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Energy Prices, Energy Intensity and Technological Progress: Impact and Causality Analysis in Tunisia

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ABSTRACT: This article aims to examine the link between oil prices, oil intensity, and technological advancement in the Tunisian economy from 1980 to 2016. Methodology- This paper applied Bayer-Hanck combined cointegration analysis and Granger causality tests to examine the causal relationships between oil prices, oil intensity and technical progress. According to the research, there is a correlation between oil prices, fuel use, and oil intensity. In addition, there is a one-way correlation between oil prices, intensity, and gasoline costs. Originality- These findings are essential for the relevant authorities in Tunisia in developing appropriate energy policy and planning for decisions

Keywords: Combined cointegration test; granger causality; oil price; oil intensity; technical progress, Tunisia

INTRODUCTION

Tunisian energy consumption differs from residential and industrial economic characteristics in neighboring countries. Energy usage is also increased when a higher percentage of urban residents. Data on energy pricing and demographics must be used to develop accurate energy consumption models (Labidi and Abdessalem, 2018; Longhi, 2015). Knowing a country's income elasticity and energy pricing is critical to gauge how much energy it uses. This means that rising incomes equate to increasing energy consumption in emerging nations. In addition, older buildings use more energy, so having fewer of them means using less (Lee, Kaneko & Sharifi, 2020; Xu, Xiao & Li, 2020). Climate indicators strongly affect residential energy demand (Chen, Ban-Weiss, and Sanders, 2018; Pablo-Romero Pozo-Barajas and Sánchez-Rivas, 2019, for example). Colder nations utilize energy for heating, whereas those with hotter climates use it for air conditioning (Randazzo, De Cian & Mistry, 2020). As a result, the factors influencing energy use differ from nation to country (Auffhammer & Mansur, 2014). In addition, policymakers and economists must understand energy consumption components in emerging nations like Tunisia to plan correctly. According to the EIA, household energy consumption accounts for 87% of total energy consumption in developing countries.

Climate change and energy policy are two of the most pressing issues facing today's global economy. Changes in supply and demand have been taking place to fulfill sustainability standards. Minimizing greenhouse gas emissions and energy efficiency in lowering energy use are the most pressing economic policy problems. According to Howarth (1997), this is the case. Given the country's high dependency on oil as a source of almost all energy. It took the place of coal as a source of transportation heat. A whopping 46% of all primary energy output is now derived from the use of oil (NACE, 2011). For this reason, we are looking at how oil prices, advancement in technology, and production interact to see how much it contributes to carbon emissions and how much it contributes to greenhouse gas production. Several empirical studies have examined the link between oil prices and economic development. The increasing oil prices could be reduced by using a computable general equilibrium model, as in Timilsina, 2015. He observed that rising oil prices benefit oil-exporting nations' economies while hurting the GDP of oil-importing countries.

Ftiti et al. (2016) also evaluated the dependency between oil prices and economic activity growth for four main nations in the Organization of the Petroleum Exporting Countries (OPEC). They observed that oil price shocks influence the link between oil and economic development in OPEC nations. Finally, Sarwar et al. (2017) utilized the panel data of 210 nations from 1960–to 2014 to evaluate the empirical link between economic growth, electricity consumption, oil price, gross fixed capital creation and population.

As a consequence of their full panel data, they found a bidirectional link between power use, the price of oil, and GDP. The findings confirm that emerging nations significantly rely on power consumption for economic development despite rising oil costs. This conclusion changes among income levels, OECD regions, and even across areas within regions. In the near term, the growth and feedback hypothesis suggests that more strong electricity policies should be enacted to achieve high economic growth. Economic development, power consumption, oil prices, capital, and labor were studied in 157 nations between 1960 and 2014 by Shahbaz et al. (Shahbaz and colleagues, 2017). According to their empirical findings, there seems to be a correlation between the factors. Therefore, it is reasonable to assume that electricity consumption and economic growth are linked, just as oil prices are linked to economic development. According to these findings, energy consumption is an essential component of economic development for emerging nations. In the near term, growth and feedback effects imply that more aggressive power policies should be enacted to maintain long-term sustainable economic growth.

