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Summary: This study uses panel cointegration techniques to examine the impact of energy consumption, and trade on economic growth for five North Africa countries within a multivariate framework over the period 1980-2009. Short-run dynamic relationship shows that there is evidence of one way short-run relationship from *i)* output, exports, and capital to imports, *ii)* fossil fuels consumption to exports, *iii)* exports to capital and *iv)* labor to combustible renewables and waste consumption. The vector error correction model shows that there is evidence of long-run relationship running from *i)* combustible renewables and waste consumption, fossil fuels consumption, exports, imports, capital, and labor to output, *ii)* fossil fuels consumption, exports, imports, capital, and labor to combustible renewables and waste consumption, and *iii)* combustible renewables and waste consumption, fossil fuels consumption, exports, capital, and labor to imports. The long-run elasticities show that combustible renewables and waste consumption is not statistically significant and only fossil fuels consumption can affect output while trade is statistically significant and have a negative impact on output through imports and positive impact through exports. The policy implication of these results is that, in these countries, trade openness is not sufficiently efficient to incite the use of energies for production.

Key words: Energy consumption; panel cointegration, North Africa countries, trade.

JEL : C33, F43, Q56.

1. Introduction

Before discussing the causal linkages between energy consumption, output, and trade it is necessary to cite some published research debating the relationship between energy consumption and economic growth (e.g. Nicholas Apergis and James Payne, 2009a, 2009b; Mohsen Mehrara, 2007; Ilhan Ozturk, 2010; Payne 2010) or between renewable-energy consumption and economic growth (e.g. Apergis and Payne, 2010a, 2010b, 2011) or between renewable and non-renewable energy consumption and economic growth (e.g. Apergis and Payne, 2012). All these research studies have shown the existence of a causal relationship between these two variables and conclude that energy contributes to the increase of economic growth. However, the potential gains coming from economic growth cannot be explained only by energy demand. There are many other determining factors that have an impact on economic growth such as capital, labor force, and trade variables. The causal relationship between energy consumption, output, and trade is an important topic studied by using the cointegration techniques and the Granger causality (e.g. Hooi Hooi Lean and Russell Smyth, 2010a, 2010b; Paresh Kumar Narayan and Russell Smyth, 2009; Perry Sadorsky, 2011, 2012).

On this occasion and in order to determine the causal relationship between energy consumption and trade and their impact on economic growth for the North Africa region, it's required to describe disparities and capacities of energy resources of each country in the region. For this reason, our econometric model involves the distinction between energy that is combustible renewables and waste and fossil fuels, and trade that is exports and imports.

In North Africa region there are seven countries, of which Algeria, Libya, Mauritania, Morocco, and Tunisia belong to the Union du Maghreb Arabe (UMA) and the Comité Maghrébin de l'Electricité (COMELEC). Egypt is a member of the East African Power Pool (EAPP). Algeria, Libya, Egypt, Sudan

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and, Mauritania are the five net hydrocarbon exporting countries of the region. Among these countries there is a strong dependence on hydrocarbon exports between Libya, Algeria and Sudan. From Mauritania and Sudan, the energy balances show that, in spite of their being net hydrocarbon exporters, traditional biomass have a large share[3].

According to the North Africa Office of the United Nations Economic Commission for Africa (UNECA, 2012), in Algeria the oil and gas sector accounts for 45.9% and the total capacity of exports is nearly 98% in 2007. Algeria was the fourth largest exporter of liquefied petroleum gas (LPG) in the world and to give advantage to the resources and capacities of renewable energy, the strategy adopted by the Algerian government is the development of the Concentrated Solar Power sector (CSP) and the objective is to produce 7.200 MW.

The Energy Information Administration (EIA,2011) suggest that, in Egypt, the natural gas reserves increased by 18.7 trillion cubic feet (tcf) over the 2010 estimate from 58.5 trillion cubic feet to 77.2 trillion cubic feet and gas exports are larger with over 14.4 Mtpe exported in 2008. In addition, Egypt is the fourth largest capacity for CSP in the Mediterranean and has the highest economic capacity for solar energy in 2005 (Paving the Way for the Mediterranean Solar Plan, 2011, p16).

Libya's economy severely dependent on exports of hydrocarbon (oil reserves are estimated at 40 billion barrels and 1.300 billion m^3 natural gas reserves) (M.Salah Ibrahim, 2006). Solar potential in Libya is about 7.5 kwh/m^2/ day and given that the desert is about 88% of the country solar potential should not have competition problems (UNECA, 2012).

Through energy conservation efforts, Tunisia presumes to save 10 million tons of oil equivalent (Mtoe) of fossil fuels over 2010-2030. This conservation strategy relies on energy efficiency with 80% and renewable energy with 20% (World Bank, 2012). According to the International Energy Agency, the energy balance for Tunisia shows that total energy resources produced in 2009 were 7811 ktoe, mostly crude oil (52.76%), natural gas (30.48%), and renewable energy (16.66%). Exports of oil industry were 4.239 ktoe and the imports were 5838 ktoe, mostly refined petroleum products (3976 ktoe) and natural gas (1862 ktoe), (Reegle, 2011).

In Sudan, oil plays a vital role in the development of the economy given that it is an oil producing country able to export refined. Energy balanced for Sudan shows that total energy produced in 2009 was 35198 ktoe, mostly crude oil (68.65%), biofuels and waste (30.56%), and hydro power (0.79%), (International Energy Agency, 2009). Exports reached 19.5 million tons petroleum equivalent (Mtpe) in 2008 and accounted for 95% of total exports and 60% of state revenues (Reegle, 2011).

Morocco is the only country in the region that produces energy from coal, imported from the United States, Colombia, and South Africa, against other energy sources given that the production costs are relatively low and this is why Morocco is the only country in the region with coal-fired power plants (UNECA, 2012). In 2008, the government published in the National energy strategy 2020-2030 that for the next decade's coal will remain the primary fossil fuel for energy production (Reegle, 2011). The massive use of coal leads to the increase of CO2 emissions, and for this cause that the Moroccan government has set up a large renewable energy (particularly wind and solar) development plan. According to the IEA, Morocco's energy balanced indicates a lower amount of total energy produced in 2009, it recorded a total energy production of 782 ktoe distributed between crude oil (0.9%), natural gas (4.73%), hydropower (28.52%), Geothermal, solar, etc. (4.35%), and biofuels and waste (61.38%).

