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Abstract

This paper investigates the existence of an environmental Kuznets curve (EKC) and its robustness for 28 countries of the Union for the Mediterranean (UfM) over the recent period. Our methodology relies on four recent estimation methods for non-stationary panel data and includes four pollutants (two global and two local). Two main results emerge from our analysis. First, the EKC does not hold for most pollutants, and its validity crucially depends on the estimation techniques considered. Second, the Pooled-Mean Group method is the most favourable one and confirms the existence of an inverted U-shaped relationship for CO_2 and SO_2. Our results provide beneficial information for decision-makers. They suggest implementing proactive instruments based on both flexible regulations and tax incentives to stimulate ecological transition.

JEL-Codes: O440, Q530, R580.

Keywords: environmental Kuznets curve, pollution, regional integration, The Union for the Mediterranean.

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1. Introduction

The period of crisis that we are currently experiencing has a systemic nature and, at the same time, economic, social as well as ecological roots, which requires operational and global solutions. Nowadays, it is generally admitted that the increase in pollutant emissions entails a rise of temperatures, which leads to an increase in the number of ecological disasters, and to a significant deterioration of the environmental situation. If nothing is done to reverse this trend, climate change could cost the global economy up to $ 550 billion (Stern, 2006). There is a certain consensus on the urgent need to implement sustainable development strategies that could reconcile economic growth, environmental preservation, reduction of inequalities, and improvement of social welfare (Oswald and Stern, 2019; Tiba and Belaïd, 2020, 2021; Omri and Belaïd, 2020). This observation has led countries to organize several international conferences and summits (Stockholm, 1972, Rio, 1992, Kyoto protocol, 1997, Johannesburg, 2002, Paris climate agreement, 2015, COP24, 2018).

Because of their ecological fragility, countries of the Union for the Mediterranean (UfM) are particularly vulnerable to climate change (MedECC, 2019). This observation is corroborated by the IPCC reports and the recent studies identifying the impact of temperature increases by 2021[1] . These impacts are stimulated by the combination of several factors, namely biodiversity degradation, climate modification, land use, and increased pollution.

In this context, the purpose of this paper is to examine the relationship between economic growth and environmental quality over the 1970-2020 period. Further it aims to empirically investigate the existence of an environmental Kuznets curve (EKC) for UfM countries, as well as to assess to what extent these countries can work together for the Mediterranean depollution. According to the EKC hypothesis (*e.g.,* the pioneering work of Grossman and Krueger, 1991 and 1994), there would be an inverted U-shaped relationship between environmental degradation and growth. Specifically, at first, when wealth increases with economic growth, environmental degradation also increases. Then, an environmental improvement would be observed from a certain level of wealth (turning point). Our empirical methodology relies on recent developments in the econometrics of non-stationary panel data[2], which permit to account for possible cross-sectional dependence between countries. To model the short-run and long-

[1] Mediterranean Experts on Climate and Environmental Change (MedECC): https://www.medecc.org/

[2] For comparison purpose, we use the estimators of the Mean Group (MG) of Pesaran and Smith (1995), those of the augmented mean group (AMG) of Eberhardt and Teal (2010), and those of the correlated common effects mean group (CCEMG) of Pesaran (2006).

run relationships between GDP per capita and pollutant emissions, we use the Pooled-Mean Group (PMG) estimator of Pesaran, Shin, and Smith (1999) based on the estimation of an Autoregressive Distributed Lag (ARDL) model.

This study makes several contributions to the existing literature. First, even though there exist a very literature on the analysis of the environmental Kuznets curve, the literature focusing on the states bordering the Mediterranean Sea is less voluminous. Indeed, most studies focus either on the countries of the Organization for Economic Co-operation and Development (OECD), which does not include countries of the southern shore of the Mediterranean, or on countries of the Middle East and North Africa (MENA), which excludes the integration of countries on the northern shore of the Mediterranean (Belaïd and Youssef, 2017; Belaïd and Zrelli, 2019). Thus, the choice of UfM is far from being arbitrary but rather a well-considered decision. This intergovernmental organization brings together countries with a long history of mutual exchanges and represents the continuity of the Barcelona process initiated in 1995. It constitutes the first circle bringing together the two Mediterranean shores and guaranteeing the dialogue strengthening of cooperation between them, as well as an increasing North-South and South-South integration in the Mediterranean region. Among the chapters on which this cooperation relates, the creation of a free trade area occupies a very important place, as well as the development of cooperation networks and platforms for the environmental clean-up of the Mediterranean.

