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Using the LMDI Decomposition Approach to Analyze the Influencing Factors of Carbon Emissions in Tunisian Transportation Sector

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ABSTRACT

The transportation sector plays a key role in the economic and commercial development of Tunisia. However, it is an energy-intensive sector that is responsible for 25.3% of greenhouse gas emissions. In this paper, we use the LMDI decomposition approach of CO_2 emissions stemming from the transportation sector with its different modes (highways, railways, civil aviation and waterways). Our objective is to evaluate the contribution of each of the main factors responsible for these emissions, namely the energy efficiency, the structure and the level of development of the transportation sector. The empirical analysis of CO_2 emissions data concerning this area for the period 1991–2016 shows that the rapid growth of these emissions is mainly due to the increase in the level of transport development in Tunisia with a particular predominance of road transportation. As for the transportation sector energy efficiency, it was shown that there is an inhibition of CO_2 emissions.

Keywords: Transportation, Carbon Emissions, LMDI, Factor Decomposition, Tunisia
JEL Classifications: P28, Q43, Q54, Q56

1. INTRODUCTION

All countries, including both developed and emerging countries, are subject to two major constraints, namely energy security and environment protection. For several years now, the Tunisian Government has adopted various policies that aim at reducing greenhouse gas (GHG) emissions and which enter within several countries' efforts to counter the problem of climate change. In fact, not only did Tunisia ratify the United Nations Framework Convention on Climate Change in 1993, but also acceded to the Kyoto Protocol in 2002, even before its entry into force in February 2005. It also participated in the 21st Conference of the Parties on Climate (COP21).

Despite the effort Tunisia has made, since 2000, a negative energy balance has been established between domestic demand and energy production with a gap that reached 1200 ktoe in 2006. Over the period 2000–2012, GHG emissions increased from 21 million tons to 28 million tons of CO_2, an increase of around 34%[1]. The transport sector contribution to these emissions is highly significant. The transport activity in Tunisia is closely linked to energy consumption and in particular that of fossil fuels. Transportation ranks first as an energy-intensive sector with a share of 33% of the total energy consumption[2]. This significant energy consumption makes it the second largest GHG emitter sector with 5648.5[3] thousand tons of CO_2, following the industrial sector. As a result, after the signing of the various pollution-fighting agreements, it is inevitable for the

1 Source: The National Agency for Energy Conservation (2012).
2 Source: The National Agency for Energy Conservation (2012).
3 Source: The National Agency for Energy Conservation (2012).

Tunisian government to undertake several measures to increase energy efficiency for more sustainable transport. This improvement in energy efficiency necessarily involves determining the main factors explaining this increase in emissions.

There are two main decomposition methods to identify and quantify the factors that directly or indirectly influence the transport sector CO_2 emissions. These methods are structural decomposition analysis and index decomposition analysis (IDA) (Hoekstra and Van der Bergh, 2003). A wide range of decomposition methods is available to perform an IDA. Over the past two decades, the Laspeyres index and the Divisia index have been the most commonly used methods in the IDA literature (for instance Howarth et al., 1991; Scholl et al., 1996; Lin and Chang, 1996; Shrestha and Timilsina, 1996; Greening et al., 1999; Zhang 2000; Paul and Bhattacharya, 2004; Steenhof, 2006). One of the most crucial choices is to determine the most appropriate decomposition formula. The decomposition of the Divisia index, in particular, the LMDI (logarithmic mean divisia index) decomposition method is used in this article to achieve perfect decomposition, handle zero values in the data series and study the decomposition of a differential change. Ang (2004) compared the different methods of decomposition and demonstrated that the LMDI method is the best thanks to its theoretical basis, adaptability, ease of use and result interpretation.

In this respect, the objective of this article is to bring to light, by the LMDI decomposition method, the main factors influencing the carbon emissions of the transport sector in Tunisia in its different modes (highways, railways, civil aviation and waterways) over the period 1991–2016. Notably, our empirical study takes into consideration four factors, namely the intensity of transport emissions resulting from energy consumption, transport energy efficiency, transport structure and transport development. Assessing the contribution of these key determinants over a defined period of time may help in designing more effective policies for reducing CO_2 emissions. Besides, this assessment can be considered as an essential step towards the sustainable use of energy sources.