2. Existing literature

The causal relationship between combustible renewables and waste consumption, fossil fuels consumption, output, and trade is one of the most important studies that we should explore. However, there is some published research and empirical studies investigating the relationship between these variables. Until today research that has been published dealing with the relationship between energy consumption (total energy use), output, and trade such as Lean and Smyth (2010a, 2010b), Sadorsky (2011, 2012).

Lean and Smyth (2010a) examine the dynamic relationship between output, electricity generation, and exports for Malaysia. In this paper they find unidirectional Granger causality running from economic growth to electricity generation. The second paper of Lean and Smyth (2010b), authors examine the dynamic relationship between output, electricity consumption, exports, labor, and capital in a multivariate model for Malaysia. They find that there is bidirectional causality between output and electricity

[3] These informations are based on the United Nations, Economic commission for Africa, Office for North Africa.

consumption. They conclude that Malaysia has to adopt the duel plan which involve to increase of investment in electricity infrastructure and to step up electricity conservation policies in order to avoid the negative effect of reducing electricity consumption on output. These two papers are almost similar but the difference occurs in the causality relationship.

The causal relationship between electricity consumption, exports and GDP have been examined by Narayan and Smyth (2009) for a panel of Middle East countries. For the panel as a whole, they find a feedback effect between these variables. They close the same policy implications founded by Lean and Smyth (2010b) that is to encourage these countries to invest in electricity infrastructure and step up electricity conservation policies to reduce the consumption of electricity that affect economic growth.

Sadorsky (2011) uses panel cointegration techniques to detect how trade can affect energy consumption for 8 Middle East countries. In the short-run, he finds Granger causality from exports to energy consumption, and bidirectional relationship between imports and energy consumption. In the long-run he concludes that increase in both exports and imports affect energy demand. Sadorsky (2012) examine the causal relationship between these variables using panel cointegration techniques for 7 South American countries. He finds that there is a long-run relationship between output and trade that runs through exports and imports in two specifications models while there is no causality between energy and output.

In this paper we use panel cointegration and Granger causality method for short-run and long-run relationship between energy consumption (combustible renewables and waste, fossil fuels), output, and trade (exports and imports). The rest of the analysis is organized as follows: section 3 defines the data. Section 4 describes some descriptive statistics. Section 5 defines the empirical model and results. Section 6 concludes and policy implications.

3. Data

The panel data set is a balanced panel of five countries of North Africa (Algeria, Egypt, Morocco, Sudan, and Tunisia) followed over the years 1980-2009 and includes annual data on combustible renewables and waste consumption, fossil fuels consumption, output and trade (exports and imports). The dimension of the panel data set is selected to include as many countries with variables. The annual data of some countries (Libya and Mauritania) is not available and for this reason we have limited our sample to these five countries of the region. Combustible renewables and waste consumption (CRW) includes biomass, biogas and waste and measured in a share of total energy use. Fossil fuels energy consumption (FF) includes coal, oil, and natural gas product and measured in a share of total energy use. Output (Y) is defined by real GDP per capita and measured in constant 2000 US dollars. The stock of capital (K) is measured using gross fixed capital formation (constant 200 US dollars) and Labor (L) is measured using a number of people in the total labor force. These values are divided by population to get gross fixed capital formation per capita and labor force per capita. Exports (EX) and Imports (IM) are measured using exports of goods and services and imports of goods and services are measured in share of GDP, respectively. Energy consumption (CRW, FF), output, capital stock, and trade (exports and imports) are obtained from the World Bank Development Indicators (2011) online database. Labor force variable is collected from the SHAREBROOKE University of Canada. All variables are transformed in natural logarithms.

4. Descriptive Statistics

Table 1 presents some descriptive statistics of each variable used for the empirical analysis. Fig (1-4) show time series graphs of CRW consumption, FF consumption, imports, and exports, respectively.

Table 1: Summary statistics

	Y	CRW	FF	EX	IM
Mean	1362.404	20.56251	78.29952	26.17500	30.12693
Median	1482.551	4.600534	93.46438	26.00000	29.00000
Maximum	3083.987	87.98156	100.1272	55.63000	58.67000
Minimum	242.7433	0.067300	11.10708	3.340000	7.070000
Observations	150	150	150	150	150

Cross sections	5	5	5	5	5

Source: Authors (EViews.7 software).

Table 1 presents some descriptive statistics (Mean, Median, Maximum, and Minimum) of each variable used for the empirical analysis. Fig (1-4) show time series graphs of CRW consumption, FF consumption, imports, and exports, respectively.