There was no long-term correlation between the price of oil and the price of the three metals evaluated (Mei-Se, Shu-Jung & Chien-Chiang, 2018). Instead, they used SVAR to highlight the time-varying impact of oil shocks on precious metals, which increased considerably during the financial crisis (Rehman, Shahzad, Uddin & Hedström 2018). However, there are favorable correlations between oil and precious metal returns, volatilities and market risk in the Fractional Integrated Autoregressive Generalized Exponential Conditional Heteroscedasticity (FIEGARCH) framework (Mokni, 2018).

On the other hand, a significant research study has focused on the link between technological innovation and energy use. It has been observed that China's energy usage is decreasing due to technical advancements (Du and Yan, 2009). According to (Tang and Tan (2013), in Malaysia, energy consumption is driven by technical innovation, whereas technological innovation negatively impacts consumption. According to (Fei and Rasiah, 2014), technical innovation in Canada, Ecuador, Norway, and South Africa has little effect on long-term variations in energy generated from fossil fuels. On the other hand, technology innovation is the driving force behind renewable energy in Nordic nations (Irandoust 2016). A distinct form of energy has been examined in each of these research. As a result of these studies, both (Sohag et al. 2015) and (Yin and Yang, 2014) concluded that technological innovation decreases energy consumption which, in turn, makes it feasible to achieve sustainability despite the wide range of the nation studied's overall energy consumption. Researchers in China's energy-intensive sectors (Lin and Tan, 2017) used a cointegration analysis to examine the factors that influence energy consumption. They discovered that R&D efforts had a direct impact on energy use. We observed that the Chinese chemical industry's electrical intensity might be reduced by increasing R&D (Huang et al., 2019; Chen et al., 2019). In addition, it was observed that oil and metals prices are not stationary between quantiles, with the cointegration models differing between quantiles.

Jbir and Zouari-Ghorbel (2009) showed that oil price fluctuations in Tunisia did not immediately affect the country's economy. A neutral asymmetric link between oil price shocks and economic activity was also discovered. From 1960-2009, (Bouzid, 2012) studied the link between oil prices and economic development in Tunisia. He concluded that oil prices result from the long-term connection between energy costs and economic growth, as well as real GDP. There is a positive feedback effect between energy use and economic development, as stated by (Shahbaz and Lean, 2012). From 1980-2009, researchers (Abidi and Mraihi, 2014) examined the relationship between Tunisia's energy consumption and GDP using aggregated and disaggregated data on oil, natural gas, and electricity. They concluded that there is no short-term causation between aggregate and disaggregated energy consumption and economic development and that electricity usage is the source of economic growth. The ARDL technique and the testing of the limits strategy for cointegration were utilized by (Brini et al. 2017) for Tunisia between 1980 and 2011.

This paper aims to study the relationship between energy prices, energy intensity, and technological progress. This is an important topic given the importance of environmental costs in energy production and consumption and the proposed methodology for reducing greenhouse gas emissions.

2. DATA, METHODOLOGY AND EMPIRICAL RESULTS

2.1. Description of data

The empirical investigation employed yearly time series data from 1980-to 2016. Oil consumption and pricing are utilized as data. The price of oil is stated in Tunisian national dinars. The fuel rate published by the Ministry of Transport in Tunisia is regarded as an indicator of technical development. The study's variables include oil intensity, which quantifies the oil utilized per unit of economic output. The fuel rate is calculated by dividing the fuel used by the vehicle's mileage. We use the natural logarithm of these variables for scaling.

Table 1 presents summary statistics for each variable used in the empirical analysis. The three series are named as follows: $\ln I_t$ is a natural log of oil intensity, $\ln P_t$ is a natural log of oil price, and $\ln F_t$ is a natural log of fuel rate.

Table 1: Summary Statistics.

Variables	Minimum	maximum	Mean	Std.Dev
lnI_t	17.13	20.45	19.11	3.041
LnP_t	100	201	160.92	34.20
lnF_t	6.62	11.56	7.62	1.46

2.2. METHODOLOGY

In the first phase, we employed the Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests (PP). Unlike the ADF test, which simply looks at autocorrelation in a series, the PP test also evaluates whether or not there is a Heteroscedasticity dimension to the time series being analyzed. Non-stationary time series have at least one instant (mean, variance, or covariance) that isn't reliant on the passage of time. The stochastic unit root of a non-stationary series needs differentiation before it can be made stationary. First, causality tests are susceptible to series stationarity (Stock and Watson, 1989), which most macroeconomic series do not possess (Stock and Watson, 1989). (Nelson and Plosser, 1982). The next step is to determine the delay using the AIC and SIC criteria and look for cointegration after the two series have been integrated in the same order (order of VAR). Engle and Granger or Johansen cointegration tests are only two of the many conceivable cointegration tests. Engle and Granger's bivariate method is quite limiting when just one cointegrating link exists. The Johansen cointegration test is used to identify the number of cointegration equations that may be tested. It is based on the trace and maximum eigenvalue statistics, two separate likelihood ratios (LR). Co-integration suggests that causation exists between the two series, but it does not show the direction in which the causality is flowing.

