environment and openness, statistical results presented in Table 4 provide support for causality running from openness to  $CO_2$  emissions growth in the long-run and the short-run (only at 10% level of significance). Support for reverse causality (from  $PCO_2$  to OPEN) is also found in the long-run. These results do not support the view that openness and  $CO_2$  emissions are neutral with respect to each other in Tunisia.

Statistical results provide support for mutual causality and feedback relationship between  $CO_2$  emissions growth and output growth only in the long-run. This pattern of development is consistent with the experiences of many developing countries.

Finally, when examining the linkage between output and openness, statistical results provide support only for bidirectional causality in the long-run. These results are consistent with the argument that international trade exerts a positive influence on per capita income in Tunisia.

Indeed, the Tunisian economy may be vulnerable to trade policy shocks in which a fall in trade barriers may adversely affect output growth.

## 5. Concluding Remarks

The objective of this paper is to assess empirically the impact of Tunisia's trade reforms over the last four decades on its  $CO_2$  emissions by taking into account not only the direct effect of trade on emissions, but also its indirect effect through growth. Using cointegration techniques we disentangle the long and short-run relationship between trade openness, income per capita

and CO<sub>2</sub> emissions in Tunisia, and explore the extent of Granger causality among these variables.

The main results can be summarized in the following points:

- The cointegration analysis reveals a positive linkage between trade openness and per capita emissions and a negative linkage between economic growth and per capita pollution emissions in the long run.
- The direct effect of trade openness on CO<sub>2</sub> emissions is positive both in the short and the long run, but the indirect effect is negative at least in the long run.
- These results may provide some evidence of the environmental degradation coming from trade openness in Tunisia.