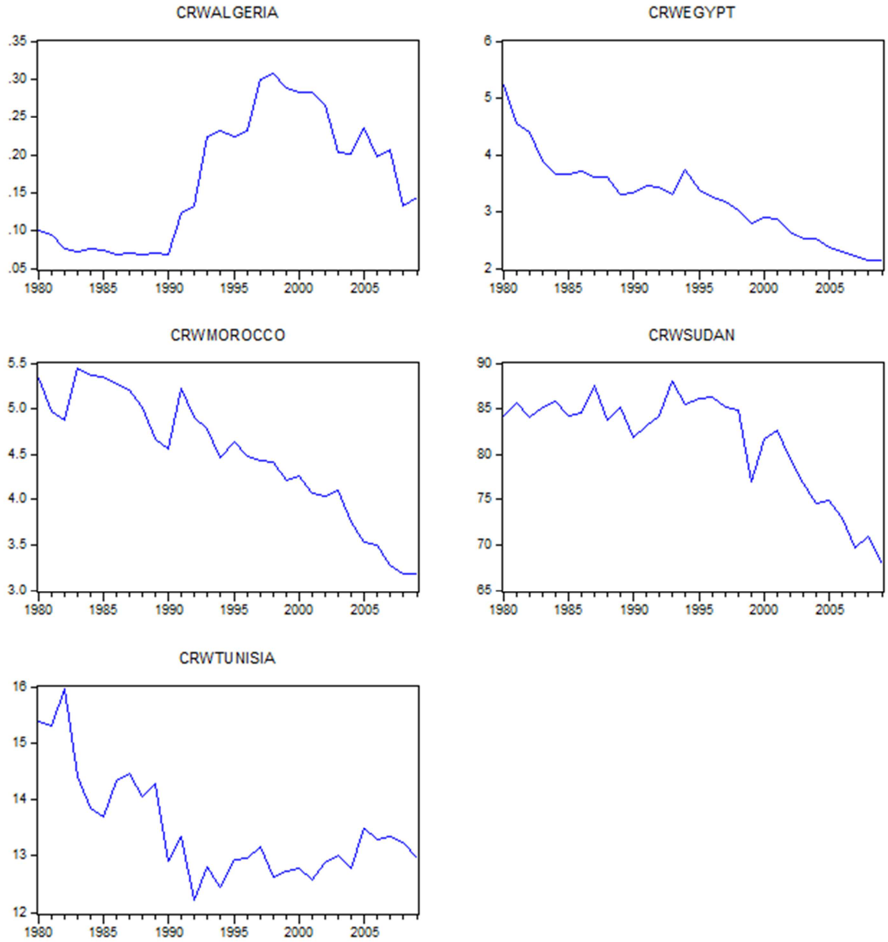

Fig 1. Combustible renewables and waste consumption (share of total energy)

Fig.1 shows how the consumption of combustible renewables and waste (measured as a percentage of total energy use) varies across time in North Africa countries over the period 1980-2009. We note that, practically the consumption of CRW energy decreases for all selected countries. Sudan is the biggest consumer with 87.98% in 1993 and Algeria is the smallest with 0.06% in 1986.

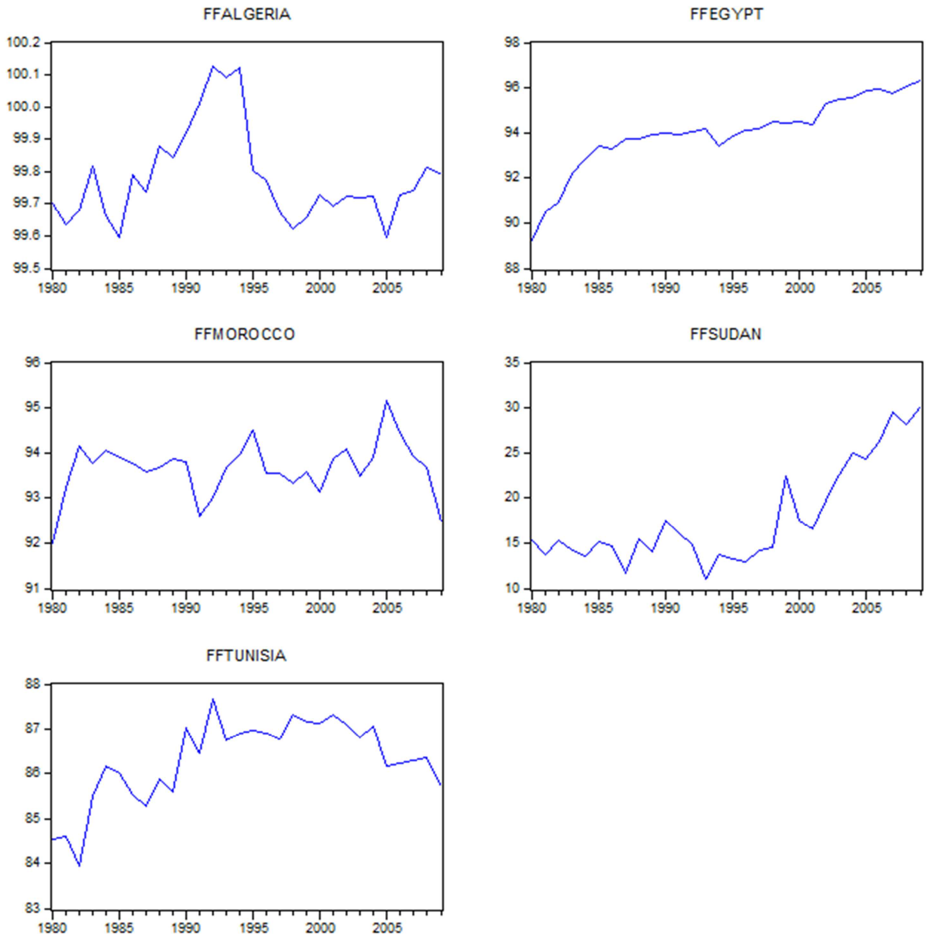

Fig 2. Fossil fuels energy consumption (share of total energy)

Fig. 2 shows the variation of the consumption of fossil fuel energy that comprises coal, oil, petroleum, and natural gas products (measured as a percentage of total energy) across time. Unlike to the inter-temporal change observed in CRW consumption, FF consumption increases across time except for Algeria and Morocco has some drop. Algeria is the biggest consumer of fossil fuel with 100.12% in 1992 and Sudan is the smallest consumer with 11.10% in 1993.