All of these cointegration tests have an econometric flaw nowadays. A lack of sensitivity to filtering out unwanted incursions in most time-series data, for example, limits the capacity of these methods to provide robust conclusions (Pesavento, 2004). The author also found that attaining a consistent outcome across the cointegration technologies is challenging. He claims that if one cointegration test rejects the null hypothesis, another may be needed to accept it. Bayer and Hanck (2013) address this issue by removing the potential bias of current outdated estimators in assessing the cointegrating features of time series data. The cointegration test approach used in this work (Bayer and Hanck, 2013) seeks to give efficient estimates by removing many unnecessary testing steps. To guarantee its robustness, (Bayer and Hanck, 2013) used Fisher's (1932) formula for cointegration:

$$EG-JOH=-2\left[In\left(P_{EG}\right)+In\left(P_{JOH}\right)\right] \quad (1)$$

$$EG-JOH-BO-BDM=-2\left[In\left(P_{EG}\right)+In\left(P_{JOH}\right)+In\left(P_{BO}\right)+In\left(P_{BDM}\right)\right] \quad (2)$$

In determining the possibility of cointegration among respective variables, (Engle-Granger, 1987; Johansen, 1995; Boswijik, 1994; Banerjee, Dolado and Mestre, 1998) used the following notations as a critical econometric guide: P_{EG}, P_{JOH}, P_{BO} and P_{BDM} respectively.

However, (Bayer and Hanck, 2013) used the Fisher statistic to guide their cointegration test. The VECM (vector error correction technique) Granger causality test is used to identify the causal link between the variables:

$$\begin{pmatrix}\Delta I_t\\ \Delta P_t\\ \Delta F_t\end{pmatrix}=\begin{pmatrix}\mu_I\\ \mu_P\\ \mu_F\end{pmatrix}+\begin{pmatrix}\Gamma_{II,1}\Gamma_{IP,1}\Gamma_{IF,1}\\ \Gamma_{PI,1}\Gamma_{PP,1}\Gamma_{PF,1}\\ \Gamma_{FI,1}\Gamma_{FP,1}\Gamma_{FF,1}\end{pmatrix}\begin{pmatrix}\Delta I_{t-1}\\ \Delta P_{t-1}\\ \Delta PF_{t-1}\end{pmatrix}++\begin{pmatrix}\Gamma_{II,P}\Gamma_{IP,p}\Gamma_{IF,p}\\ \Gamma_{PI,P}\Gamma_{PP,P}\Gamma_{PF,P}\\ \Gamma_{FI,P}\Gamma_{FP,P}\Gamma_{FF,P}\end{pmatrix}\begin{pmatrix}\Delta I_{t-P}\\ \Delta P_{t-P}\\ \Delta PF_{t-P}\end{pmatrix}+\begin{pmatrix}\alpha_I\\ \alpha_P\\ \alpha_F\end{pmatrix}\times\left(ECM_{t-1}\right)+\begin{pmatrix}\varepsilon_{I,t}\\ \varepsilon_{P,t}\\ \varepsilon_{F,t}\end{pmatrix} \quad (3)$$

Where Δ stands for the notation of the difference operator, while the ECM_{t-1} is obtained from the estimation of the long-run relationship. In this case, the long-run causal relationship is ascertained by determining the significant position of the coefficient for the ECM_{t-1} following the T-test statistics. Apart from that, F-statistic for the first-differenced lagged independent variables is used for testing the direction of short-run causal relationship between the variables.

3. EMPIRICAL RESULTS

The unit root qualities of the variables were investigated using the ADF and PP unit root tests, respectively. Table 2 shows the results of the ADF and PP tests.

Table 2: Unit Root Analysis.