Second, the unique context of this study makes our specific empirical framework very attractive. Indeed, this paper makes a methodologically rigorous contribution to a small but growing literature related to the examination of the validity of the environmental Kuznets curve in the Mediterranean basin, a region that is suffering the full brunt of global warming. Our empirical results could provide a vehicle for strategic information regarding adaptation policy choices in the Mediterranean basin. Indeed, the accumulation of scientific knowledge would make it possible to understand better the risks involved. In this sense, it is crucial to understand the interactions between economic growth and environmental quality in this region involved in guiding effective public policy actions to control the impact of economic activity on the environment.

The Union for the Mediterranean created in 2008 during the Paris summit, is an intergovernmental institution bringing together 42 countries[3] (15 countries spread across North Africa, the Middle East, and Southern East Europe as well as 28 E.U. States, see Appendix A1) and aims to strengthen the cooperation between them. It ensures the implementation of priority strategies such as solar plans development, higher education, and scientific research quality improvement, as well as civil protection. Moreover, as a process of regional integration, the UfM must set up innovative projects that respond to ecological, economic, and human challenges. In this context, the fight against the primary sources of pollution in the Mediterranean is also one of the most critical chapters carried by this cooperation. In addition, since 2010, one year after the creation of the European Investment Bank (EIB), the main financial partner of the Mediterranean area, several projects for the depollution and development of renewable energies of general interest, focusing on six sectors[4] have emerged (*e.g.,* the Tafila Wind Farm wind parc in 2015, MedCoast4BG in 2017, Clima-Med in 2019, EuroMed in 2022). Even if the energy mix in the UfM zone remains dominated by the consumption of fossil fuels, investment in this type of project underlines the importance of clean and renewable energies development. In addition, the rate of renewable energies consumption in the UfM zone, even if it does not have a significant break. It has constantly been increasing since 1990, is considered low and modest. Indeed, renewable energies represent 17.08% of final energy consumption in the UfM zone, around 7.33% more than in 1990 (9.74%) (See appendix A2). It should be noted that these 42 countries are among the 195 signatory states of the Paris climate agreement in 205.

To our knowledge, this is the first recent study on the relationship between economic growth and environmental degradation especially in the UfM (including such a large set of global (2) and local (2) pollutants) and relying on recent methods of non-stationary panels[5]. In addition, we provide helpful insight to decision-makers to guide them in setting the objectives of pollution control policies.

The rest of this paper is organized as follows. The second section provides a brief literature review of the relationship between economic growth and environment based on the EKC

[3] The UfM initially included 44 countries before Syria suspended its participation on November 30, 2011, due to EU sanctions. Libya has the observer status at the UfM.

[4] Business development, improvement of the quality of higher education and scientific research, civil and social affairs, transport and urban development, energy and action for the climate and water and environment.

[5] The only econometric study testing for the EKC hypothesis in the UfM region is that of Sebri (2009), which analyses the trajectory of CO_2 according to per capita income over the 1980-2005 period. Using three different models (linear, log-linear, and semi-log-linear), he confirms the EKC hypothesis for UfM countries.

hypothesis. The third section is devoted to the econometric specification (model and data). In the fourth section, we report and discuss the results of our short-and long-run estimates for the four pollutants in UfM countries. Finally, the fifth section concludes the analysis and provides some economic policy recommendations.