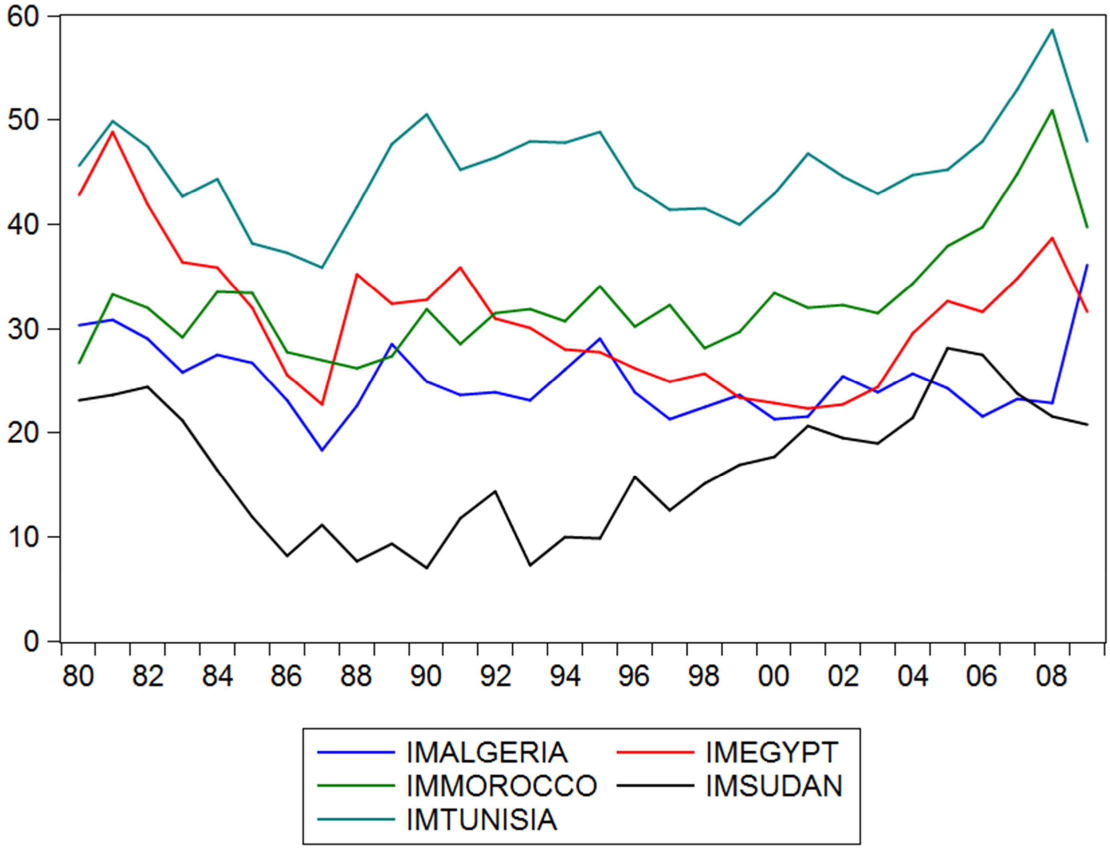

Fig 3. Imports goods and services (share of GDP)

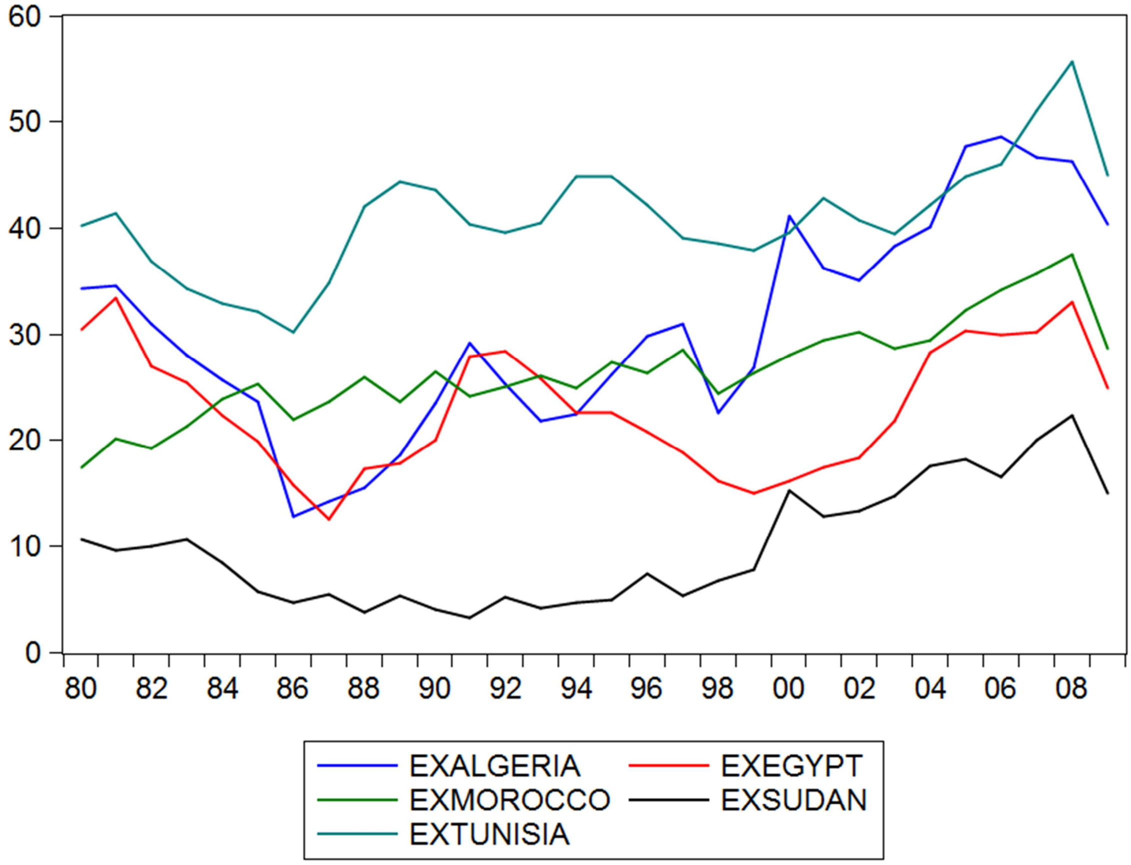

Fig 4. Exports goods and services (share of GDP)

Fig. (3-4) show the variation of imports and exports (measured as a share of GDP) in North Africa countries. Tunisia is the biggest in the exports (imports) of goods and services with 55.63% (58.67%) in 2007 while Sudan is the smallest in the exports (imports) of goods and services with 3.34% (7.07%) in 1991 (1990).

