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On the Causal Nexus of Road Transport CO_2 Emissions and Macroeconomic Variables in Tunisia: Evidence from Combined Cointegration Tests

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Abstract
This paper investigates the causal relationship between road transportation energy consumption, fuel prices, transport sector value added and CO_2 emissions in Tunisia for the period 1980-2012. We apply the newly developed combined cointegration test proposed by Bayer and Hanck (2013) and the ARDL bounds testing approach to cointegration to establish the existence of long-run relationship in presence of structural breaks. The direction of causality between these variables is determined *via* vector error correction model (VECM).

Our empirical exercise reveals that the cointegration is present. Energy consumption adds in CO_2 emissions. Fuel prices decline CO_2 emissions. Road infrastructure boosts in CO_2 emissions. Transport value-added also increases CO_2 emissions. The causality analysis indicates the bidirectional casual relationship between energy consumption and CO_2 emissions. Road infrastructure causes CO_2 emissions and similar is true from opposite side in Granger sense. The bidirectional causality is also found between transport value-added and CO_2 emissions. Fuel prices cause CO_2 emissions, energy consumption, road infrastructure and transport value-added. This paper provides new insights to policy makers to design a comprehensive energy, transport and environment policies for sustainable economic growth in long run.
Keywords: Road Transport, CO_2 Emissions, Tunisia

1. Introduction

It has been an established fact that transport-related energy consumption represents 27% of the global energy demand and is responsible for 22% of total carbon dioxide emissions (IEA, 2012a). In the year 2030, the world transport energy consumption and CO_2 emissions will increase by more than 50% (IEA, 2008). Transportation sector emissions in developing and transition countries, which are expected to have a higher economic growth, represent a serious problem. Transport CO_2 emissions are expected to increase dramatically in developing and transition countries from one third to one half of global emissions by 2030 (IEA, 2006).

In Tunisia, as in most developing countries, transport sector is one of the largest energy consuming sectors. It accounts for 26.9% of total energy used by the country (IEA, 2012b) and responsible for more than 30% of CO_2 emissions in 2010 (Mraihi et al. 2013). Particularly, the road transport is the major part of the transportation system in Tunisia with 80%. It consumes around 70% of the total energy demand in transport sector. Consequently, the management of road transport sector is of particular priority in Tunisia. This is due to the rapid increase of ownership cars with annual growth rate of 6.57% (Abdallah et al. 2013) which result in an increase in fuel consumption (3.7% on average per year during the period 1980-2012) and as a result in an accelerated rise in dioxide carbon emissions (4% on average per year during the period 1980-2012). In addition, Tunisia became a net oil importer for the first time in 2000 and currently it imports over half of its petroleum product demand.

Therefore, from the sustainability standpoint, it is important to examine the more influencing factors of transport-related energy consumption and GHG emissions changes. Understanding key driving forces of transport energy demand (economic growth, fuel price, urbanization, road infrastructure, the growth rate of vehicle ownership, average fuel intensity...) provides insight for development mitigations measures and policies in order to control GHG emissions. Moreover, any policy or sustainable measure to mitigate transport emissions needs a better understanding of causality relationship between economic growth, transport energy consumption, transport activity and some main macroeconomic variables.

This paper contributes in existing literature by investigate the road CO_2 emissions function in case of Tunisia. We apply Bayer-Hanck combined cointegration approach for cointegration and structural break unit root test is applied for integrating properties of the variables. The robustness of cointegration results is tested by applying the ARDL bounds testing. The causal relationship among the variables is investigated by applying the VECM Granger causality approach. We find the presence of cointegration. Energy consumption adds in CO_2 emissions. Fuel prices decline CO_2 emissions. Road infrastructure boosts in CO_2 emissions. Transport value-added also increases CO_2 emissions. The causality analysis indicates the bidirectional casual relationship between energy consumption and CO_2 emissions. Fuel prices cause CO_2 emissions, energy consumption, road infrastructure and transport value-added. Road infrastructure causes CO_2 emissions and similar is true from opposite side in Granger sense. The bidirectional causality is also found between transport value-added and CO_2 emissions. The remainder of this paper proceeds as follows. Section 2 presents the detailed information on Tunisian road transport sector. Section 3 reviews the previous empirical studies. Section 4 outlines the modelling framework and data collection. Section 5 details the empirical methodology. Section 6 contains the interpretations of the empirical estimations results, and finally, section 7 concludes the paper and provides some policy implications.

2. Tunisian road transport sector

In Tunisia, the transport sector is a driving force for economic growth. Its share in GDP is 6% with average annual growth rate of 5.5% over the period 2002-2008 (National Institute of Statistics – NIS-, 2013). The transportation sector value added contributes about 31% of the value added generated by services which represents 2.28 billion dollars. The transport sector in Tunisia employs 120,000 people which represent 3.9% of labor force. The road transport covers 95% of passengers transport against 5% for railways. In 2008, the volume of road traffic was 22 billion person-km distributed between collective bus transport (17%), transport using "louage" cars (18%) and private cars (65%). The national vehicle fleet recorded in 2007 about 1.3 million units against 0.4 million in 1988 with average annual growth rate of 7%. Private cars constitute the bulk of the fleet structure with about 59% followed by light commercial vehicles (25%), heavy commercial vehicles (trucks, road tractors, agriculture tractors, trailers and articulated trailers) with 13% and collective transportation vehicles (buses, minibuses) with 1%. The urban transportation accounts for 80% of the fleet on a network covering more than 3000 kilometers.

The transport sector in Tunisia accounts for 29.6% of total energy consumption after the residential (30.6%) and industrial (25.1%) sectors. In 1997, Tunisia's Agency for Energy Management (AME) has estimated that the transport and residential sectors will both correspond to the largest energy consumer by 2020 (AME, 1997). Between, 1980 and 2012, transport energy consumption in Tunisia grew at an average annual rate of 2.86% reaching 198.5 kg of oil equivalent per capita in 2012, up from 80.5 kg of oil equivalent per capita in 1980. The concentration of population in capital cities across the country and economic development generate new demand for transport services.

In 1997, a study on the evolution of energy demand by sector has been completed by the AME. This study demonstrated that energy demand will increase considerably over the next three decades (Table-1). The share of transport sector remained stable accounting for almost one third of total energy consumption. The estimated average annual growth rate of road transport-related energy consumption is 3.7%. The sustainable growth of transport energy demand is explained by the fact that the public and private road transports are the main mode of transport for Tunisian households. Public transport however does not meet the recommended quality. In this sense, Tunisia is still facing problems as the existing transport sector is seriously biased towards private transportation with inadequate alternatives to public transport. In accordance with the Ministry of Transport, the disorganized public transport system leads the urban residents to choose private cars instead of the public transportation. Furthermore, urbanization, economic development sustained over the two past decades, the fuel subsidies and the increase of ownership Cars Park contributed in rapid growth of road transport energy consumption.