2. Literature review

Given the existence of ambitious policy goals to reduce the impact of climate change, understanding the dynamic links between economic growth and sustainability is a challenge for researchers and policymakers. Indeed, the difficulty of assessing the lasting state of a country or a region is exacerbated by the absence of a clear and generalizable relationship between economic growth and sustainability (Mongo *et al., 2021a, b*). In this context, the apparent contradiction between economic progress and natural resources preservation has led economists to consider economic development and sustainability in the context of environmental issues. These initiatives gave rise to the environmental Kuznets curve (EKC) hypothesis. It is based on the empirical finding that economic growth is associated with an increasing environmental degradation up to a certain threshold beyond which environmental quality begins to improve (*e.g.,* Grossman and Krueger, 1991, and 1994).

Since this pioneering work, abundant literature related to the existence of an EKC hypothesis and its validation using different econometric methods has emerged in the context of various pollutants. This literature can be divided into two categories (Almulali *et al.*, 2015; 2016): the former deals with the relationship between economic growth and pollution country by country, and the latter examines this relationship for a panel of countries. In this section, we only consider the latter. In addition, within this category, it is possible to distinguish between works with results for the sample of countries considered as a whole (1st sub-category) and those providing specific results for each country within the panel (2nd sub-category). We summarize below these two sub-categories successively.

Within the 1st sub-category, Hassan and Salim (2015) consider the correlation between the rate of elderly people, the increase of income, and CO_2 emissions for 25 OECD countries over the 1980-2010 period. They find that the elderly population negatively affects per capita carbon dioxide emissions in the long run, the EKC being verified with a turning point of $24,675. To test for the validity of the EKC, Kasman, and Duman (2015) refer to 15 E.U.

countries[6] over the 1992-2010 period. They use Pedroni's (1999) and Westerlund's (2008) cointegration tests to show that the EKC is verified after integrating urbanization and trade openness as control variables. Apergis and Ozturk (2015) conclude that the EKC is valid using the generalized method of moments for 4 Asian countries during the 1990-2011 period. The effect of corruption on EKC has also been analysed by Mendes and Junio (2012).

Within the framework of cooperation between the two shores of the Mediterranean, Sebri (2009) analyses the trajectory of CO_2 as a function of income per capita over the 1980-2005 period. Using three different models (linear, log-linear, and semi-log-linear), he confirms the EKC hypothesis for the three groups considered: E.U., MEDA, and UfM. Pao and Tsai (2011) examine the impact of economic growth and financial development on environmental degradation. They implement panel Granger non-causality tests for four countries (Brazil, Russia, India, and China) over the 1980-2007 period. Their investigation validates the existence of an inverted U-shape (except for Russia). It reveals the presence of a robust bidirectional causality between CO_2 emissions and FDI, which confirms the pollution haven hypothesis.

The 2nd sub-category of studies provides specific results for each country within the panel. Shahbaz *et al.* (2015a) explore the relationship between the use of coal, industrial production, and CO_2 emissions for India and China over the 1971-2011 period. They show that the EKC is only confirmed for India. Shahbaz *et al.* (2015b) use Pedroni's cointegration tests and Johansen's analyses of the relationship between economic growth and energy intensity for 12 African countries over the 1998-2012 period. The inverted "U" shape is confirmed only for South Africa, the Republic of Congo, Ethiopia, and Togo.

Al-Mulali and Ozturk (2016) examine the existence of the environmental Kuznets curve hypothesis and the effect of energy prices on pollution in 27 advanced economies over the 1990–2012 period. The inverted U-shaped relationship between GDP and CO2 emissions is empirically confirmed which provides evidence of the EKC hypothesis. Besides, panel cointegration test reveal that CO2 emissions, economic growth, renewable non-renewable energy consumption, trade openness, urbanization, and energy prices are cointegrated.

Atasoy (2017) tests for the EKC over the 1960-2010 period for 50 American states, using two estimators considering possible cross-sectional dependence (the AMGs, and the

[6] Countries are Bulgaria, Croatia, Estonia, Hungary, Iceland, Latvia, Lithuania, Macedonia, Malta, Romania, Slovak Republic, Czech Republic, Romania, Slovenia, and Turkey.