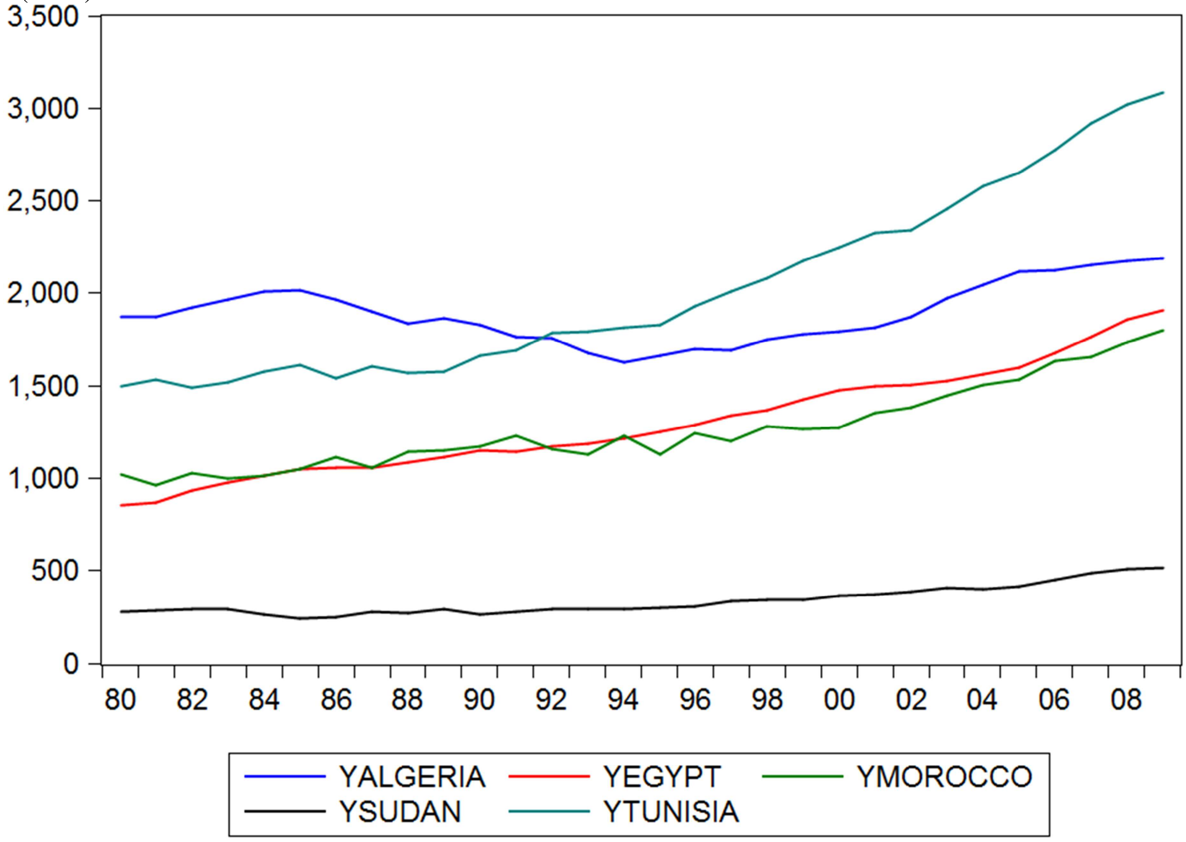

Fig 5. Real GDP per capita (constant 2000 US dollars)

Fig.5 reports the evolution of real GDP per capita (measured in constant 2000 US dollars) for each country of the region. Countries can be classified into three groups; the first one includes Tunisia and Algeria which are characterized by a higher level of GDP compared to other countries with 3083.987 US dollars and 2192.704 US dollars in 2009, respectively. These results are similar to the evolution of exports in which Tunisia and Algeria are the two both great country exporters of goods and services in comparison with other countries in the region. The second group of countries includes Egypt and Morocco and records a real GDP per capita which increases slowly during the period until to be stabilized to 1911.96 US dollars and 1797.40 US dollars in 2009, respectively. The third group includes only Sudan which is characterized by a very low and stable level of real GDP per capita during the period. This result leads to a very interesting close that is economic growth and exports move together and any changes in exports will change economic growth.

5. Empirical model and results

The relationship between energy consumption, output, and trade is modeled using a production function (see Lean and Smyth, 2010a, 2010b; Sadorsky, 2012). In fact, the model in Lean and Smyth (2010b) only includes exports as trade variable and the model in Sadorsky (2012) includes exports and imports in two different models to examine the linkages between energy consumption, output and trade. In this paper we use the model in Sadorsky (2012) to investigate the causal association between combustible renewables and waste and fossil fuels energy consumption, output and trade. Our estimated model differs from that of Sadorsky (2012) by the fact that:

- We include both combustible renewables and waste and fossil fuels energy consumption in the same specification model to determine how total energy consumption can be affected by trade openness.
- Exports and imports are measured as a share of GDP and used together in the same empirical estimated model.

The production modeling framework given below can be written as a function of capital, (K), labor, (L), energy (CRW, FF), trade openness, (O), and a country specific variable (V):

$$Y_{it} = f(CRW_{it}, FF_{it}, O_{it}, K_{it}, L_{it}, V_i) \quad (1)$$

Eq. (1) can be parameterized as follows:

$$Y_{it} = CRW_{it}^{\alpha_{1i}} FF_{it}^{\alpha_{2i}} EX_{it}^{\alpha_{3i}} IM_{it}^{\alpha_{4i}} K_{it}^{\alpha_{5i}} L_{it}^{\alpha_{6i}} V_i \quad (2)$$

The natural log of Eq. (2) denotes the lowercase letters as the natural log of uppercase and adding a random error term gives the following equation:

$$y_{it} = \alpha_{1i} crw_{it} + \alpha_{2i} ff_{it} + \alpha_{3i} ex_{it} + \alpha_{4i} im_{it} + \alpha_{5i} k_{it} + \alpha_{6i} l_{it} + v_i + \varepsilon_{it} \quad (3)$$

Where $i = 1,\ldots,N$ for each country in the panel and $t = 1,\ldots,T$ denotes the time period. (ε) and (v) denote the stochastic error term and the individual fixed country effects, respectively. Trade openness is measured using exports (ex) and imports (im).

This paper uses a panel cointegration techniques regression to investigate the relationship between energy consumption (CRW, FF), output, and trade in a sample of five economies of North Africa during the period 1980-2009. The results of panel cointegration of models estimated from cross sections of time series are more efficient and have more degrees of freedom than models estimated from individual time series.

5.1. Unit root test

To check for unit root we employ Peter C. B. Phillips and Pierre Perron (1988) test. The null hypothesis is that there is a unit root test and the alternative hypothesis is that there is no unit root. We assume that the test regressions contain an intercept and no trend. The result of this test is reported in Table 2 and indicates that the statistics significantly confirm the level values of all series are non-stationary except fossil fuels consumption is stationary at level. All variables are stationary at the 1% significance level of the first difference except labor force variable is stationary at the 5% significance level of the first difference and the null hypothesis of a unit root can be rejected.