Table-1: Evolution of Energy Consumption by sector 1985-2020

Year	1985	1990	1996	2010*	2020*
Total energy consumption (in Mtoe)	2.9	3.5	4.3	9.3	14.2
Share by sector	%	%	%	%	%
Industry	40.6	40.9	35.1	29.5	28.1
Transport	**32.3**	**30.2**	**31.8**	**32.8**	**31.8**
Residential/Treritiary	21.1	22.3	25.4	32.0	35.6
Agriculture	6.0	6.6	7.7	5.7	4.5

* estimation (assuming an average annual rate growth of 5% in energy demand between 1996 and 2020)

Source: AME - Energie 21 : Analyse de la Demande et Maîtrise de l’Energie-Septembre 1997.

Interestingly, in the case of Tunisia, the national vehicles park grew at an average annual rate of 6.1% over period 1990-2006 (Mraihi et al. 2013). The major share of fleet is contributed by passenger cars with a share of 68.8% (Abdallah et al. 2013). The continuous growth of the large cities in Tunisia (Tunis, Sousse and Sfax) and rural-urban migration lead to a substantial increase in private transport. Car registration increased from an annual average of 38,000 over the period 1988-1997 to 55,000 for the 1998-2007 period[1]. The increasing number of private transport mainly passenger cars has shown growing interest in its effect on transportation issues especially road congestion, fossil fuel energy consumption and CO_2 emissions. The road infrastructure has not followed the development of the park structure in large cities, roads suffer from significant congestion. Increased congestion in these cities due to increased vehicle fleet leads to overconsumption of energy and greenhouse gas emissions. The rapid growth in ownership cars can be explained particularly by facilitating access to "popular cars loan" and credit leasing for road freight vehicles. The road freight transport has already been liberalized in 1990. As a result, there are today 578 goods transportation companies and 1,070 private operators. These operators utilize a fleet of approximately 330,000 vehicles (8,000 trailers, 22,000 trucks and 300,000 light duty vehicles). In 2008, the road transport of goods amounted to about 28 billion tons/kilometers. In addition to rapid growth in transport fleet, all energy prices in Tunisia are subsided. The total subsidy for the oil product has reached 1.070 million TND (Tunisian National Dinars) in 2010 (on the basis of a Brent crude price at 80 USD/bbl and a parity dollar/dinar at 1.48)[2]. The fuel subsidies especially petrol, diesel and liquefied petroleum gas have undesirable effects such as energy overconsumption and carbon emissions.

Consequently, road transport CO_2 emissions increase tremendously from 1980 to 2012 with over 30%. In 2010, the road transport was responsible for more than 30% of total

[1] EuroMed Transport study road transport in Maghreb countries (2010)

[2] The total subsidy to the energy sector has reached 2.1 billion dinars (€1.1 billion) in 2010 or 11% of the state budget expenditure (5% of GDP).

pollution in the country. The growth of CO_2 emissions from road transport has followed the growth of GDP. The carbon dioxide emissions from road transport rose from 1.75 million metrics tons to 5.96 million metrics between 1980 and 2012, with an annual increase rate of 4%. The growing of urbanization rate[3] leads to increasing transport distance that requires, as a consequence, an additional consumption of fossil fuels quantities. With regards to rapidly gowning cities and as a result the strong growth national vehicle park, the European Institute for Environment and Sustainability (2013) predicts an increase in transport CO_2 emissions by 2020. The rise and the spread of the largest cities in Tunisia will reinforce the trend of energy consumption in road transport sector. Hence, it is essential to adopt regulatory measures in order to control future increases in urban energy demand in the transport road sector, and consequently achieve the country environmental benefits.

In order to regulate and restrict transport road CO_2 emissions, Tunisia has already implemented a legal arsenal. The article 61 of the "Tunisian road code" (Law n° 99-71 dated July 26, 1999) asserts that vehicles, trailer or articulated trailer used in traffic must comply with technical requirements (pollution and noise levels, clearance, weights, tires, equipment and design...). Furthermore, the Tunisian government issued other decree (n° 2000-147 dated January 24, 2000) that details the technical visit's periodicity for each type of vehicle. The technical controls are carrying out by *The Road Transports Technical Agency*, created in 1998. This Agency is also responsible for creation and maintenance of road public transport stations.

Nonetheless, despite of the government efforts to reduce the greenhouse fuel emissions, the country will need to adopt new regulatory measures for achieving the objective of efficient energy use in road transport sector. From this perspective, it is crucial to understand the factors affecting CO_2 emissions from the road transport sector in order to

[3] The urban population in Tunisia represents 60% of total population and the annual rate of urbanization is 1.34%.

implement a mitigating policy agenda for environmental degradation and sustainable road transportation development.

3. Literature Review

The direction and the sign of long-run causality between transport activity, economic growth and environmental quality[4] has received a great deal of attention from economists. Meanwhile, relatively few previous researchers have been interested in disaggregated sectoral data (e.g., transport, industry and residential sectors). Understanding the nexus between these variables is very crucial in the energy policies, emissions control and the implementation of transport policies. However, the empirical findings in terms of causality have been paradoxical and inconclusive. The literature remains divided on the issue of whether the causal relationship between variables will be unidirectional, bidirectional or absent.

It is well recognized that the road transport demand is determined by GDP per capita and energy consumption. For example, Kulshreshtha et al. (2001) applied a multivariate cointegrating vector autoregressive (VAR) model to investigate the long-run structural relationship for Indian railways freight transport demand over the period 1960-1995. It has been found that there exists long-run causality that is bidirectional between economic growth and freight transport demand. The results also indicate that the freight demand system seems to be stable in the long-run and the short-run disequilibrium can be corrected within a period of around three years by adjustments in GDP and freight transport demand. Applying similar cointegration approach for the same country, Rudra (2010) has examined the nexus between transport infrastructure, energy consumption and economic growth over the period 1970-2007. He found that the unidirectional causality exists running from transport

[4] Additionally to these economic variables, transport sector and transport energy consumption are impacted by population growth and urbanization (Chemin, 2009; Schafer, 2006; Scholl et al. 1996; Liddle, 2004 and Rodrigue et al. 2006).

infrastructure to economic growth, from economic growth to energy consumption and from transport infrastructure to energy consumption. In the case of Australia, Samimi (1995) has used a cointegration technique in order to investigate the short-run and long-run characteristics of energy demand in the road transport sector over a period using quarterly data from 1980:1 to 1993:2. It has been confirmed the existence of the bidirectional causality between output and energy demand and a unidirectional path from energy consumption to energy price. However, the short-run price elasticity is found to be insignificant. Akinboade et al. (2008) also found that the gasoline demand in South-Africa is price and income inelastic. It implies that price increases alone will not discourage gasoline consumption and that increases in income will only generate small increases in gasoline demand. Liddle and Lung (2013) used panel techniques to determine the direction and sign of long-run causality between transport energy consumption per capita and real GDP per capita of 107 countries panel over the period 1971-2009. They found that panel long-run-granger-causality runs from GDP per capita to transport energy consumption per capita and neither the direction nor the sign of long-run causality is a function of income level. However, some researchers (Chemin, 2009; Dargay et al. 2007) suggest that the growth in private cars ownership is essentially due to income growth.