Variable	ADT Test		PP Test	
	T-statistic	P. value	T-statistic	P. value
$\ln I_t$	-1.090	0.915	-1.063	0.920
$\ln P_t$	-2.081	0.531	-0.879	0.946
$\ln F_t$	-2.107	0.6244	-1.797	0.310
$\Delta \ln I_t$	-5.897	0.000	-5.976	0.000
$\Delta \ln P_t$	-4.431	0.008	-10.605	0.000
$\Delta \ln F_t$	-9.961	0.000	-11.124	0.000

In terms of levels, the series are non-stationary, but they are in terms of the first difference. As a result, order one integration is used to account for all variables. i.e., I(1). Given that all variables are integrated in the same order, the next step was to test for cointegration using the Bayer-Hanck combined cointegration. Table-3 illustrates the combined cointegration tests including $EG-JOH$ and $EG-JOH-BO-BDM$ tests. The results reveal that Fisher-statistics for $EG-JOH$ and $EG-JOH-BO-BDM$ tests are more significant than 1% critical values, indicating that both $EG-JOH-BO-BDM$ tests statistically reject the null hypothesis of no cointegration between variables. We cannot reject the hypothesis of no cointegration once we used I_t and P_t as dependent variables in case of Tunisia. This shows the presence of one cointegration that confirms the existence of cointegration between the variables. This validates the fact of a long-run relationship between oil prices, fuel rate and energy intensity in Tunisia over 1980-2016.

Table 3: The Results of Bayer and Hanck Cointegration Analysis.

Estimated Models	EG-JOH	EG-JOH-BO-BDM	Cointegration
$I_t = f(P_t, F_t)$	1.980	1.813	No
$P_t = f(I_t, F_t)$	3.080	3.039	No
$F_t = f(I_t, P_t)$	13.217	21.443	Exists

The VECM Granger causality divides causality results into long-term and short-term outcomes. Table 4 presents the findings of the VECM Granger causality test. There is a one-way correlation between oil price and fuel rate, implying that energy-saving innovations allow better energy use in terms of consumption. Thus the influence of energy prices on technology decreases energy intensity by reducing energy demand due to a decrease in energy demand. According to (Popp, 2002), a rise in energy costs has a favorable effect on the energy sector's patenting rate. (Bessec and Méritet, 2007) reveal that the increase in oil prices favors technological innovations in OECD countries. Tang and Tan (2013) report that technological innovation negatively influences electricity consumption in Malaysia. Likewise (Fei et al. 2014) found a relationship between energy prices and technological innovation in Ecuador, Canada, Norway and South Africa, i.e., technological innovation negatively influences electricity consumption.

As a result of the second connection, improving energy efficiency via innovations decreases the energy required to create one unit of GDP. A more efficient process uses less energy and hence has a lower cost, which stimulates more usage. As a result of increased energy costs, some experts have concluded that innovation in energy conservation is to blame for the fall in energy intensity (Holdren, 2001). According to the findings of (Herring and Roy, 2007), technological advances lower energy use efficiency, and measures such as taxes or regulation have been proposed to enhance energy use efficiency. As a result, in both rich and emerging nations, the amount of energy used per unit of economic production has decreased (Stern, 2011). Technological innovation could alter product compositions by substituting energy-efficient items with more energy-intensive ones to modify the link between energy consumption and economic development. Because Tunisia is an energy-dependent country, any limits on energy usage may slow economic development. So, to maintain economic growth, the Tunisian government must promote energy infrastructure and energy efficiency measures that can be implemented quickly. The Tunisian government must also reduce energy intensity to reduce reliance on imported energy. These findings also suggest that genuine price increases lead to energy savings via improved energy efficiency.

Fuel rate is causally linked to oil prices and intensity to fuel rate in the near term. The empirical data shows a clear association between energy costs and technical development as assessed by the fuel rate variable. In addition, the findings show the effect of growing costs on technology. From oil prices to oil efficiency, we establish one-way causation. Due to increasing prices, consumers have reduced consumption: more fuel-efficient cars, more insulated houses and businesses, and improved industrial energy efficiency. Since the first oil shock, a worldwide surge in oil costs has impacted consumption. High costs affect demand.