Table 2: Panel unit root tests (Phillips and Perron, 1988)

Y		***Δy***		***crw***		***Δcrw***		***ff***		***Δff***	
Statistic	**Prob.**	**Statistic**	**Prob.**	**Statistic**	**Prob.**	**Statistic**	**Prob.**	**Statistic**	**Prob.**	**Statistic**	**Prob.**
0.39383	1.0000	81.1190	0.0000*	5.81658	0.8304	118.083	0.0000*	27.9878	0.0018*	113.719	0.0000*

Ex		***Δex***		***im***		***Δim***		***k***		***Δk***	
Statistic	**Prob.**	**Statistic**	**Prob.**	**Statistic**	**Prob.**	**Statistic**	**Prob.**	**Statistic**	**Prob.**	**Statistic**	**Prob.**
11.4408	0.3242	3.9413	0.0000*	4.9565	0.1337	6.3586	0 .0000*	.45077	0.9916	7.8397	0.0000*

L		***Δl***	
Statistic	**Prob.**	**Statistic**	**Prob.**

1.74077	0.9980	20.5956	0.0241**

Null hypothesis: Unit root.
All units root tests regressions are run with constant.
Newey-West bandwidth selection using Bartlett kernel.
"*" indicates significance at 1% level.
"**" indicates significance at 5% level.

5.2. Panel cointegration tests

To determine whether variables are cointegreted, this paper employs two kinds of panel cointegration tests, i.e. Peter Pedroni (2004) and Soren Johansen (1988). Pedroni (2004) proposes two groups of cointegrartion tests. The first is a panel group based on four statistics and includes v-statistic, rho-statistic, PP-statistic and ADF-statistic. These statistics are classified on the within-dimension and take into account common autoregressive coefficients across countries. The second group is based on three statistics and includes rho-statistic, PP-statistic, and ADF statistic. These tests are classified on the between-dimension and based on the individual autoregressive coefficients for each country in the panel. All these tests are based on the residual of Eq. (3). The null hypothesis is that there is no cointegration while the alternative hypothesis is that there is cointegration between variables.

Table 3: Pedroni panel cointegration test

Alternative hypothesis: common AR coefs. (within-dimension)		
	Statistic	**Prob.**
Panel v-Statistic	1.091035	0.1376
Panel rho-Statistic	0.962785	0.8322
Panel PP-Statistic	-1.797714	0.0361**
Panel ADF-Statistic	-2.076598	0.0189**
Alternative hypothesis: individual AR coefs. (between-dimension)		
	Statistic	**Prob.**
Group rho-Statistic	1.903548	0.9715
Group PP-Statistic	-1.171645	0.1207
Group ADF-Statistic	-1.014931	0.1551

"**" indicates statistical significance at the 5% level.
Null hypothesis: No cointegration.
Trend assumption: No Deterministic trend.
Lag selection: Automatic SIC with a max lag of 5.
Newey-West bandwidth selection with Bartlett kernel.

Table 3 reports the results of Pedroni's (2004) heterogeneous panel test which indicate that two within-dimension panel statistics indicate the existence of cointegration between variables at the 5% level.

Table 4: Johansen (1988) cointegration test

Hypothesized No. of CE(s)	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stat.* (from max-eigen test)**	**Prob.**
None	208.7**	0.0000	116.4**	0.0000
At most 1	128.2**	0.0000	58.42**	0.0000
At most 2	79.83**	0.0000	51.21**	0.0000
At most 3	37.13**	0.0001	20.21**	0.0273
At most 4	24.34**	0.0067	11.63	0.3103
At most 5	21.49**	0.0179	17.22	0.0696

At most 6	18.29	0.0502	18.29	0.0502

"**" indicates statistical significance at the 5% level.
Linear deterministic trend.
Lag selection: Automatic SIC with a max lag of 5.
* Probabilities are computed using asymptotic Chi-square distribution.

Table 4 reports Johansen (1988) residual cointegration test results. Based on Fisher statistic, the Johansen (1988) test is established on two different approaches. The likelihood ratios trace statistics and the maximum eigenvalue value. These tests are based on the aggregates of the p-values of the individual statistics. If p_i is the p-value from an individual cointegration test for cross-sections i, then under the null hypothesis the test statistic for the panel is given by:

$$-2\sum_{i=1}^{N}\log(p_i) \sim \chi^2_{2N}$$

Where the χ^2 value is based on the James G. Mackinnon, Alfred A. Haug, and Leo Michelis (1999).

The results from Johansen (1988) cointegration test indicate the existence of long-run equilibrium relationship between variables at the 5% level.

5.3. Granger causality test

Given the presence of cointegration between variables, then we can apply the approach of Robert F. Engle and Clive William John Granger (1987) to investigate the long-run and the short-run dynamic relationship. The presence of cointegration between a set of variables means that there exists causality between them. A panel vector error correction model is estimated to infer the causal dynamics on two-step procedure. The first is to estimate the long-run model specified in Eq. (3) to get the estimated residuals. The second is to define the lagged residuals estimated as the error correction term (*ect*) in the estimation of the vector error correction model as follows:

$$\Delta y_{it} = \delta_{1i} + \sum_{j=1}^{q}\delta_{1,1ij}\Delta y_{it-j} + \sum_{j=1}^{q}\delta_{1,2ij}\Delta crw_{it-j} + \sum_{j=1}^{q}\delta_{1,3ij}\Delta ff_{it-j} + \sum_{j=1}^{q}\delta_{1,4ij}\Delta ex_{it-j} + \sum_{j=1}^{q}\delta_{1,5ij}\Delta im_{it-j}$$

$$+\sum_{j=1}^{q}\delta_{1,6ij}\Delta k_{it-j} + \sum_{j=1}^{q}\delta_{1,7ij}\Delta l_{it-j} + \theta_{1,i}ect_{it-1} + \omega_{1it} \tag{5a}$$