PMGs). He concludes that the EKC is validated for 30 States based on the AMG estimator, with turning points varying between $ 1,292 and $ 48,597. In contrast, with CCEMG estimators, this is only verified for ten states, with turning points between $ 2,457 and $ 14,603. Katsuya (2017) implemented PMGs and GMMs for 42 developed countries over the 2002-2011 period to test for the existence of a long-term relationship between economic growth, CO_2 emissions, renewable energy, and fossil consumption. The results indicate that fossil energy has a negative impact on economic growth in the long-run and that renewable energy contributes positively to economic growth.

By adopting an ARDL approach for China, Sun *et al.* (2017) examine the impact of FDI, economic growth, energy consumption, urbanization, financial development, and trade openness on CO_2 emissions over the 1980-2012 period. Their analysis confirms the validity of the pollution haven hypothesis and concludes that the positive effect of FDI comes mainly from manufacturing industry, mining, and electricity transferred from developed countries. Solarin *et al.* (2017) use several determinants of pollution for Ghana over the 1980-2012period. Their analysis based on the ARDL approach reveals the existence of a long-term relationship between economic series, with a positive impact of FDI on CO_2 emissions, which confirms the validity of the pollution haven hypothesis.

Seyfettin *et al.* (2019) explore the causality nexus between CO2 economic growth in BRICS-T countries (Brazil, Russia, India, China, South Africa, and Turkey) during the 1992-2016 period. Using various panel cointegration techniques they found that economic growth and carbon emissions are cointegrated, and the existence of a bi-directional causal relationship between them. Their results confirm the existence of macroeconomic and social costs associated with a feedback relationship between growth and pollution.

To, conclude, at the end of this brief review of the literature, it appears that the existing empirical results concerning the validity of the EKC are mixed and depend on the countries considered and, on the period, analysed. Therefore, the primary purpose of this paper is to provide new empirical evidence in the context of Union for the Mediterranean (UfM) countries.

3. Econometric specification

3.1 Empirical model

In applied works, the environmental Kuznets curve (EKC) is generally tested by estimating the following equation:

$$\text{POL}=\alpha_0+\alpha_1 GDP+\alpha_2 GDP^2+\alpha_3 X+\varepsilon_{i,t} \qquad \textbf{(1)}$$

, where:

- POL measures environmental degradation, including degradation of land quality, deforestation and water quality or air pollution.
- X denotes control variables that can affect environment quality (*e.g.*, energy consumption, population density, commercial openness, governance indicators, or the number of companies certified ISO14001).
- GDP and GDP^2 are respectively per capita income and its quadratic form.

The existence of a relationship having an inverted U form (EKC assumption) holds if $\alpha_1 > 0, \alpha_2 < 0$.

In what follows, we consider the following equation:

$$ENVI_{it} = \lambda_i d_t + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ENERG_{it} + \beta_4 OP\_TRA_{it} + \beta_5 DPOP_{it} + \beta_6 FDI_{it} + u_{it} \qquad \textbf{(2)}$$

$$u_{it}=\theta_i f_t+\varepsilon_{it} \quad ; \ i=1........N, t=1........T$$

, where **ENVI** denotes different variables contributing to environmental degradation, one per specification (see subsection **3.2), GDP** is the gross domestic product expressed in constant 2015 dollars, **ENERG** is the energy consumption per capita, expressed in kg of oil equivalent per capita, **OP_TRA** denotes trade openness, measured by the ratio [(export + import) / GDP], **DPOP** is the population density (number of people per square kilometre of land area)[7], and **FDI** are investment flows, direct foreign input consumption, expressed in millions of U.S. dollars at

[7] Additional estimations including a larger number of control variables (such as Kaufman's governance indicators, urbanization, education, energy intensity, electricity consumption, agriculture (% of GDP), industry (% of GDP)) were also carried out without fundamentally changing the results. Therefore, not to overload tables, we limit ourselves thereafter to these four control variables.

current prices[8]. In equation (2) d_t denotes the observed common effect, the error term u_t combining a common unobservable factor (f_t) and an idiosyncratic error term (ε_{it}). All variables are expressed in natural logarithm[9].