The rest of the article is organized as follows: Section two involves an overview of the literature addressing the decomposition methods implemented in the CO_2 emissions issues as well as in the transport sector. Object of the third section of this article, the empirical study perceives the driving forces behind the increase of carbon emissions of the four main modes of transport in Tunisia, namely, highways, waterways, railways and airways for the period 1991–2016 using the LMDI decomposition method. The 5th section is devoted to the interpretation of the main findings. Conclusions and discussions will be the subject of the last section.

2. LITERATURE OVERVIEW

Decomposition analysis is a popular and widely used method to identify factors that influence carbon emissions or energy consumption. A large number of decomposition techniques is available to address the complex issues of energy and environment. IDA is a technique that has been extensively used in the environmental field to analyze the evolution of indicators such as energy consumption, energy intensity or GHG emissions. In economic literature, several studies have focused on decomposition analysis in the transport sector. Schipper et al. (1997) analyzed the contribution of modal structure, transport activity and energy intensity to CO_2 emissions originating from freight transport in ten industrialized countries during the period 1973–1992. Mazzarino (2000) used the decomposition method to emphasize the relative effects of the main factors on the total variation in carbon dioxide in the transport sector in Italy over the period 1980–1995. He showed that the main driver of the variation in carbon emissions is GDP growth. Timilsina and Shrestha (2009) used the LMDI method to identify factors impacting CO_2 emissions in 20 Latin American countries for the period 1980–2005. Their empirical analysis showed that economic growth is the main factor behind the increase of CO_2 emissions resulting from the transport sector in the countries surveyed. Qipeng et al. (2013) used the LMDI method to identify the determinants of the transportation system energy consumption in China. They decomposed energy consumption into three components: Energy efficiency, transportation structure, and transportation intensity. They concluded that the Chinese transportation structure explains the rapid growth of energy consumption. Yang et al. (2014) examined the effects of the individual travel behavior on carbon emissions stemming from urban transport in Beijing from 2000 to 2011. They claimed that transport intensity and the emission factor contribute significantly to the reduction of carbon emissions. Nevertheless, the modal split plays a very minor role during the study period. Lu et al. (2007) used the Divisia index approach to investigate the impacts of five factors on the total road transport carbon dioxide emissions in Germany, Japan, South Korea and Taiwan between 1990 and 2002. They concluded that the rapid economic growth and vehicle ownership represented the major factors behind the rapid increase in emissions. Andreoni and Galmarini (2012) used the decomposition method to study the effects of four factors, namely: Carbon dioxide intensity, energy intensity, structural changes, and economic activity growth on CO_2 emissions generated by shipping and aviation activities for the period 2011–2008. They figured out that economic growth is the main factor responsible for CO_2 emission growth of the modes considered in their analysis. Dong et al. (2017) combined the decoupling index together with the LMDI method to identify the driving forces of CO_2 emissions in the Xinjiang transport sector for the period 1990–2014. They showed that economic growth, the size of the population and the energy mix contributed to the rise in CO_2 emissions. Liang et al. (2017) chose the LMDI method to discuss the effects of six factors on China's transport sector emissions: energy structure, energy efficiency, transportation form, transport development, economic growth and the population size for the period 2001–2014. Results indicate that economic growth is the main factor behind the strong evolution of CO_2 emissions in the transport sector, while energy efficiency is the main inhibiting factor.

As for the Tunisian empirical analysis, applying the decomposition analysis on the Tunisian economy and more particularly on the transport sector is restricted. Mraihi et al. (2013) used the decomposition approach to quantify the effects of economic, demographic and urban factors on the evolution of transportation energy consumption. They showed that fuel intensity, vehicle intensity, GDP per capita, urban kilometers and the national road network are the main drivers of increasing energy consumption in the road transport sector during the period from 1990 to 2006. M'raïhi and Harizi (2014) analyzed the connection between annual carbon dioxide emissions stemming from road freight transport, emission intensity, fuel consumption and road freight transport intensity. To that end, a method of emission decomposition was implemented. The intensity of fossil fuel emissions happens to be the main factor behind emissions reduction, while energy intensity and intensity of transport are the main drivers of emissions growth. Daldoul and Dakhaloui (2016) adopted the Divisia index approach to study the effects of five factors namely the emission factor, the vehicle fuel intensity, vehicle ownership, population intensity and economic growth on total carbon dioxide emissions resulting from road vehicles in Tunisia between 1980 and 2011. Results showed that rapid economic growth and vehicle ownership were the factors that contributed the most to the increase of CO_2 emissions, while population intensity contributed significantly to the decrease of emissions.