Some other studies suggest that cars ownership changes across different phases of economic development. Using a dataset covering 45 countries over the period 1960-2002, Dargay et al. (2007) found that the relationship between car ownership and per capita income has a general S-shaped form. They revealed that the income elasticity of vehicle ownership starts to grow slowly at low income level. When income levels increase, vehicle ownership increases rapidly. Finally, at very high level of income vehicle ownership slows down again and slowly approaches the vehicle saturation stage. Furthermore, Schafer (2006) examined dataset from eleven world regions over the period 1950–2000, and found that GDP per capita not only increases the passenger mobility level, but also impacts transport modes. Growth in per capita income encourages passengers to change the transport mode (non-motorized by motorized mode). As income increases, the travelers increasingly change the low-speed public transportation (buses and low-speed rail) by faster modes of transport (private cars, aircraft and high-speed rail). Identically, Rodrigue et al. (2006) found that during the first stage of economic development, the passengers change their transport mode from non-motorized to motorized transport forms, while the second stage is characterized by an increase in the public transportation and automobile demand. Throughout the third stage, the demand for public transportation decreases in favor of private cars ownership.

Because road transport sector growth is highly correlated with energy consumption growth, the transportation activities have environmental implications. Recently, Saboori and al. (2014) applied the Fully Modified Ordinary Least Squares cointegration approach to investigate the bi-directional long-run link between CO_2 emissions, energy consumption in road transport sector and economic growth for 27 OECD countries over the period 1960-2008. They found that there is a positive significant long-run bi-directional relationship between economic growth, CO_2 emissions from transport and energy consumption in transport road sector for all the 27 OECD countries. Their empirical evidence also found that exist a significant effect of energy consumption in the transport sector on both economic growth and CO_2 emissions in the OECD countries in the long-run. Therefore, alleviating energy efficiency in transport sector is still a helpful policy option for dealing with the increase of transport energy demand and CO_2 emissions since more energy will be consumed by this sector without energy efficiency enhancement. Using a forecasting model on oil consumption and CO_2 emissions data from China's road transport sector over the period 1997-2002, He et al. (2005) have come to the conclusion that China's road transportation will increasingly become the most important oil consumer and as a result the biggest source of

CO_2 emissions in China in the next two decades. They suggest that in order to control the significant growth in transport oil use, China needs to increase vehicle fuel economy urgently. Pongthanaisawan and Sorapipatana, (2013) applied semi-parametric models to estimate the historical trend of fuel consumption and GHG emissions in Thailand's transport sector over the period 1989-2007 and to forecast future trends to 2030. For tracking accurate GHGs emission trends, two mitigations option scenarios (fuel switching and highly efficient vehicle options) have been designed. It has been found that the fuel-switching option has a higher potential to mitigate GHG emissions in short-run, whereas the energy efficiency option will be more effective in the long-run for reducing the amount of GHG emissions.

In the case of Tunisia, Abdallah et al. (2013) applied the Johansen cointegration technique for long run to detect the causal relationship between transport value added, road transport-related energy consumption, road infrastructure, fuel price and CO_2 emissions from transport sector over the period of 1980–2010. They conclude that there is a long-run mutual causal relationship between the variables. Their findings refute the Environmental Kuznets curve hypothesis between transport value added and CO_2 emissions in Tunisia. They suggest that the policy makers in Tunisia should plan urban transport, relocate production units, improve fuel efficient-vehicles and reinforce legislation to deal with the transport road emissions problem. However, the Johansen cointegration approach suffers from low power and do not have good small sample proprieties like the ARDL technique. Moreover, using the decomposition analysis approach, Mraihi et al. (2013) studied the evolution of energy use in the Tunisian road transport sector during the period 1990-2006 by determining the deriving factor of energy consumption evolution. It is found that vehicle fuel intensity, vehicle intensity, GDP per capita urbanization and road infrastructure are main derivers of energy consumption change in the road transport sector.

This present study is humble effort to fill the gap in existing literature regarding the case of Tunisia.

4. Model Specification and Data Collection

In order to investigate the relationships between transport CO_2 emissions, fuel prices, transport value added, energy consumption and road infrastructure, we argue that we can adopt a log-linear model. The empirical relationship between variables is modelled as follows:

$$lnCO2_t = \alpha_1 + \alpha_2 lnFP_t + \alpha_3 lnVA_t + \alpha_4 lnEC_t + \alpha_5 lnRI_t + \epsilon_t \quad (1)$$

Where ln is the natural logarithm, CO_2 is per capita transport CO_2 emissions, the fuel price is denoted by *FP* (expressed in National Tunisian Dinar-TND), *VA* is per capita transport value added expressed on National Tunisian Dinar (constant 2000 TND), *EC* is per capita road transport energy consumption is expressed in terms of kg tone oil equivalent (ktoe), *RI* is per capita road infrastructure (expressed in meter) and ϵ are residual terms that are normally distributed. The study covers the period of 1980-2012. Annual data on per capita CO_2 emissions, per capita transport value added and transport-related energy consumption have been collected from world development indicator (WDI-2013). Data concerning annual fuel price and annual per capita road infrastructure are taken from National Institute of Statistics (NIS).

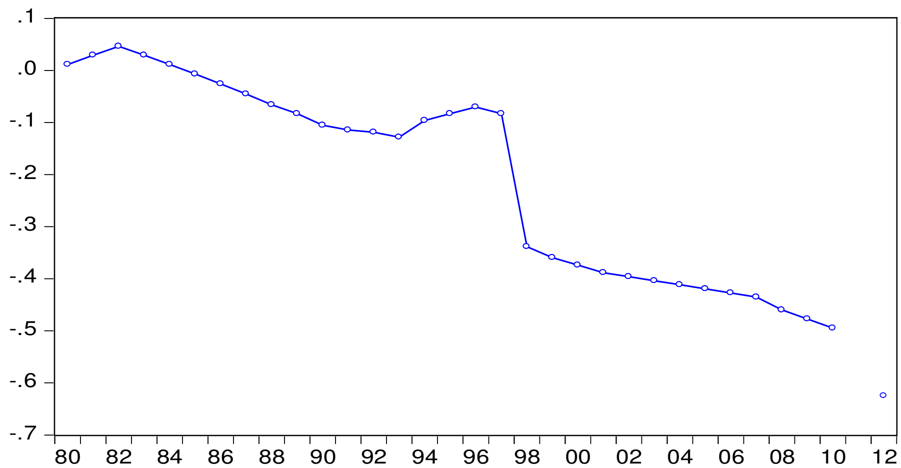


Fig. 1: Evolution of CO_2 emissions per capita (metric tons)