Our sample includes 28 developed and developing countries[10] belonging to the UfM zone and covers the 1970-2020 period (balanced panel). The econometric methodology relies on recent developments in the econometrics of non-stationary panels. First, we test the null hypothesis of cross-sectional independence between countries using the CD and L.M. * statistics of Pesaran (2004). Second, since this hypothesis turns out to be rejected by data, we test for the potential stochastic non-stationarity of the variables introduced in our econometric specifications using Pesaran's second-generation panel unit root test (2007), which accounts for cross-sectional dependence between countries. Third, we test for the existence of a cointegrating relationship between variables using the second-generation panel cointegration test of Westerlund (2008). Finally, to compare the results, we estimate the parameters of the cointegration vectors using different versions of the Autoregressive Distributed Lag (ARDL) model: Mean Group (M.G.) of Pesaran and Smith (1995), Augmented Mean Group (AMG) of Eberhardt and Bond (2009), and Eberhardt and Teal (2010), Common Correlated Effects Mean Group (CCEMG) of Pesaran (2006), and of Kapetanios *et al.* (2011), and Pooled Mean Group (PMG) of Pesaran, Shin and Smith (1999).

The choice of the ARDL approach is motivated by several reasons. First, it has the advantage of providing valid results in small and large samples, even though variables are integrated of different orders (I (0), I (1)), and/or cointegrated. This contrasts with the classical time series approaches, for instance, Johansen (1995), which requires all variables to be integrated of order 1 to test for the existence of a long-term cointegration relation between them.

Second, unlike traditional panel methods, the ARDL approach permits to obtain simultaneously estimates of short and long-run parameters, and accounts for possible heterogeneity between countries and common macroeconomic shocks. In addition, the PMG estimator of Pesaran, Shin, and Smith (1999) is robust to outliers and the choice of the number

[8] The GDP, ENERG, DPOP OP_TRA variables come from the World Bank database. FDI is taken from the database of the United Nations Conference on Trade and Development (UNCTAD).

[9] Note that the increase in temperatures is not directly considered in the estimated equation and could be a common factor modifying the impact of growth on pollution. The main reason is that we do not have data on the evolution of temperatures. In addition, it is likely that given our relatively short time series analysis, the temperature evolution is not important enough to significantly impact this relationship. However, this aspect is considered indirectly by introducing temporal effects in the econometric specification.

[10] Some UfM countries had to be eliminated from the sample during estimations due to the unavailability of data and geopolitical wars in some regions which suspended their membership, or if countries have had the observer status. See Appendix A1 for the list of selected countries.

of lags. The M.G. estimator of Pesaran and Smith (1995) is calculated as the unweighted mean of the coefficients obtained from individual regressions. It allows the variability of the short-run and long-run coefficients. The PMG estimator imposes a constraint of equality of long-run coefficients but allows short-run parameters to differ across countries, which is the main difference between the M.G. and PMG estimators [see Appendix A4 for further details].

3.2 A brief overview of the environmental indicators used and of their effects

Pollution is essentially linked to the emission of products being a danger and nuisance for the soil quality, water bodies as well as air quality. There exist different types of pollution (atmospheric, biological, or chemical (hydrocarbons, carbon monoxide, and nitrogen oxide), physical (heat, noise, and radioactivity)). Nowadays, special attention is paid to air pollution since it is responsible for severe environmental problems.

This paper successfully considers the four pollutants below **(ENVI** variable in equation 2), which measure greenhouse gas (GHG) and atmospheric pollution.

Table 1. Environmental degradation variables and their sources

pollutants (ENVI)	measuring units	Source
CO_2	Expressed in metric tons per capita	**WDI***
CH_4	Expressed in metric tons per capita	**EDGAR****
SO_2 **PM10**	Expressed in giga grams and converted to metric tons per capita[11]	

Notes: *: World Development Indicators; **: Emissions Database for Global Atmospheric Research.

In Table 1, we can distinguish between global pollutants (2), and local pollutants (2).