As previously stated, our work rests on the previous literature and makes an original contribution since we used a more in-depth decomposition analysis that takes into account the carbon emissions of each type of energy emitted by each transportation mode. Indeed, the Tunisian transport system is composed of four modes namely highways, waterways, railways and airways. For this reason, a deeper analysis of the main factors that impact CO_2 emissions involving the entire transport system in Tunisia is deemed necessary in order to develop an appropriate strategy aimed at reducing CO_2 emissions. What makes our work distinctive from the existing national literature is that it takes into consideration all the modes that underpin our transport system during the decomposition of emissions over the period 1991–2016, which provides decision makers with an overview on the entire transport system in Tunisia when implementing an adequate strategy to reduce energy consumption and CO_2 emissions.

3. EMPIRICAL ANALYSIS OF THE POTENTIAL REDUCTION OF CO_2 EMISSIONS IN TUNISIA FOLLOWING THE LMDI DECOMPOSITION METHOD

Methodology

Based on the index decomposition method of (Albrecht et al., 2002; Ding et al., 2013), the transport sector CO_2 emissions can be subdivided as follows:

$$C=\sum_{ij}C_{ij}=\sum_{ij}\frac{C_{ij}}{E_{ij}}\times\frac{E_{ij}}{V_i}\times\frac{V_i}{V}\times V \quad (1)$$

With C is the carbon emission of the transport sector, C_{ij} is the carbon emission of the energy j for the transport mode i, E_{ij} is the energy consumption j by the transport mode i, V_i is the annual volume of ton-km transported by transport mode i and V is the total volume of ton-km transported[4] by all modes of transport (highways, railways, civil aviation and waterways).

Equation (1) can be written as follows:

$$C=\sum_{ij}F_{ij}I_{ij}R_i V \quad (2)$$

Where:

$F_{ij}=\frac{C_{ij}}{E_{ij}}$ is the intensity of emissions stemming from energy. It represents the carbon emissions related to energy consumption j by mode of transport i.

$I_{ij}=\frac{E_{ij}}{V_i}$ is the transport energy efficiency. It represents the energy consumption per unit of transport service.

$R_i=\frac{V_i}{V}$ is the transport structure. It represents the proportion of tons-km transported by mode of transport i in the total volume of tons-km transported by all modes of transport.

By implementing the LMDI decomposition method suggested by Ang et al. (1998), the CO_2 emissions variations of the transport sector in Tunisia can be subdivided according to two approaches: additive and multiplicative.

According to the additive approach, changes in carbon emissions are equal to the sum of emission contribution values caused by the various fluctuating factors:

$$\Delta C=C^t-C^0=\sum_{ij}F_{ij}^t I_{ij}^t R_i^t V^t-\sum_{ij}F_{ij}^0 I_{ij}^0 R_i^0 V^0$$

$$=\Delta C_F+\Delta C_I+\Delta C_R+\Delta C_V \quad (3)$$

We note that:

$$\Delta C_F=\sum_{ij}W_{ij}\ln\frac{F_{ij}^t}{F_{ij}^0};\quad \Delta C_I=\sum_{ij}W_{ij}\ln\frac{I_{ij}^t}{I_{ij}^0}$$

$$\Delta C_R=\sum_i W_i\ln\frac{R_i^t}{R_i^0};\quad \Delta C_V=\sum_i W_i\ln\frac{V_i^t}{V_i^0}\ \text{and}\ \ W_{ij}=\frac{C_{ij}^t-C_{ij}^0}{\ln\left(C_{ij}^t/C_{ij}^0\right)} \quad (4)$$

According to the multiplicative approach, variations in carbon emissions are equal to the multiplication of emission contribution rates caused by the evolution of different factors.

$$D=\frac{C^t}{C^0}=D_F D_I D_R D_v \quad (5)$$

We note that:

$D_F=exp(W\Delta C_F)$, $D_I=exp(W\Delta C_I)$,

4 It is the sum of ton-km and passengers-km transported. The volume of passengers-km transported is converted into ton-km by the conversion coefficient. According to Ding et al. (2013), this conversion coefficient is equal to 1 for rail transport, 0.1 for road transport, 0.3 for maritime transport and 0.072 for air transport.