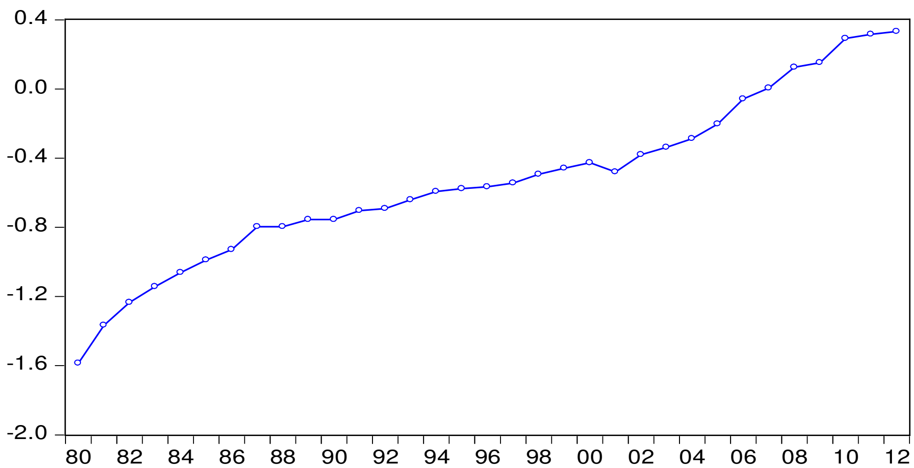


Fig. 2: Fuel Price (TND)

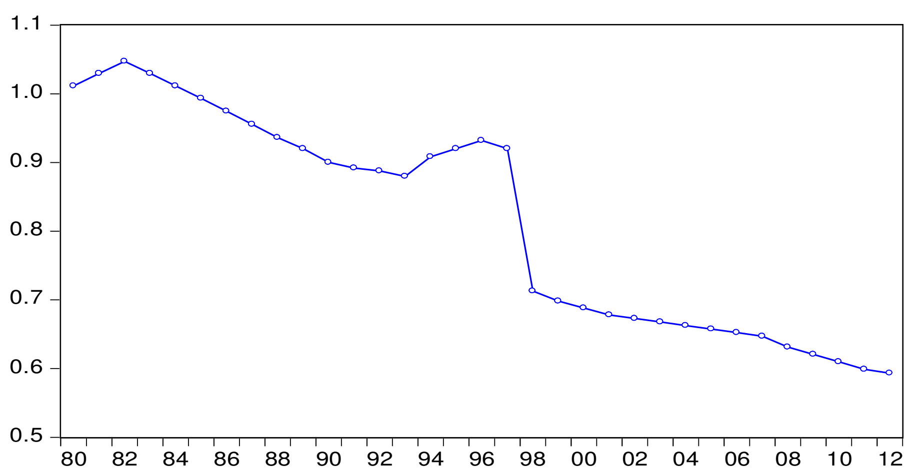


Fig. 3: Per capita transport value added (constant 2000TND)

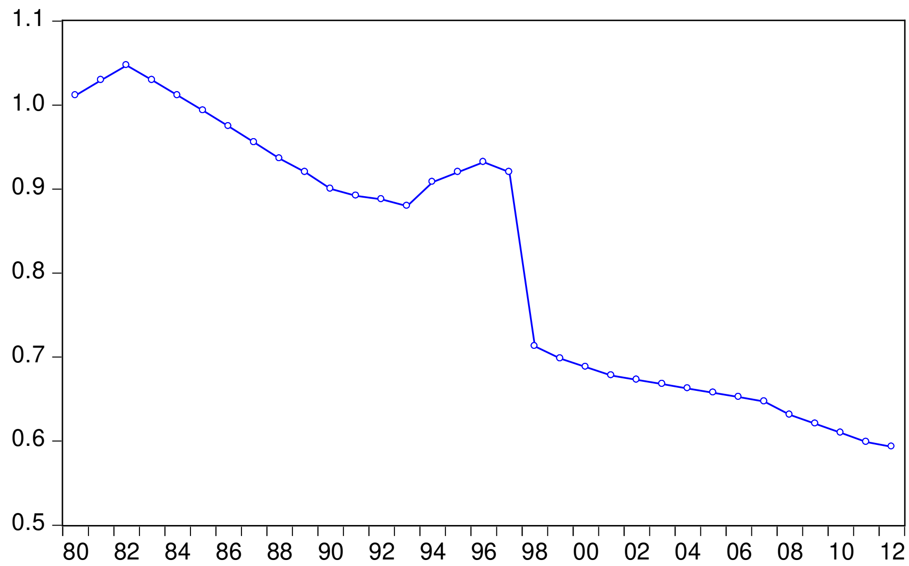


Fig. 4: Per capita road infrastructure (meter)

5. Methodological Framework

Before testing for cointegration, we start by investigating the order of integration of the data series. As a benchmark exercise, we apply the standards Augmented Dickey-Fuller (ADF) and Philips-Perron (1988) (PP) stationarity tests. However, theses conventional unit root tests do not take into account the structural breaks. The ADF and PP tests that assume no structural break are biased towards the non-rejection of null hypothesis (Perron, 1989). Hence, to make the analysis more robust, we should examine the existence the structural breaks by using the Zivot and Andrews (1992) unit root test which allow for one structural break in the series. This test determines the break point 'endogenously' from the data. After having information on stationarity of the series, we go to the next step selecting the lag order and investigating the presence of cointegrating relationships between variables.

In order to examine the long run relationship among the model variables, there are several tests of cointegration. The first one that has been extensively used and discussed in the literature is the popular Engel and Granger (1987) test which is applicable only for same order integrated variables. Subsequently, many other approaches have been developed some of which are the Error-correction Cointegration technique of Johansen (1988) which is more general and flexible than the Engel and Granger (1987) approach, the Phillips and Ouliaris (1990) test, Johansen and Juselius (1990) test, the Structural Error Correction Model (ECM) proposed by Boswijk (1994), and the test suggested by Banerjee et al. (1998) which is based on the t-test for the null hypothesis. However, these standards approaches have been criticized as being highly unreliable in small samples, inconsistent with different order integrated variables, lead to significantly misleading results and biased against the rejection of null hypothesis (no-cointegration) which requires an adjustment for critical values. Hence, in order to increase the power of test, more robust cointegration techniques are employed such as the recently combined cointegration test (null no-cointegration) proposed by Bayer and Hanck (2013) and the autoregressive distributed lag (ARDL) bounds testing approach.

The combined cointegration test newly introduced by Bayer and Hanck (2013) applied the following fisher (1932) formulae to combine the p-values of the individual tests:

$$EG - JOH = -2\left[ln(p_{EG}) + ln(p_{JOH})\right] \qquad (2)$$

$$EG - JOH - BO - BDM = -2\left[ln(p_{EG}) + ln(p_{JOH}) + ln(p_{BO}) + ln(p_{BDM})\right] \qquad (3)$$

Where p_{EG}, p_{JOH}, p_{BO} and p_{BDM} are the p-values of Engel-Granger (EG), Johansen (JOH), Boswijk (BO), and Baneerjee-Doladoe-Mestre (BDM) cointegration tests, respectively. If the computed Fisher's statistic is greater than the critical value tabulated in Bayer and Hanck (2013), we reject the null hypothesis of no-cointegration.