- **Global pollutants**

*__Carbon dioxide (CO_2):__ this is the main greenhouse gas. It comes mainly from burning fossil fuels (coal, oil, and gas) and the overexploitation of land (agriculture and deforestation). It results primarily from the acceleration of industrial activities, the combustion of fuels in transportation and housing by lighting, air conditioning, and energies used for heating. According to statistics from the Intergovernmental Panel on Climate Change (IPCC), the air contains almost 0.04% of carbon dioxide, but if the concentrations of this gas increased, the consequences would undoubtedly be serious on health and cause premature mortality. Climate

[11] For CH4, SO2 and PM10 we have converted the giga gram to metric ton (1 giga gram = 1000 metric tons) and we have divided by the number of inhabitants for each year, to have the results expressed in metric tons per capita, as for carbon dioxide emissions (CO2).

scientists point out that if the concentration of CO_2 in the air increased to 3%, there would be an increase in respiration amplitude. At 15% concentration, visual disturbances and tremors may occur with loss of consciousness. At 25% concentration, there would be an increase in the number of deaths following respiratory arrest.

***Methane (CH_4):** CH_4 is a potent greenhouse gas that contributes to global warming. It has an impact on the greenhouse effect 25 times higher than carbon dioxide. Methane is primarily made by bacteria that live in oxygen-free wetlands such as ocean sediments in basements. Nowadays, the increase in CH_4 emission levels is explained by the release of a large amount of CH_4 which has been trapped in the arctic basements following the acceleration of glaciers melting with the temperature rise. The increase in CH_4 emissions can also be explained by the increase in livestock, intensive farming, and the use of fossil fuels.

The two global pollutants above are the leading greenhouse gases of natural origin. Note that there are other types which are produced only by human activities, such as chlorofluorocarbons (CFC_s), and sulfur hexafluoride (S_6F_6).

- **Local pollutants**

* **Sulfur dioxide (SO_2):** is produced by the combustion of sulfur contained in coal, fuel oil, and gas oil. Under the rainwater effect, it produces sulphuric acid, which turns into acidic rain, acidifying lakes and attacking building stones when they are calcareous.

* **Particles or Soot (PM10 or PM2.5):** they come from the combustion of all fossil fuels and biomass. Diesel engines produce a lot of them in a black smoke form that escapes from cars and old trucks. Particles with a diameter less than 10 microns are referred to as PM10, and those with a diameter of fewer than 2.5 microns are referred to as PM2.5. These layers of black smoke prevent breathing and block the progress of the photosynthesis process.

4. Empirical results

4.1 Cross-sectional dependence test

Cross-sectional dependence is an essential element in panel data econometrics. Failure to take it into account can lead to several problems, including size distortion of unit root tests (O'Connell, 1998). Indeed, several factors, such as spatial interactions, the effects of omitted variables, or the possibility of interactions between socioeconomic variables, can be at the origin of this dependence (*e.g.*, Chudik and Pesaran, 2013).

The existence of cross-sectional dependence is examined here with the test of Pesaran (2004) using the CD statistic, and with that of Pesaran *et al.* (2008), via the L.M. statistic (which is a corrected version of the CD statistic). The null hypothesis is the absence of cross-sectional dependence between countries, and under H_0, these two statistics asymptotically follow a normal distribution.

Table 2 summarizes the results of the test for our 28 UfM countries. It appears that the null of cross-sectional independence between countries is firmly rejected by data, regardless of the pollutant considered.

Table 2. Cross-sectional Dependence Test Results for four pollutants

	CO_2	**CH_4**	**SO_2**	**PM10**
CD Test	11.344***	28.914***	62.971***	14.989***
Bias Adjusted LM Test	277.918***	244.226***	347.278***	298.133***

Notes: *, ** and *** indicate statistical significance at respectively 10%, 5% and 1% level.
The null hypothesis is the absence of cross-sectional dependence between countries.

4.2 Panel unit root tests

Since our 28 UfM countries cannot be treated independently within the panel, the next step is to test for the existence of unit-roots in each series with a second-generation panel unit root test. We consider here the test of Pesaran (2007) [CIPS hereafter], which accounts for possible cross-sectional dependence between panel members, as well as parameter heterogeneity.