$D_R = exp(W\Delta C_R), D_V = exp(W\Delta C_V)$ and $W = \frac{\ln C^t - \ln C^0}{C^t - C^0}$ (6)

Data Sources

The study required the collection of statistical data on the main factors that influenced CO_2 emissions over the period 1991–2016. These factors include the intensity of transport emissions due to the consumption of energy *F*, the transport efficiency *I*, transport structure *R* and transport development *V*. We relied on national and international data sources, such as the National Institute of Statistics (NIS), the National Agency for Energy Conservation (NAEC), the World Development Indicators (WDI, 2010) and the Ministry of Transport.

The transportation energy emissions intensity factors *F* is a constant value. Its value depending on the different types of energy is shown in Table 1.

The transport energy efficiency factors depend mainly on the energy consumed per unit of transport service[5] and on the different modes of transport. The results of our calculations are set out in Table 2.

5 Tons-km transported.

The transport structure factors take into account the proportion of the different modes of transport. In our study, we used the proportion of tons-km transported to reflect the transport structure. The total annual volume of tons-km transported represents the sum of the tons-km for freight transport; however, the variation of passengers-km is to be converted into tons-km by multiplying the passenger-km by the conversion coefficient in ton-km. The converted transport structures are shown in Table 3.

The transport development factors are mainly manifested in the total annual volume of tons-km transported by all modes of transport; its values are shown in Table 4.

4. RESULTS AND DISCUSSION

The decomposition of carbon emissions of transportation in Tunisia over the period 1991–2016 are shown in Table 5. The changes in CO_2 emissions can be attributed to the variations of the three factors: energy efficiency, structure and the degree of transport development, since the transportation energy emissions intensity factor presents a fixed value.

Table 1: Carbon emissions intensity F of different energy (unit: tons of CO_2/toe).

Type	Diesel	Gasoline	Liquefied petroleum gas (LPG)	Jet Fuel	Bunker Fuel
Carbon emission intensity F	3.101	2.901	2.64	2.994	3.239

Source: NAEC

Table 2: Energy efficiency of different transportation modes

Year	Road			Rail	Air	Water
	Gasoline (kg/10⁶ Ton-km)	Diesel (kg/10⁶ Ton-km)	LPG (kg/10⁶Ton-km)	Diesel (kg/10⁶ Ton-km)	Jet Fuel (kg/10⁶ Ton-km)	Bunker Fuel (kg/10⁶ Ton-km)
1990	0.130270	0.356514	0.000804	0.014193	0.563042	0.920237
1991	0.119435	0.335962	0.000795	0.015405	0.432472	1.061027
1992	0.115615	0.320913	0.000767	0.014713	0.589974	0.845870
1993	0.116957	0.324368	0.000781	0.015411	0.662666	0.539589
1994	0.111133	0.306813	0.000752	0.016079	0.793454	0.668808
1995	0.108633	0.307940	0.000725	0.016710	0.716719	0.810603
1996	0.106466	0.315324	0.000744	0.008850	0.685004	0.871921
1997	0.108236	0.324611	0.002526	0.008954	0.789850	0.673152
1998	0.106161	0.323598	0.002887	0.009397	0.852645	0.686860
1999	0.110666	0.334151	0.004791	0.009821	0.870541	0.651394
2000	0.110780	0.327743	0.004980	0.010178	0.751222	0.739106
2001	0.112813	0.324119	0.005694	0.010586	0.701157	0.598462
2002	0.113353	0.331770	0.003312	0.011014	0.652849	0.643973
2003	0.104506	0.313689	0.003127	0.011949	0.635657	0.666539
2004	0.102075	0.309207	0.003406	0.012156	0.588722	0.655448
2005	0.097444	0.304332	0.001744	0.012542	0.524643	0.634070
2006	0.112099	0.243617	0.006516	0.011942	0.520025	0.630926
2007	0.104594	0.260829	0.007865	0.012400	0.579754	0.657496
2008	0.083851	0.269161	0.008068	0.012547	0.551319	0.706106
2009	0.082078	0.252435	0.007346	0.012835	0.541515	0.617021
2010	0.085831	0.249234	0.005724	0.013431	0.632984	0.651619
2011	0.091043	0.215260	0.004082	0.013638	0.646780	0.664195
2012	0.084845	0.212230	0.003785	0.013807	0.687063	0.672113
2013	0.079785	0.205414	0.002658	0.014089	0.727578	0.671715
2014	0.079721	0.196598	0.004304	0.014606	0.693775	0.784485
2015	0.076866	0.192937	0.005246	0.014868	0.710751	0.711682
2016	0.074969	0.184130	0.004980	0.015008	0.715449	0.738710