As a robustness check, we also employ the ARDL bound testing approach in the presence of structural breaks in order to find the cointegrating relationships between transport CO_2 emissions, transport value added, energy consumption and road infrastructure. This technique has the advantage to allow for the inclusion of a mixture of I(0) and I(1) variables in cointegration analysis. The bounds approach to cointegration provides robust estimates in small samples and as well in presence of some endogenous variables. According to Pesaran and Shin (1999), "appropriate modification of the orders of ARDL model is sufficient to simultaneously correct for residual serial correlation and problem of endogenous variables". The ARDL bounds test approach defines a dynamic unrestricted error model (UCEM) *via* a linear transformation (Pesaran et al. 2001). The UCEM joins together the short-run dynamic with the long run equilibrium without losing any information for long-run. The UCEM can be represented by the following model:

$$\Delta lnCO2_t = \theta_1 + \theta_{DUM} DUM + \theta_{FP} lnFP_{t-1} + \theta_{VA} lnVA_{t-1} + \theta_{EC} lnEC_{t-1} + \theta_{RI} lnRI_{t-1} + \sum_{j=1}^{p} \theta_j \Delta lnCO2_{t-j} + \sum_{k=0}^{q} \theta_k \Delta lnFP_{t-k} + \sum_{l=0}^{r} \theta_l \Delta lnVA_{t-l} + \sum_{m=0}^{s} \theta_m \Delta lnEC_{t-m} + \sum_{n=0}^{t} \theta_n \Delta lnRI_{t-n} + \mu_t \quad (4)$$

Where Δ is the operator of the first difference, DUM is the dummy variable that allow for structural break in the series and μ_t is normally distributed residual term. Thereafter, in order to investigate the cointegrating relationships among variables, we calculate the ARDL F-statistic. The selection of optimal lag length is based on the Akaike information criteria (AIC). The Wald test can be achieved by imposing restrictions on the estimated long-run coefficients. The null hypothesis of no-cointegration is: $H_0: \theta_{FP} = \theta_{VA} = \theta_{EC} = \theta_{RI} = 0$ against the alternative hypothesis $H_1: \theta_{FP} \neq \theta_{VA} \neq \theta_{EC} \neq \theta_{RI} \neq 0$. Two sets of asymptotic critical values (upper bound and lower bound) are given by Pesaran et al. (2001). We reject the null hypothesis of no cointegration if the F-statistic exceeds the upper critical bounds. We cannot reject the null hypothesis if the computed F-statistic is smaller than the lower critical bound. On the other hand, if the calculated F-statistic falls between the lower and upper critical values, then we cannot make decision about cointegration. Therefore, the computed F-statistic from the Wald test is compared with the critical lower and upper bounds tabulated in Pesaran et al. (2001). However, given the relatively small sample size in our study (33 observations), we adopt the critical values tabulated by Narayan (2005) rather than Pesaran et al. (2001) since it is more suitable for small sample size (T=30 to T=80). Then, we carry out a variety of tests to check the problem of normality, serial correlation, Autoregressive conditional heteroskedasticity, white heteroskedisticity and specification of the ARDL bounds testing approach to cointegration.

Next step, in order to examine the long-run and short-run dynamic causal relationships among variables, we apply the vector error correction model (VECM) when there is evidence of cointegration (Granger, 1969). The VECM specification can be written as follows:

$$(1-L)\begin{bmatrix} \ln CO2_t \\ \ln FP_t \\ \ln VA_t \\ \ln EC_t \\ \ln RI_t \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} b_{11i}\, b_{12i}\, b_{13i}\, b_{14i}\, b_{15i} \\ b_{21i}\, b_{22i}\, b_{23i}\, b_{24i}\, b_{25i} \\ b_{31i}\, b_{32i}\, b_{33i}\, b_{43i}\, b_{53i} \\ b_{41i}\, b_{42i}\, b_{43i}\, b_{44i}\, b_{45i} \\ b_{51i}\, b_{52i}\, b_{53i}\, b_{54i}\, b_{55i} \end{bmatrix} \times \begin{bmatrix} \ln CO2_{t-1} \\ \ln FP_{t-1} \\ \ln VA_{t-1} \\ \ln EC_{t-1} \\ \ln RI_{t-1} \end{bmatrix}$$
$$+ \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix} \quad (5)$$

Where $(1-L)$ is the lag operator, ECT_{t-1} is the lagged error correction term, λ_j (j=1, 2, 3, 4, 5) are the adjustment coefficients and ε_{jt} (j=1, 2, 3, 4, 5) are homoscedastic error terms. The long run causality between variables is defined by the statistical significance of the lagged error correction term coefficient. The short-run causality is confirmed by the statistical significant relationship in the first difference of variables by using the Wald-test. At last, in order to check the stability of the ARDL parameters, we use the Cumulative Sum (CUSUM) and the Cumulative Sum of squares (CUSUMsq) suggested by Pesaran and Shin (1999).

6. Results Interpretations

The descriptive statistics and correlation matrix results are reported in Table-1. The road transport-related energy consumption is significantly positively correlated with CO_2 emissions. The correlation between fuel price and emissions is negative, but insignificant. Transport value added and road infrastructure are positively and non-significantly linked with emissions. The results of Jarque-Bera test indicate that all the series are normally distributed at the five percent level. The transport value added variable shows the large standard deviation.

Table-1: Descriptive Statistics and Correlation Matrix

Variables	$\ln CO2_t$	$\ln FP_t$	$\ln VA_t$	$\ln EC_t$	$\ln RI_t$
Mean	-0.2158	-0.5339	5.3648	4.7799	0.8164
Std. Dev.	0.2012	0.4821	0.6166	0.2765	0.1587
Jarque-Bera	3.1378	0.2288	1.5779	1.9138	3.7608
Probability	0.2082	0.8918	0.4531	0.3840	0.1522
$\ln CO2_t$	1.0000				
$\ln FP_t$	-0.0006	1.0000			
$\ln VA_t$	0.0830	-0.2446	1.0000		
$\ln EC_t$	0.9980	0.0065	0.0964	1.0000	
$\ln RI_t$	0.0111	-0.4481	-0.2452	-0.0279	1.0000

Table-2 reports the results of ADF (Dickey and Fuller, 1979) and PP (Phillip and Perron, 1988) tests of unit root. The both tests provide evidence supporting the stationarity of CO_2 emissions, fuel price, transport value added, energy consumption and road infrastructure at first differenced but not at their level. Therefore, the series are integrated at I(1). However, these standards tests were criticized for their exclusion of the presence of structural breaks, which can lead to biased results. Hence, in order to make robust conclusion about the time series proprieties of the data, we apply the Zivot-Andrews (1992) unit root test, which allows for a potential endogenous structural break at some unknown point in the alternative hypothesis. The Zivot-Andrews test results presented in Table-3 clearly show that none of the series is stationary at the level and all the variables used in our empirical investigation are integrated at I(1). The test identified a break for CO_2 emissions and road infrastructure in 1998 which correspond to the year of expansion of road infrastructure and creation of the Road Transports Technical Agency which is responsible for technical control of vehicles. The effects of break on CO_2 emissions and infrastructure road are illustrated Figures 1 and 4.

Table-2: The ADF and PP Unit Root Analysis

Variable	ADF		PP	
	Level	1st Difference	Level	1st Difference
$\ln CO2_t$	-2.4679	-4.8047***	-2.5797	-4.7785***
$\ln FP_t$	-2.8275	-5.2268***	-2.9304	-5.2372***
$\ln VA_t$	-3.0579	-4.7434***	-3.2888*	-5.3292***
$\ln EC_t$	-2.3168	-5.4853***	-2.3738	-5.8377***
$\ln RI_t$	-2.5384	-4.9368***	-2.5384	-4.9113***
Note: *, ** and *** represent significant at 1%, 5% and 10% level of				

significance.