The results reported in Table 3 indicate that except for foreign direct investment all series are non-stationary in level (presence of a unit root) at the 1% level of significance and they are stationary in first differences. This result is robust to the deterministic component specification (constant only, or constant and linear trend)[12]

[12] Other second-generation panel unit root tests (not reported here) have also been implemented, especially those of Bai and Ng (2004), Moon and Perron (2004), and Smith *et al.* (2004), without changing the conclusions.

Table 3. Pesaran's second generation panel unit root tests (2007)

	CIPS	
	Constant	Constant + Trend
In level		
GDP	-1.785	-1.566
GDP²	-1.794	-1.563
CO2	-2.011	-2.093
CH4	-1.939	-1.497
SO_2	-2.373	-2.376
PM10	-2.121	-2.002
OV_COMM	-2.520	-2.717
FDI	-4.262***	-4.542***
ENERG	-2.237	-2.477
DPOP	-1.166	-2.263
First difference		
ΔGDP	-5.052***	-5.568***
ΔGDP²	-5.107***	-5.616***
ΔCO2	-5.985***	-6.174***
ΔCH4	-5.322***	-5.443***
ΔSO2	-5.879***	-6.079***
ΔPM10	-6.021***	-6.231***
ΔOV_COMM	-5.881***	-6.058***
ΔFDI	-6.176***	-6.396***
ΔENERG	-6.077***	-6.289***
ΔDPOP	-2.714***	-2.851***

Notes: (*), (**) and (***) indicate statistical significance at the 10%, 5% and 1% level. The null hypothesis of the test is the existence of a unit root for all countries. Critical values are -2.02, - 2.08 and -2.19 respectively at 10%, 5% and 1% for the model with constant and without trend, and -2.52, -2.58, and -2.69 at 10%, 5 % and 1% for the model with constant and trend. In each case, the number of lags introduced for getting residuals to be white noise in the individual ADF regressions has been determined with the AIC criterion.

4.3. Panel cointegration tests

Since all variables are integrated of order 1, we must test for the existence of a cointegrating relationship between series using second-generation panel cointegration techniques. Here we use the Durbin-Hausman cointegration test (Westerlund, 2008) based on the estimation of an error correction model. This test accounts for possible dependence between countries and is related to the specific long-term parameter denoted speed of adjustment. To test for the null hypothesis of non-cointegration, four statistics can be used: G_α, G_τ, P_α and

P_τ.The "group mean" tests are performed with G_α and G_τ, the alternative hypothesis being that there is at least one cointegrating relationship between series. P_α and P_τ are associated with "panel" tests, the alternative hypothesis being that the panel is entirely cointegrated. The weighted average estimated for each country of the adjustment speed is used to perform the group mean tests. Besides, from the adjustment speed estimator (α_i) of the whole panel, panel tests can be carried out. Under the null hypothesis, these four statistics follow a normal distribution.

Table 4 summarizes the results of the four statistics of panel cointegration tests (G_α, G_τ, P_α and P_τ) of Westerlund (2008) for the four econometric specifications considered. From this table, it appears that there is a long-term relationship between pollutant emissions, gross domestic product per capita, and control variables for each of these specifications. Indeed, apart from four test statistics (for G_a (1), (2) and (3) and P_τ (3)), 12 test statistics reject the null hypothesis of the absence of a cointegrating relationship for the 28 UfM countries, at the 5% level. Therefore, the conclusion that there is a long-run panel relationship between our countries of the UfM zone for the four pollutants seems to be robust.

Table 4. Westerlund Cointegration Test Results for the 4 econometric specifications considered

Statistics	(1) CO_2 and GDP	(2) CH_4 and GDP	(3) SO_2 and GDP	(4) PM10 and GDP
$\boldsymbol{G_t}$	-2.017*	-2.463***	-2.200***	-2.139**
$\boldsymbol{G_a}$	-8.127	-7.988	-7.730	-8.861*
$\boldsymbol{P_t}$	-11.348***	-21.219***	-8.428	-11.494***
$\boldsymbol{P_a}$	-7.508***	-12.944***	-5.822**	-8.999***

*, **, *** indicate statistical significance at respectively 10%, 5% and 1% level.