Source: Authors' calculation

Results show that total carbon emissions reached 4.267 million tons in 2016, with a growth rate of 90% compared to 1991. The influence of highway, railway, aviation and water transport on total CO_2 emissions is respectively in the order of 4.490 million tons, 0.042 million tons, 0.275 million tons and 0.047 million tons. This striking increase in carbon emissions is mainly due to the growth in the level of transport development and more specifically the evolution of the road transport mode. In 2016, the number of passenger-km and tonne-km transported by road transport increased 322% and 271% more than 1990, respectively. Figure 1 shows how the contribution of transport evolution to carbon emissions has increased and shows an exponential growth trend. In 2016, carbon emissions caused by transport development reached 4.855 million tons compared to 0.072 Mtoe in 1991 (Table 5).

The energy efficiency of the transport sector showed an inhibition of CO_2 emissions during the period 1991–2016, and its impact on the growth of global carbon emissions showed a bearish trend (Figure 1). The latter is explained by the continuous improvement of the energy conservation concerning the road transport mode, which led to an emission reduction of 1.915 million tons. This result supports the work of Timilsina and Shrestha (2009). Thus, improving the energy efficiency of the transport sector in Tunisia and reducing GHG emissions related thereto must therefore be seen as priority areas. The Tunisian GHG reduction strategy for the transport sector focuses on measures whose objective is to reduce average CO_2 emissions from the car fleet, increase the use of renewable energy sources and develop the public transport infrastructures and services, as well as railway infrastructures over long distances.

Table 3: Structure of different transportation modes

Year	rail	road	water	air
1990	0.541608	0.386192	0.009191	0.063008
1991	0.517383	0.415624	0.009098	0.057896
1992	0.518724	0.417426	0.008816	0.055034
1993	0.509311	0.425459	0.008658	0.056572
1994	0.508006	0.432785	0.007977	0.051232
1995	0.502270	0.436687	0.007899	0.053144
1996	0.487414	0.449036	0.007955	0.055595
1997	0.489776	0.449111	0.008035	0.053078
1998	0.484117	0.457407	0.007515	0.050962
1999	0.486305	0.454611	0.007426	0.051658
2000	0.471460	0.470278	0.007509	0.050753
2001	0.463051	0.478254	0.008151	0.050543
2002	0.457648	0.489996	0.007828	0.044528
2003	0.437959	0.512732	0.007587	0.041722
2004	0.425892	0.515774	0.007534	0.050800
2005	0.416489	0.524083	0.007695	0.051732
2006	0.405874	0.539187	0.007207	0.047732
2007	0.407269	0.541405	0.007583	0.043743
2008	0.398896	0.547633	0.007364	0.046107
2009	0.384471	0.567017	0.007299	0.041214
2010	0.370850	0.580313	0.006867	0.041971
2011	0.360313	0.596042	0.006473	0.037172
2012	0.351778	0.600355	0.006689	0.041178
2013	0.351357	0.604418	0.006272	0.037954
2014	0.341199	0.611279	0.005609	0.041913
2015	0.328652	0.622998	0.005983	0.042367
2016	0.315650	0.638143	0.005592	0.040615

Source: Authors' calculation

The transport structure is the combination of transport modes. The mechanism influencing transport structure and carbon emissions is defined as follows (Wei et al., 2013): On the one hand, the different modes energy intensity varies significantly. On the other hand, carbon emissions caused by the transport sector depend heavily on the transport energy intensity. Therefore, if the transport structure changes, the transport energy intensity will change as well, which will result in a significant difference in transport-related carbon emissions.

We have demonstrated that the transport structure plays mainly a pulling role in carbon emissions. Total carbon emissions originating from the transportation structure reached 1.213 million tons in 2016 (Table 5). Mazzarino (2000) proved that optimizing the transport structure could effectively reduce carbon emissions. Over the 1991–2016 period, the effect of the transportation sector structure on carbon growth heightened over a year-over-year basis. This can be explained by the predominance of the road mode in Tunisia which represents the most energy-consuming transport form. Indeed, the road mode turnover proportion rose from 38.61% in 1990 to 63.81% in 2016. In regards to 1990, the proportion railway, water and aviation transport modes shrunk from 54.16% to 35.56%, from 0.91% to 0.55% and from 6.3% to 4.06%, respectively (Table 3).