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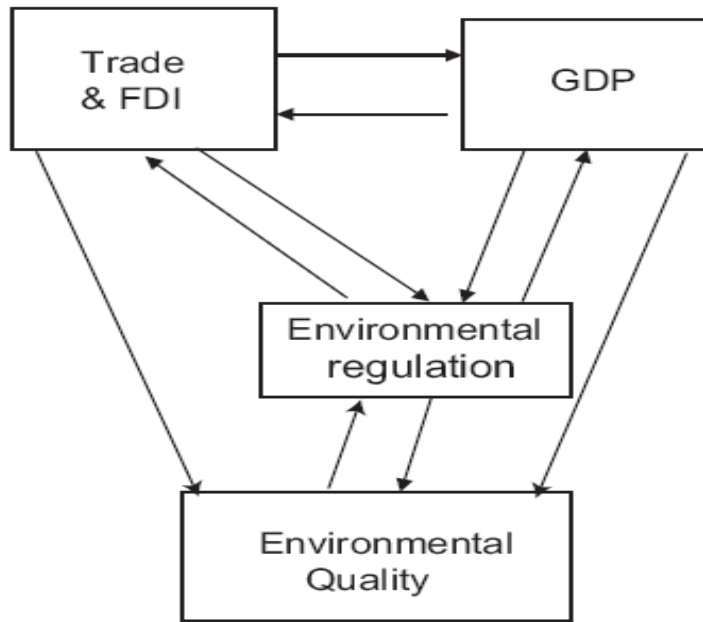
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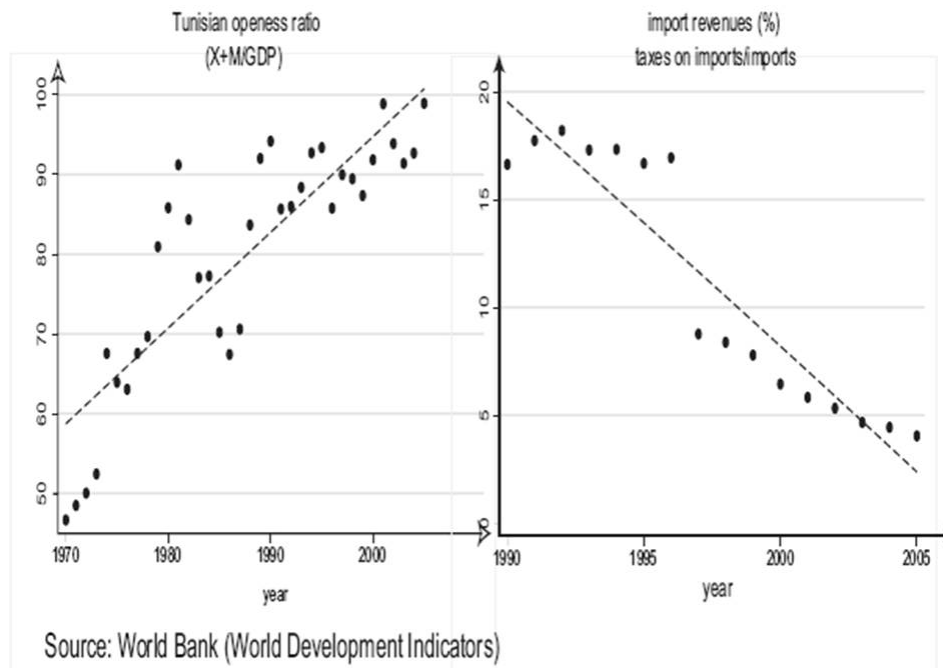
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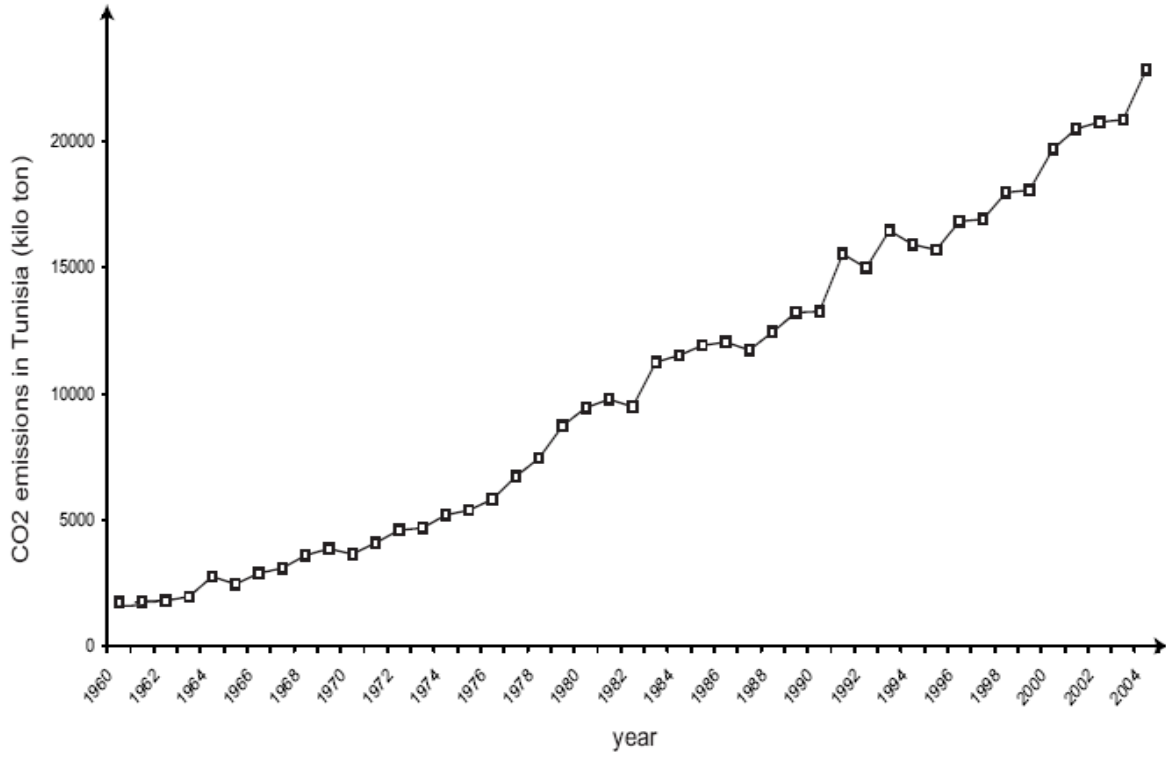
**Figure 1: Openness, Income and the Environment: Causal Relationships**