$$\Delta crw_{it} = \delta_{2i} + \sum_{j=1}^{q}\delta_{2,1ij}\Delta y_{it-j} + \sum_{j=1}^{q}\delta_{2,2ij}\Delta crw_{it-j} + \sum_{j=1}^{q}\delta_{2,3ij}\Delta ff_{it-j} + \sum_{j=1}^{q}\delta_{2,4ij}\Delta ex_{it-j} + \sum_{j=1}^{q}\delta_{2,5ij}\Delta im_{it-j}$$

$$+\sum_{j=1}^{q}\delta_{2,6ij}\Delta k_{it-j} + \sum_{j=1}^{q}\delta_{2,7ij}\Delta l_{it-j} + \theta_{2,i}ect_{it-1} + \omega_{2it} \tag{5b}$$

$$\Delta ff_{it} = \delta_{3i} + \sum_{j=1}^{q}\delta_{3,1ij}\Delta y_{it-j} + \sum_{j=1}^{q}\delta_{3,2ij}\Delta crw_{it-j} + \sum_{j=1}^{q}\delta_{3,3ij}\Delta ff_{it-j} + \sum_{j=1}^{q}\delta_{3,4ij}\Delta ex_{it-j} + \sum_{j=1}^{q}\delta_{3,5ij}\Delta im_{it-j}$$

$$+\sum_{j=1}^{q}\delta_{3,6ij}\Delta k_{it-j} + \sum_{j=1}^{q}\delta_{3,7ij}\Delta l_{it-j} + \theta_{3,i}ect_{it-1} + \omega_{3it} \tag{5c}$$

$$\Delta ex_{it} = \delta_{4i} + \sum_{j=1}^{q}\delta_{4,1ij}\Delta y_{it-j} + \sum_{j=1}^{q}\delta_{4,2ij}\Delta crw_{it-j} + \sum_{j=1}^{q}\delta_{4,3ij}\Delta ff_{it-j} + \sum_{j=1}^{q}\delta_{4,4ij}\Delta ex_{it-j} + \sum_{j=1}^{q}\delta_{4,5ij}\Delta im_{it-j}$$

$$+\sum_{j=1}^{q}\delta_{4,6ik}\Delta k_{it-j}+\sum_{j=1}^{q}\delta_{4,5ij}\Delta o_{it-j}+\theta_{4,i}ect_{it-1}+\omega_{4it} \tag{5d}$$

$$\Delta im_{it}=\delta_{5i}+\sum_{j=1}^{q}\delta_{5,1ij}\Delta y_{it-j}+\sum_{j=1}^{q}\delta_{5,2ij}\Delta crw_{it-j}+\sum_{j=1}^{q}\delta_{5,3ij}\Delta ff_{it-j}+\sum_{j=1}^{q}\delta_{5,4ij}\Delta ex_{it-j}+\sum_{j=1}^{q}\delta_{5,5ij}\Delta im_{it-j}$$

$$+\sum_{j=1}^{q}\delta_{5,6ik}\Delta k_{it-j}+\sum_{j=1}^{q}\delta_{5,7ij}\Delta l_{it-j}+\theta_{5,i}ect_{it-1}+\omega_{5it} \tag{5e}$$

$$\Delta k_{it}=\delta_{6i}+\sum_{j=1}^{q}\delta_{6,1ij}\Delta y_{it-j}+\sum_{j=1}^{q}\delta_{6,2ij}\Delta crw_{it-j}+\sum_{j=1}^{q}\delta_{6,3ij}\Delta ff_{it-j}+\sum_{j=1}^{q}\delta_{6,4ij}\Delta ex_{it-j}+\sum_{j=1}^{q}\delta_{6,5ij}\Delta im_{it-j}$$

$$+\sum_{j=1}^{q}\delta_{6,6ik}\Delta k_{it-j}+\sum_{j=1}^{q}\delta_{6,7ij}\Delta l_{it-j}+\theta_{6,i}ect_{it-1}+\omega_{6it} \tag{5f}$$

$$\Delta l_{it}=\delta_{7i}+\sum_{j=1}^{q}\delta_{7,1ij}\Delta y_{it-j}+\sum_{j=1}^{q}\delta_{7,2ij}\Delta rec_{it-j}+\sum_{j=1}^{q}\delta_{7,3ij}\Delta nrec_{it-j}+\sum_{j=1}^{q}\delta_{7,4ij}\Delta ex_{it-j}+\sum_{j=1}^{q}\delta_{7,5ij}\Delta im_{it-j}$$

$$+\sum_{j=1}^{q}\delta_{7,6ik}\Delta k_{it-j}+\sum_{j=1}^{q}\delta_{7,7ij}\Delta l_{it-j}+\theta_{7,i}ect_{it-1}+\omega_{7it} \tag{5g}$$

$$ect_{it}=y_{it}-\hat{\alpha}_{1i}crw_{it}-\hat{\alpha}_{2i}ff_{it}-\hat{\alpha}_{3i}ex_{it}-\hat{\alpha}_{4i}im_{it}-\hat{\alpha}_{5i}k_{it}-\hat{\alpha}_{6i}l_{it} \tag{6}$$

where Δ is the first difference operator; q denotes the lag length determined automatically by the Schwarz Information Criterion (SIC); ω is a random error term. (*ect*) is the error correction terms derived from the long-run cointegration relationship of Eq. (3). The significance of the error correction term and the short-run dynamics can be tested using the t-statistic tests and Granger causality F-statistic tests, respectively.

Table 5 reports the results of the short-run and the long-run causality tests. With respect to Eq. (5d) we show that, in the short-run association, exports have positive and significant impacts on imports and capital at 1% and 10% levels of significance, respectively. From the other equations we show that at the 10% level of significance there is some evidence of a short-run causality. Output Granger causes imports (Eq.(5a)), fossil fuels consumption Granger causes exports (Eq.(5c)), exports Granger causes imports and capita (Eq.(5c)), capital Granger causes imports (Eq.(5e)), and labor force Granger causes combustible renewables and waste consumption (Eq.(5g)).

The error correction term is negative statistically significant for output, combustible renewables and waste consumption, and imports equations (Eq.(5a), Eq.(5b), and Eq.(5e)). This result indicates that long-run adjustment to equilibrium is important in explaining short-run movements in output, combustible renewables and waste energy consumption, and imports.