Variations in carbon emissions can also be analyzed by focusing on the contribution rates of the various factors to the CO_2 emissions of the transport sector. Figure 2 shows that, over the period 1991–2016, the gap between the contribution rate of the positive factors (the level of development and the transport structure) and the negative factors (energy efficiency) to the total CO_2 emissions of the transport sector witnessed a gradual expansion, which led to an exponential increase in total carbon emissions in the transport sector in Tunisia. The improvement of energy efficiency could not therefore prevent the continuous growth of carbon emissions, due to the predominance of the road transport mode which characterizes the Tunisian transport structure.

5. CONCLUSIONS AND POLICY IMPLICATIONS

This article was intended to highlight the contribution of the factors that impact the carbon emissions of the Tunisian transport sector

Table 4: Level of transport development (unit: billion ton-km)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total volume of tons-km	5.24291	5.47563	5.93187	5.98848	6.39362	6.56619	7.76426	6.98891	7.17802
Year	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total volume of tons-km	7.32257	7.50647	7.67518	7.68494	7.79754	7.92454	8.10585	8.82294	9.04562
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total volume of tons-km	9.93548	9.27509	9.61576	9.87475	10.11434	10.39398	11.19287	12.12527	13.39774

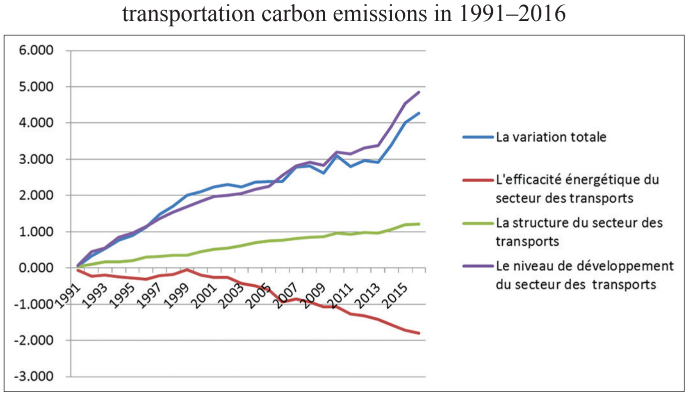
Source: Authors' calculation

Table 5: Decomposition results of carbon emissions of transportation in Tunisia during 1991–2016

Year	Changes of carbon emissions		Transportation energy efficiency		Transportation structure		Transportation development level	
	ΔC ($\times 10^6$)	D	ΔC_I ($\times 10^6$)	D_I	ΔC_R ($\times 10^6$)	D_R	ΔC_V ($\times 10^6$)	D_V
1991	0.047	1.012	−0.062	0.883	0.037	1.098	0.072	1.044
1992	0.337	1.085	−0.225	0.887	0.109	1.082	0.453	1.132
1993	0.527	1.133	−0.189	0.887	0.164	1.118	0.551	1.143
1994	0.773	1.196	−0.237	0.888	0.168	1.103	0.842	1.220
1995	0.898	1.227	−0.279	0.865	0.210	1.132	0.967	1.253
1996	1.128	1.286	−0.315	0.828	0.304	1.203	1.140	1.290
1997	1.475	1.373	−0.206	0.868	0.314	1.186	1.366	1.333
1998	1.707	1.432	−0.175	0.873	0.346	1.199	1.537	1.369
1999	2.001	1.507	−0.051	0.905	0.356	1.192	1.697	1.397
2000	2.107	1.533	−0.186	0.849	0.452	1.261	1.841	1.432
2001	2.238	1.567	−0.255	0.820	0.515	1.305	1.978	1.464
2002	2.299	1.582	−0.252	0.813	0.546	1.329	2.005	1.465
2003	2.244	1.568	−0.427	0.749	0.621	1.409	2.050	1.486
2004	2.371	1.600	−0.495	0.716	0.699	1.480	2.166	1.511
2005	2.387	1.605	−0.613	0.677	0.744	1.533	2.255	1.545
2006	2.391	1.606	−0.930	0.611	0.770	1.561	2.551	1.682
2007	2.784	1.705	−0.851	0.640	0.811	1.545	2.824	1.724
2008	2.819	1.714	−0.943	0.614	0.849	1.587	2.913	1.758
2009	2.620	1.664	−1.070	0.572	0.865	1.646	2.826	1.765
2010	3.106	1.787	−1.063	0.577	0.971	1.690	3.199	1.832
2011	2.806	1.711	−1.270	0.533	0.936	1.706	3.140	1.882
2012	2.972	1.753	−1.326	0.522	0.986	1.740	3.312	1.929
2013	2.922	1.740	−1.421	0.513	0.958	1.712	3.385	1.982
2014	3.404	1.862	−1.572	0.496	1.066	1.763	3.910	2.130
2015	4.006	2.014	−1.719	0.480	1.195	1.827	4.530	2.297
2016	4.267	2.081	−1.801	0.438	1.213	1.961	4.855	2.420