**Figure 2: Trade Openness and Taxes on Imports in Tunisia**

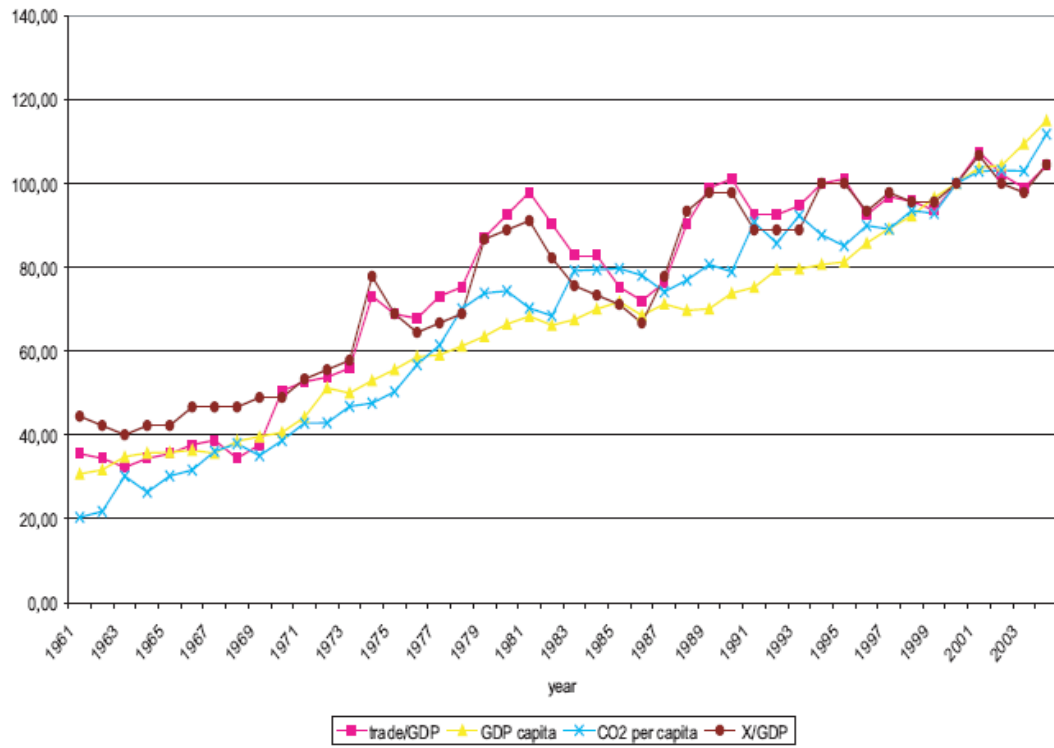


**Figure 3: CO<sub>2</sub> Emissions in Tunisia**



Source: World Development Indicators (World Bank)

**Figure 4: Trends in Trade Openness, Income and CO<sub>2</sub> Emissions (Basis year 2000=100)**



**Table 1: Results of the ADF and KPSS tests<sup>9</sup>**

<b>Panel A: ADF Test (null hypothesis is non-stationarity)</b>									
	<b>Level form</b>				<b>First difference</b>				
	<b>Intercept time trend</b>		<b>Intercept, no time trend</b>		<b>Intercept, no time trend</b>				
Income per capita	2.8166		0.9818		8.7645				
CO <sub>2</sub> emissions	2.3636		2.2248		7.2017				
Openness	2.8067		1.7022		6.7333				
<b>Critical values</b>									
	<b>Intercept time trend</b>				<b>Intercept, no time trend</b>				
1%	3.96				3.43				
5%	3.41				2.86				
10%	3.13				2.57				
<b>Panel B: KPSS Test (the null hypothesis is stationarity)</b>									
	<b>l=1</b>		<b>l=3</b>		<b>l=1</b>		<b>l=3</b>		
	$\eta_{\mu}$	$\eta_{\tau}$	$\eta_{\mu}$	$\eta_{\tau}$	$\eta_{\mu}$	$\eta_{\tau}$	$\eta_{\mu}$	$\eta_{\tau}$	$\eta_{\tau}$
Income per capita	1.6399	0.2370	0.9337	0.1286	0.2145	0.2043	0.2091	0.1990	
CO <sub>2</sub> emissions	1.5039	0.2985	0.8627	0.1933	0.3604	0.1102	0.3160	0.1113	
Openness	1.5927	0.2030	0.9087	0.1498	0.2341	0.1228	0.2316	0.1302	
<b>Critical values</b>									
	<b>Level stationarity</b>					<b>Trend stationarity</b>			
1%	0.739					0.216			
5%	0.463					0.146			
10%	0.347					0.119			