Table 5: Panel causality test results

Dependent variable	**Sources of causation (independent variables)**							
	Short-run							**Long-run**
	Δy	***Δcrw***	***Δff***	***Δex***	***Δim***	***Δk***	***Δl***	**ECT**
Δy	-	0.06924 (0.9331)	0.26842 (0.7650)	0.81101 (0.4464)	2.56174 (0.0807)[c]	0.40838 (0.6655)	0.08959 (0.9144)	-0.077726 [-2.26940][b]

Δcrw	0.55827	-	0.05736	0.05004	0.08346	0.07270	0.02856	-0.094207
	(0.5734)		(0.9443)	(0.9512)	(0.9200)	(0.9299)	(0.9719)	[-2.22685][b]
Δff	0.41231	0.11522	-	2.96527	2.30103	0.48226	0.05786	0.025190
	(0.6629)	(0.8913)		(0.0547)[c]	(0.1039)	(0.6184)	(0.9438)	[2.59837]
Δex	1.11091	0.46810	0.35395	-	5.80107	2.80126	1.75860	0.067083
	(0.3321)	(0.6271)	(0.7025)		(0.0038)[a]	(0.0641)[c]	(0.1760)	[1.49782]
Δim	0.34407	0.24951	1.33580	0.92071	-	1.32345	1.76783	-0.664797
	(0.7095)	(0.7795)	(0.2662)	(0.4006)		(0.2695)	(0.1744)	[-5.00923][a]
Δk	0.07342	0.24126	0.30112	0.26240	2.51826	-	0.00623	0.256383
	(0.9292)	(0.7860)	(0.7405)	(0.7696)	(0.0842)[c]		(0.9938)	[2.19715]
Δl	1.21189	2.99718	0.64642	0.08855	0.66119	0.38307	-	0.004980
	(0.3007)	(0.0531)[c]	(0.5254)	(0.9153)	(0.5178)	(0.6825)		[0.23851]

"a" indicates statistical significance at the 1% level.
"b" indicates statistical significance at the 5% level.
"c" indicates statistical significance at the 10% level.
P-value listed in parentheses and t-statistic listed in brackets.

On the other side, short-run Granger causality test results indicate that there is no evidence of a statistically significant relationship between output and energy consumption (CRW, FF) and between output and trade. In the long-run, there is evidence of causal relationship running from energy consumption and exports to imports, and a feedback relationship between output and CRW consumption which indicate that any reduction in the consumption of CRW leads to a reduction in economic growth. Sadorsky(2012) finds the same results with energy consumption. He showed that in the short-run there is no evidence of a statistically significant relationship between output and energy consumption while there is evidence of an indirect effect between trade (through exports) and output, and a feedback relationship between output and energy in the long-run.

5.4. Panel long-run estimates

Pedroni (2001, 2004) proposed more efficient estimation approaches than the OLS which takes into account the cointegrating vectors such as fully modified OLS (FMOLS) and dynamic OLS (DOLS) is one of the approaches of panel estimation improved by Chihwa Kao and Min-Hsien Chiang (2001) then by Nelson C. Mark and Donggyu Sul (2003). The long-run structural coefficients are estimated using OLS, FMOLS, and DOLS panel approaches and all results are reported in table 6.

Table.6: panel long-run elasticities (*y, crw, ff, ex, im, k,* and *l*)

Variables	*crw*	*ff*	*ex*	*im*	*k*	*l*
OLS	0.009682	0.206406*	0.153320**	-0.311865**	0.561459*	0.248250***
FMOLS	1.224559	1.560861	1.011944	-2.506972**	6.697702*	0.435965
DOLS	0.009682	0.206406***	0.153320	-0.311865***	0.561459*	0.248250

"*" indicates statistical significance at the 1% level.
"**" indicates statistical significance at the 5% level.
"***" indicates statistical significance at the 10% level.

The results from the OLS panel long-run elasticities show that all explanatory variables are statistically significant and affect economic growth except CRW consumption variable. FF consumption and capital are positive and statistically significant at the 1% level. Exports (resp. imports) are positive (resp. negative) and statistically significant at the 5% level. Labor positively affects economic growth at 10% level of significance. A 1% increase in FF increases output by 0.20%. A 1% increase in exports (resp. imports) increases (resp. decreases) output by 0.15% (resp. 0.31%). The FMOLS test results suggest that a 1% increase in capital increases output by 6.69% while a 1% increase in imports decreases output by -2.50%. For the DOLS results, a 1% increase in capital (FF consumption) increases output by 0.56% (0.20%) while a 1% increase in imports decreases output by 0.31%.

6. Conclusion and implications

Following the methodology of Lean and Smyth (2010a, 2010b) and Sadorsky (2012), our paper try to investigate the dynamic relationship between energy consumption (CRW, FF), output, and trade (exports and imports) for a panel of North Africa economies during the period 1980-2009. The specific estimation model of our study is the same as that developed by Sadorsky (2012) while in our model we include exports and imports in one function production.

We start our analysis by verifying the stationarity of each variable by using Phillips and Perron (1988) test. After checking that all variables are integrated of order 1, (I(1)), we employ Pedroni (2004) and Johansen (1988) panel cointegration tests to provide whether variables are cointegrated. The rest of our empirical analysis is devoted to investigate the short-run and the long-run dynamic relationship by employing Engle and Granger (1987) test and to estimate the long-run elasticities for the panel.

The Granger causality test indicates that there is evidence of one way short-run relationship from output to import, FF energy consumption to exports, exports to imports and capital, capital to imports, and labor to CRW energy consumption. There is no evidence of a short-run relationship between energy (CRW, FF) and output. In the long-run there is evidence of a feedback relationship between CRW consumption and output. This means that reductions in CRW consumption will reduce economic growth. In the long-run there is evidence of causal relationship running from energy consumption (CRW, FF) and exports to imports. This means that any changes in energy consumption and exports will changes imports.

Long-run output elasticities show that CRW consumption is not significant but FF energy consumption is positive and statistically significant at the 1% and 10% levels from OLS and DOLS, respectively. FMOLS long-run elasticities show that a 1% increase in imports decreases output by 2.5%. Long-run elasticities calculated from OLS show that a 1% increase in exports increases output by 0.15% while a 1% increase in imports decreases output by 0.31%. The policy implication of these results is that, in these countries, trade openness is not sufficiently efficient to incite the use of energies for production.

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