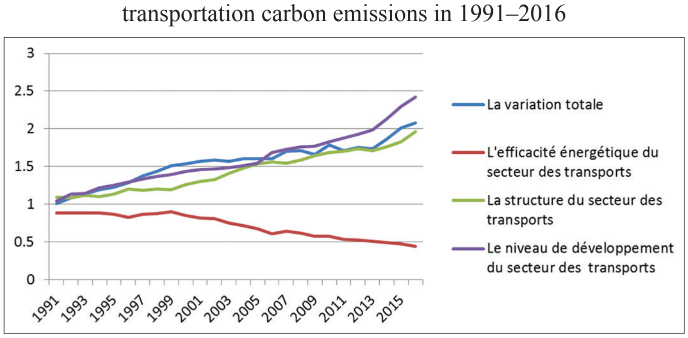
The negative value indicates the reducing of carbon emissions. Source: Authors' calculation

Figure 1: The contribution value of different factors to the transportation carbon emissions in 1991–2016



Source: Authors' calculation

Figure 2: The contribution rate of the various factors to the transportation carbon emissions in 1991–2016



Source: Authors' calculation

using the LMDI method over the period 1991–2016. To identify the determinants, the CO_2 emissions growth is decomposed into four factors: emissions intensity, transport structure, energy efficiency and transport development. The key findings of the current study can be summarized as follows:

- The level of transport development in Tunisia is considered as the main factor behind carbon emissions increase. Since the 1990s, Tunisia's transport industry has experienced an unprecedented growth. The total turnover of the transport sector in Tunisia increased from 5.24 billion tons-km in 1990 to 13.40 billion tons-km in 2016 (Table 4). Simultaneously with the rise in the level of transport development, carbon emissions stemming from transportation have increased rapidly.
- The transport structure factor can be added to the development factor to explain the emissions upward trend. The transport structure in Tunisia is characterized by the predominance of the road transport mode. This sector has experienced a great public investment in road infrastructure and private interventions. This predominance of the road modal share is associated with the growth of fossil fuel consumption. Then, numerous negative environmental effects have appeared, notably air pollution analyzed through carbon dioxide emissions that are dramatically increasing.
- The transport sector energy efficiency turned to be the main inhibiting factor that limits the CO_2 emissions of the transport sector. Hence, energy efficiency is a critical parameter for policymakers wishing to set up carbon emissions reduction policies. Optimizing energy conservation and reducing its intensity has a significant binding effect on increasing carbon emissions.

The results of this work do not exclude political implications for Tunisia. First, in order to control GHG emissions, the transport sector energy efficiency should be upgraded. Technological progress is the most effective way to increase energy efficiency (Achour and Belloumi, 2016). In addition, incentives to use renewable energy (solar energy, wind energy, bioenergy, etc.) are also viewed as useful tools for achieving such a result. Moreover, in order to reduce the energy intensity, the Tunisian authorities must particularly focus on the optimization of transportation structure by encouraging modal transport towards the milder modes of transport. Finally, the Tunisian fuel pricing policy, characterized by subsidy can affect the energy performance. Therefore, as planned by the government, the reform of the energy subsidy is necessary, given its significant impact on the well-being of households and energy-intensive sectors, such as the transport sector and its CO_2 emissions.

To conclude, our work is not only a methodological basis to identify and measure the factors that influence CO_2 emissions of the entire Tunisian transportation system. It is also a theoretical basis for implementing an energy sustainable transportation policy that aligns with global policies and strategies that are moving towards the establishment of a sustainable transportation system, as part of a broader global trend of sustainable development.

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