Table-3: Zivot-Andrews Structural Break Unit Root Test

Variable	**At Level**		**At 1st Difference**	
	T-statistic	Time Break	T-statistic	Time Break
$\ln CO2_t$	-3.2690 (3)	1997	-5.6909 (0) ***	1998
$\ln FP_t$	-3.6769 (4)	2006	-4.9734 (1)**	2002
$\ln VA_t$	-4.0192 (1)	1997	-5.0158 (0)**	2003
$\ln EC_t$	-3.0251 (0)	1986	-5.9292 (0) ***	1989
$\ln RI_t$	-3.5770 (4)	1998	-5.8046 (0) ***	1998
Note: *, ** and *** represent significant at 1%, 5% and 10% level of significance. Lag order is shown in parenthesis.				

Since the variables are integrated at I(1), we applied the combined cointegration test developed by Bayer and Hanck (2013). The results are reported in Table-4. They show that the calculated Fisher statistics of EG-JOH and EG-JOH-BO-BDM for the variables CO_2, VA, EC and RI consistently exceed the critical values at 1% (tabulated in Bayer and Hanck, 2013). This indicates that the combined cointegration test statistics reject the no cointegration null hypothesis between series. Therefore, we can infer that the series CO_2, VA, EC and RI are cointegrated, meaning that a long-run relationship exists between transport CO_2 emissions, transport value added, energy consumption and road infrastructure in Tunisia over the period 1980-2012. This finding corroborates the results of Abdallah et al. (2013). However, the combined cointegration test statistics fail to reject the null hypothesis of no cointegration for fuel price variable.

Table-4: The Results of Bayer and Hanck Cointegration Analysis

Estimated Models	EG-JOH	EG-JOH-BO-BDM	Lag Order	Cointegration
$CO2_t = f(FP_t, VA_t, EC_t, RI_t)$	16.564*	31.815	2	Yes
$FP_t = f(CO2_t, VA_t, EC_t, RI_t)$	14.783	31.047	2	No
$VA_t = f(CO2_t, FP_t, EC_t, RI_t)$	16.567*	31.087	2	Yes
$EC_t = f(CO2_t FP_t, VA_t, RI_t)$	18.588*	33.147	2	Yes
$RI_t = f(CO2_t FP_t, VA_t, EC_t)$	16.543*	35.902	2	No
Note: ** represents significant at 1 per cent level. Critical values at 1% level are 15.845 (EG-JOH) and 30.774 (EG-JOH-BO-BDM) respectively. Lag length is based on minimum value of AIC.				

The results of ARDL F-statistic are reported in Table-5. We found that the computed F-statistics are greater than upper critical bounds at 5% level of significance once transport CO_2 emissions is used as dependent variable in the presence of structural break in 1997. Furthermore, we discovered that we can reject the hypothesis of no cointegration at 1% level of significance once we use energy consumption and road infrastructure as forcing variables at 1986[5] and 1998 breaks respectively. Thus, in total we have three cointegration vectors and as a result we can reject the no cointegration null hypothesis. We may therefore confirm that there is a long-run relationship among transport CO_2 emissions, transport value added, energy consumption and road infrastructure in the case of Tunisia over the period 1980-2012. This result validates the findings of the combined cointegration test which support a robust conclusion.

Table-5: ARDL Cointegration Analysis

Variable	$\ln CO2_t$	$\ln FP_t$	$\ln VA_t$	$\ln EC_t$	$\ln RI_t$

[5] In 1986, Tunisia had undertaken a program of economic liberalization and structural adjustment supported by International Monetary Fund.

F-statistics	8.595**	3.635	3.420	11.766*	12.096*
Structural Break	1997	2006	1997	1986	1998
Critical values#	1 % level	5 % level	10 % level		
Lower bounds	10.150	7.135	5.950		
Upper bounds	11.130	7.980	6.680		
Diagnostic Test					
R^2	0.6720	0.9998	0.9998	0.8799	0.7377
$Adj-R^2$	0.3440	0.9995	0.9994	0.6999	0.3881
F-statistic	2.0498***	37.4092*	36.5700*	4.8881*	2.1104***
Note: *, ** and *** show significant at 1%, 5% and 10% level respectively. # Critical values bounds are from Narayan (2005) with unrestricted intercept and unrestricted trend.					

The long-run marginal impacts of the road transport-related energy consumption, fuel prices, road infrastructure and transport value added on transport CO_2 emissions are presented in Table-6. The results show that energy consumption, road infrastructure and transport added value have a positive and statistically significant impacts on transport CO_2 emissions. The effect of fuel price on CO_2 emissions is negative and statistically significant at 1% level. We find so that a 1% increase in fuel price will decrease transport CO_2 emissions by 0.097%, ceteris paribus. Although Tunisia is a net-importer of fuel, energy subsidies in the country have been doubled between 2010 and 2011 which lead to overconsumption. That's why, in a country like Tunisia, the fuel subsidy program needs to be reformed in order to decrease the transport CO_2 emissions. The impact of road infrastructure on transport CO_2 emissions affirms that the evolution of per capita road infrastructure is the major contributor to transport energy pollutants. Between 1980 and 2012, the road infrastructure per capita has decreased but, in the same period, the road transport energy consumption per capita in Tunisia has increased from 80.5 to 198.6 kg oil equivalent, representing more than a two-fold increase. In 2011, transport accounted for more than 55% of total energy consumption. This situation is due, notably, to an important average annual growth rate (5.7% for the sample period 1980-2012) of Vehicle Park structure (Abdallah et al. 2013). The high vehicle intensity may be the source of an energy consumption increase. An abrupt increase in the car ownership over the period 1980-2012 due the political decision of "popular cars" imported for the middle classes income. Overall, the motor vehicle ownership (vehicles per 1000 persons) increased from 81.18 in 2000 to 130.01 in 2011, an increase of about 60%.

Table-6: Long and Short Runs Results

Dependent Variable: $\ln CO2_t$			
Long Run Results			
Variable	Coefficient	Std. Error	t-Statistic
Constant	-1.1184*	0.3119	-3.5849
$\ln EC_t$	0.1084*	0.03220	3.3608
$\ln FP_t$	-0.0970**	0.0426	-2.2751
$\ln RI_t$	1.1545*	0.0693	16.6478
$\ln VA_t$	0.0892**	0.0356	2.5001
Short Run Results			
Variable	Coefficient	Std. Error	t-Statistic
Constant	0.0011	0.0015	0.7577
$\ln EC_t$	-0.0111	0.0177	-0.6314
$\ln FP_t$	-0.0282**	0.0113	-2.4955

$\ln RI_t$	1.2078*	0.0941	12.8352
$\ln VA_t$	0.0107	0.0095	1.1255
ECM_{t-1}	-0.1354*	0.0430	-3.1485
R^2	0.4991		
$Adj-R^2$	0.4496		
F-statistic	17.2850*		
Diagnostic Test	F-statistic	Prob. value	
$\chi^2 NORMAL$	0.6874	0.7091	
$\chi^2 SERIAL$	2.0870	0.1479	
$\chi^2 ARCH$	0.5591	0.4611	
$\chi^2 WHITE$	1.2542	0.3769	
$\chi^2 REMSAY$	2.4715	0.1122	
Note: * and ** show significance at 1% and 5% levels of significance respectively.			