**Table 2: Results of Cointegration Tests (Trend and Intercept Included)<sup>10</sup>**

<b>H0 : r =</b>	<b>H1 : <math>\rho - r =</math></b>	<b>Critical Values</b>			
		<b>LR-Trace</b>	<b>(90%)</b>	<b>(95%)</b>	<b>(99%)</b>
0	3	50.93b	44.47	47.71	54.18
1	2	21.70	26.72	29.32	34.61
2	1	5.25	12.58	14.47	18.47

<sup>9</sup> The lag length for the ADF tests to ensure that the residuals were white noise has been chosen based on the Akaike Info Criterion. The KPSS statistics test for lag-truncation parameters one and three (l=1 and l=3) since it is unknown how many lagged residuals have been used to construct a consistent estimator of the residual variance.

<sup>10</sup> Superscripts a, b and c indicate the rejection of the null hypothesis at the 1, 5 and 10 percent level of statistical significance, respectively.

**Table 3: Normalized Cointegration Relations and Loading Coefficients ( $\alpha$ )<sup>11</sup>**

$$\alpha = \begin{pmatrix} -0.325^a \\ (-3.532) \\ -0.120^a \\ (-3.155) \\ 0.316^a \\ (2.758) \end{pmatrix} \text{ and } \beta' = \begin{pmatrix} 1.000 & 0.538 & -0.945^a \\ & (1.331) & (-5.94) \end{pmatrix} \times \begin{pmatrix} LPCO2^b \\ LPGDP^c \\ LOPEN^d \end{pmatrix} + \begin{pmatrix} -0.022^a \\ (-2.77) \end{pmatrix} \times TREND$$

**Table 4: Results of Non-Causality Tests<sup>12</sup>**

Hypothesis of short non causality	Run Granger long non causality	Run weak overall strong exogeneity	Hypothesis of short exogeneity
H0 : LOPEN $\nrightarrow$ LPCO2	3.5149 <sup>c</sup>	6.9911 <sup>a</sup>	11.4743 <sup>a</sup>
H0 : LPCO2 $\nrightarrow$ LOPEN	0.0105	10.9203 <sup>a</sup>	10.9505 <sup>a</sup>
H0 : LPGDP $\nrightarrow$ LPCO2	1.7506	8.9350 <sup>a</sup>	10.7709 <sup>a</sup>
H0 : LPCO2 $\nrightarrow$ LPGDP	0.8554	10.9203 <sup>a</sup>	11.5921 <sup>a</sup>
H0 : LOPEN $\nrightarrow$ LPGDP	0.3769	6.9911 <sup>a</sup>	8.5010 <sup>b</sup>
H0 : LPGDP $\nrightarrow$ LOPEN	0.3710	8.9350 <sup>a</sup>	9.3519 <sup>a</sup>

<sup>11</sup> Superscripts a, b and c indicate the rejection of the null hypothesis at the 1, 5 and 10 percent level of statistical significance, respectively. Figures in parenthesis are t-statistics.

<sup>b</sup>LPCO<sub>2</sub> is the log of per capita CO<sub>2</sub> emissions.

<sup>c</sup>LPGDP is the log of per capita GDP.

<sup>d</sup>LOPEN is the log of the openness ratio.

<sup>12</sup> Superscripts a, b and c indicate the rejection of the null hypothesis at the 1, 5 and 10 percent level of statistical significance, respectively.