Table 4: The VECM Granger Causality Analysis

Dependent Variable	Type of Causality						
	Short Run			Long Run	Short-run and long-run joint causality		
	$\sum\Delta\ln I_{t-1}$	$\sum\Delta\ln P_{t-1}$	$\sum\Delta\ln F_{t-1}$	ECM_{t-1}	$\sum\Delta\ln E_{t-1}, ECM_{t-1}$	$\sum\Delta\ln I_{t-1}, ECM_{t-1}$	$\sum\Delta\ln F_{t-1}, ECM_{t-1}$
$\Delta\ln I_t$	...	2.498 [0.102]	31.314 [0.000]	-0.291 [-1.003]	...	...	...
$\Delta\ln P_t$	0.226 [0.799]	...	1.528 [0.236]	-0.695 [-1.537]	...	...	...
$\Delta\ln F_t$	0.113 [0.056]	0.750 [0.482]	...	-0.631* [-3.166]	5.772 [0.003]	5.082 [0.007]	...

The results of the variance decomposition method are presented in Table 5. We find that its innovative shocks contribute 69.738% of the oil intensity and a standard deviation shock of the oil price and the fuel rate explains the oil intensity of 16.02% and 14.23%, respectively.

Table 5: Variance Decomposition Analysis.

Variance Decomposition of I_t				Variance Decomposition of P_t			Variance Decomposition of F_t		
Horizons	I_t	P_t	F_t	I_t	P_t	F_t	I_t	P_t	F_t
1	100.000	0.0000	0.000	0.143	99.856	0.000	0.001	2.068	97.930
2	91.939	1.801	6.259	0.154	99.843	0.002	0.001	4.045	95.952
3	86.800	3.363	9.836	0.164	99.830	0.004	0.002	7.647	92.350
4	83.590	4.687	11.721	0.175	99.818	0.006	0.003	11.039	88.957
5	81.322	5.892	12.784	0.186	99.805	0.008	0.004	13.908	86.086
6	79.543	7.035	13.420	0.197	99.792	0.009	0.005	16.299	83.695
7	78.043	8.141	13.814	0.209	99.779	0.011	0.005	18.295	81.698
8	76.720	9.219	14.060	0.221	99.765	0.013	0.005	19.973	80.020
9	75.519	10.271	14.209	0.233	99.752	0.014	0.006	21.391	78.602
10	74.407	11.298	14.293	0.245	99.737	0.016	0.007	22.595	77.396
11	73.368	12.299	14.331	0.257	99.723	0.018	0.007	23.624	76.367
12	72.388	13.274	14.337	0.270	99.709	0.020	0.007	24.506	75.486
13	71.460	14.220	14.319	0.283	99.694	0.022	0.008	25.264	74.727
14	70.578	15.138	14.283	0.295	99.679	0.024	0.008	25.917	74.073
15	69.738	16.027	14.234	0.308	99.664	0.026	0.008	26.482	73.508

The contribution of oil intensity and fuel rate contribute to oil prices are minimal, i.e. 0.30% and 0.026%, respectively, while 99.66 of oil prices are contributed by innovative shocks. On the other hand, the contribution of oil intensity and oil prices to fuel rate is 0.008% and 26.48%, respectively, while the rest contribute to fuel rate through innovative shocks.

4. CONCLUSION AND POLICY IMPLICATIONS

This study used Bayer-Hanck combined cointegration analysis and Granger causality testing with the Tunisian economy in mind. The first differences appear stationary for all three series. Then, the three variables seem to be cointegrated. Finally, Granger causality studies reveal a link between oil prices and technological advancement. These findings have policy consequences. First, the Tunisian government must create energy savings that enable better energy use in terms of consumption and raise energy pricing, lowering energy intensity by decreasing energy demand. Secondly, focusing on the link that improving energy efficiency decreases energy demand by reducing the energy consumed to create one unit of GDP. Indeed, when a process's energy efficiency increases, it becomes less costly, encouraging its usage.

Finally, considering the significance of environmental costs associated with energy production and use, the Tunisian government must enhance energy efficiency and explore alternative energy sources without compromising economic growth. Energy conservation is one of the key goals of energy policy since it reduces greenhouse gas emissions by employing renewable energy sources and substitutability. The energy strategy to decrease GHG emissions is expected to improve several technologies (e.g., transportation) and abolish others (e.g., coal power plants). As a result of the ETS, energy-intensive capital and consumer items will be gradually replaced. Effective energy conservation strategies cannot be established without addressing other economic and environmental aspects besides our study's underlying variables. In the future, national elements like energy supply infrastructure, energy efficiency concerns, or institutional limits should be considered as international trends.

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No Conflict of interest.

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