The results of short run dynamics are reported as well in Table-6. We find that fuel price has a negative and statistically significant impact on transport CO_2 emissions. It reveals that a 1% increase in fuel price decreases transport emissions by 0.028%, ceteris paribus. The results show also that the impact of road infrastructure on transport CO_2 emissions is positive and significant at 1% level. A 1% rise in infrastructure road raises road transport emissions by 1.2%, keeping other things constant. Transport value added has a positive short-run relationship with transport CO_2 emissions but it is statistically insignificant. During the 10^{th} development plan, the investment in the transport road sector has reached 6 million dollars. Nevertheless, the investment in road infrastructure has not followed the rapid growth of road

Vehicles Park and as a result the road suffers from significant congestion. Hence, the development of road infrastructure should have an important consideration during the next 13th development plan.

The estimated lagged error term ECT_{t-1} is statistically significant at 1% level of significance with negative sign. It shows the speed of adjustment from the short-run towards the log-run equilibrium path. It means that any change in transport CO_2 emissions from short run towards long-run is corrected by 13.54% every year. Moreover, the significance of lagged error term confirms the established long run relationship between the variables. The lower part of Table-6 shows that the error term of short-run model is white noised. The serial correlation does not exist between the error term and CO_2 emissions. There is an absence of autoregressive conditional heteroskedisticity and the same is true for white heteroskedisticity. According to Ramsey Regression Equation Specification Error Test (RESET), the model is well specified.

We investigate the stability of the model by applying Cumulative Sum (CUSUM) and the Cumulative Sum of the Squares (CUSUM sq).

Figure-5. Plot of Cumulative Sum of Recursive Residuals

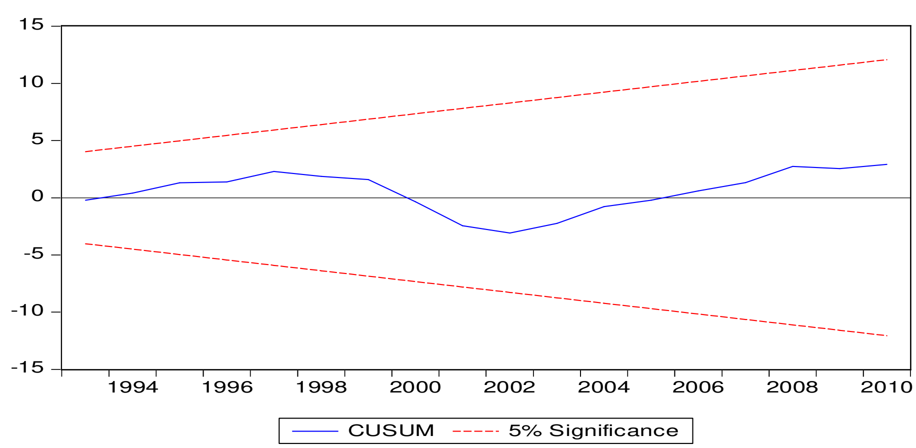
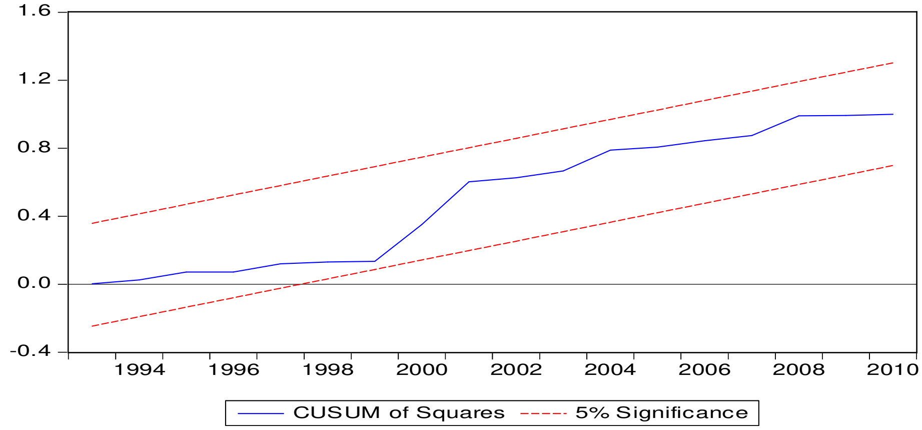


Figure-6. Plot of Cumulative Sum of Squares of Recursive Residuals



The results of CUSUM and CUSUMsq are reported in Figure-5 and 6. We find that the graphs of CUSUM and CUSUMsq are within critical bounds and it is significant at 5% levels. This entails that long-run and short-run parameters are stable and consistent.

Table-7: VECM Causality Analysis

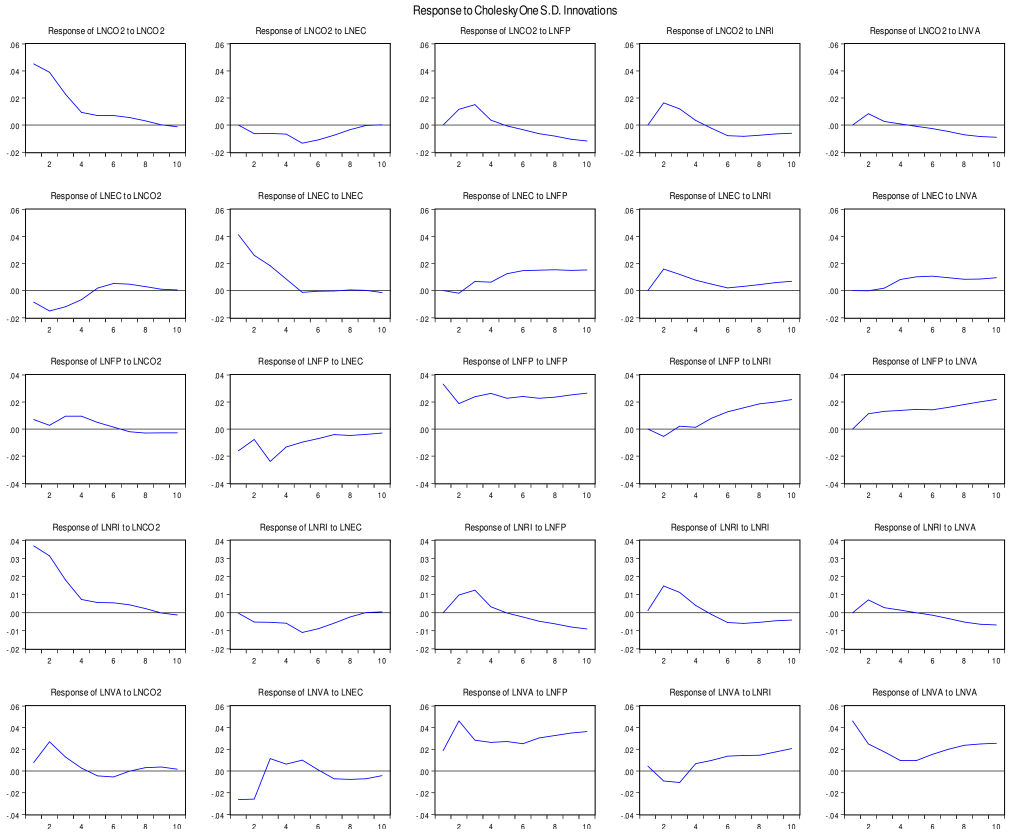
Dependent Variable	Short Run					Long Run
	$\Delta \ln CO2_{t-1}$	$\Delta \ln EC_{t-1}$	$\Delta \ln FP_{t-1}$	$\Delta \ln RI_{t-1}$	$\Delta \ln VA_{t-1}$	ECM_{t-1}
$\Delta \ln CO2_t$	…	0.9064 [0.4216]	1.1781 [0.3305]	6.9474* [0.0003]	1.1894 [0.3272]	-0.1145*** [-1.7081]
$\Delta \ln EC_t$	3.3818*** [0.0566]	…	2.3012 [0.1288]	3.3618*** [0.0577]	0.1119 [0.3505]	-0.3430** [-2.7244]
$\Delta \ln FP_t$	0.3049 [0.7407]	2.2295 [0.4950]	…	0.3089 [0.7378]	0.5604 [0.5701]	…
$\Delta \ln RI_t$	7.1506* [0.0001]	2.0715 [0.1545]	1.3295 [0.2894]	…	1.6472 [0.2203]	-0.1090*** [-2.0520]
$\Delta \ln VA_t$	0.5649 [0.5782]	1.5443 [0.2404]	0.0345 [0.9661]	0.5579 [0.55820]	…	-0.4094** [-2.2080]
Note: *, ** and *** show significance at 1%, 5% and 10% levels of significance						

respectively.

We used the Granger causality test within the VECM framework to provide the directional relationship between the road transport-related energy consumption, fuel prices, road infrastructure, transport value added and CO_2 emissions. Table-7 presented the empirical findings of the VECM Granger causality analysis. It is noted that the estimates of ECT_{t-1} are statistically significant with negative signs in all the VECMs except fuel prices equation. In addition to this, the results show that the long-run convergence of shocks towards the equilibrium path is faster for both energy consumption (-0.3430) and transport value added (-0.4094) than adjustment speed of CO_2 emissions (-0.1145) and road infrastructure (-0.1090).

The results indicate that the relationship between transport CO_2 emissions and energy consumption is bidirectional in the long-run. Similarly, the feed-back effect is found to exist between CO_2 emissions and road infrastructure i.e. in the long run, CO_2 emissions Granger causes road infrastructure and in its turn road infrastructure Granger causes transport CO_2 emissions. The feed-back effect exists between transport value added and CO_2 emissions. The bidirectional causality is found also between energy consumption and road transport. The unidirectional causality is found running from fuel prices to CO_2 emissions, road transport-related energy consumption, transport value added and road infrastructure. This result is consistent with Abdallah et al. (2013) findings for Tunisia. In addition to this, we discovered that the bidirectional causality exists between energy consumption and transport value added and the same is true for value added and road transport. In short run, bidirectional causality is found between CO_2 emissions and road infrastructure. Furthermore, road transport Granger causes energy consumption.

Impulse Response Function (IRF)



The impulse response functions measure the effect of shock stemming in independent variables on dependent variable. The results show that the response in CO_2 emissions due to forecast error stemming in transport value added growth initially rises, goes to peak and then starts to decline after 2nd time horizon. This presents the phenomenon of environmental Kuznets curve or inverted U-shaped relationship between transport value growth and CO_2 emissions. This finding does not give evidence for the previous result about Tunisia which refute the Kuznets Curve hypothesis (Abdallah et al., 2013). The results indicate similarity in the response of CO2 emissions due to forecast error stemming in fuel price and road transport. It begins by increasing and decline after 3rd time horizon and 2nd time horizons respectively. The forecast error in energy consumption (CO_2 emissions) and road infrastructure stimulates (increases) transport value added growth. The response of fuel price is positive due forecast error in value added and road transport infrastructure.

7. Conclusion and Policy Implications

This paper examined the impact of road transport energy consumption on CO_2 emissions by incorporating fuel prices, road transport value added and road infrastructure in CO_2 emissions using Tunisian data for period of 1980-2012. The issue of unit root properties of the variables is handled by applying traditional as well as structural break unit root tests. The cointegration amongst the variables is investigated by employing *Bayer-Hanck* combined cointegration approach and robustness of cointegration results is tested by applying the ARDL bounds testing.

The empirical evidence showed the presence of cointegration amongst the variables. The road transport energy consumption adds in CO_2 emissions. Fuel prices have negative impact on CO_2 emissions. Road value added and road infrastructure increase CO_2 emissions. The causality test explored the bidirectional causality between road transport energy consumption and CO_2 emissions. Road infrastructure Granger causes CO_2 emissions and in results CO_2 emissions Granger cause road infrastructure. The feedback effect is found road valued and CO_2 emissions. Fuel prices Granger cause CO_2 emissions, road transport energy consumption, road value added and road infrastructure.

The findings of our study have implications for policies and strategies that should be undertaken by Tunisian government in order to mitigate the environmental impacts of road transport sector. First, we found that there is a long-run relationship between transport value added and infrastructure road. Actually, the creation of the Road Transports Technical Agency which is responsible for technical control of vehicles has provided incentive to reduce GHG emissions from road transport sector. However, increasing energy consumption in the road transport sector due to economic growth continues to create a growing threat to national energy security. A new challenge arises for Tunisian policy makers that require them to build a new road infrastructure needed to support the rapid growth in private car ownership which will adversely affect long GHG emissions. Therefore, the use of more energy efficient transport modes and alternative technologies for road transport should be developed and promoted by the Tunisian government towards achieving sustainability in transport sector. Moreover, the government has to put in place a modern public transportation system in order to encourage passengers to use it more often. Second, the finding of unidirectional causality running from fuel price to road transport energy consumption has an important policy implication. The use of economic instruments like taxation of fuel can stimulate a more efficient use of energy and encourage substitution from private cars to public transport. However, one quarter of all fuel consumed in Tunisia is illegally imported from Algeria[6] which make it difficult to generalize fuel taxes instrument. The decision-makers should do more to reinforce the environmental legislation to deal with energy consumption and road transport sector emissions. Third our results suggest that fuel prices have negative impact on CO_2 emissions. The total value of energy subsidies has increased significantly from US$121.2 million in 2003 to US$ 970.7 million in 2007 that represent an almost eight-fold increase over the period 2003-2007. Hence, the Tunisian authority should review its energy subsidy program in order to improve energy efficiency in road transport sector and control CO_2 emissions.

[6] The cost of diesel fuel is $0.82 per liter in Tunisia, but in Algeria it costs only $0.19.

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