4.4 Estimation results and economic interpretation

Tables 5, 6, 7 summarize the estimations results of the long-run parameters of the four econometric specifications (one per pollutant), according to the estimation method considered (M.G., AMG, and CCEMG)[13], for our 28 countries of the UfM zone.

First, if we refer to the results obtained with the M.G. estimator, the EKC is not verified for the four (CO2, CH4, SO2, and PM10) pollutant emissions[14].

[13] See Appendix A4 for a brief overview of each method.

[14] The EKC hypothesis is empirically verified only if the estimated coefficients of the income per capita (GDP) and the income per capita squared (GDP^2) are respectively positive and negative (and significant).

In addition, the coefficient of energy consumption is positive and statistically significant for the four pollutant emissions (model with constant and with a trend). The highest elasticity of energy consumption is related to carbon dioxide emissions. When energy consumption increases by 1%, CO_2 emissions increase between 0.95 and 0.81. The coefficient of population density is negative and statistically significant only for CH_4 emissions. Therefore, the increase in population generates a decrease in CH_4 emissions in the UfM zone, where the lifestyles are environmentally friendly. When the population increases by 1% in the UfM region, emissions of this pollutant decrease by 0.03%. Trade openness has a positive and statistically significant impact only for SO_2 emissions (model with constant and model including a trend). Foreign direct investment is statistically insignificant in the four specifications.

The results of the AMG estimator do not validate the EKC hypothesis for the four pollutant emissions. In addition, the coefficient of energy consumption is positive and statistically significant for the four pollutant emissions. Our estimates reveal that if energy consumption increases by 1%, CO_2 emissions increase between 0.85 and 0.8%, those of CH_4 between 0.015% and 0.01%, those of SO_2 between 0.02% and 0.016% and those of PM10 by 0.026%

The population density coefficient is negative and statistically significant only for CH_4 emissions (model with constant). The coefficient is positive and statistically significant only for SO_2 emissions (model with constant). Thus, if the population density increases by 1%, SO_2 emissions increase by 0.05%, in the UfM region.

Then, the EKC is rejected for CO_2, CH_4, and PM10 if one refers to the CCEMG estimator but is not rejected for SO_2 emissions. The inverted U-shape only holds for SO_2 emissions, and the turning point in US$2015 is 8785.7147 and 8467.2075 respectively for the model with constant and the model including a trend. It is reached by most European Union countries (except Italy and Poland), but not for countries of the southern part of the Mediterranean basin (except Israel). Consequently, SO_2 emissions will continue to increase in the UfM zone.

The coefficient of energy consumption is positive and statistically significant in all specifications (except for CH_4 emissions with model including a trend): if energy consumption increases by 1%, emissions of CO_2, CH_4, SO_2, and PM10 increase respectively by 0.88%, 0.007%, 0.015%, and 0.002% (model with constant) (if we refer to the model with trend, energy consumption increases by 1%, emissions of CO_2, SO_2, and PM10 increase respectively by 0.85%, 0.015%, and 0.0023%). In addition, the coefficient of population density is negative and statistically significant only for CO_2: if the population density increases by 1%, is accompanied by a drop in CO_2 emissions of 0.52%. Foreign direct investment is statistically significant and positive only for CH_4 emissions. Thus, a 1% increase in foreign direct investment inflows (% of GDP) is accompanied by an increasing in CO_2 emissions of 0.003%.

Table 5. Estimation of long-run parameters with the Mean Group (M.G.) method

Variables	(1) CO_2		(2) CH_4		(3) SO_2		(4) PM10	
	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend
GDP	0.0628 (1.4815)	-0.2658 (1.3818)	0.0662 (0.0961)	0.0748 (0.0987)	0.0707 (0.1595)	0.0067 (0.1829)	0.0104 (0.0136)	-0.0014 (0.0138)
GDP^2	-0.0140 (0.0758)	0.0071 (0.0710)	-0.005 (0.0052)	-0.0024 (0.0049)	-0.0027 (0.0095)	-0.0008 (0.0096)	-0.0005 (0.0007)	0.00005 (0.0008)
ENERG	0.9372*** (0.09502)	0.8139 *** (0.0745)	0.0139*** (0.0036)	0.0077*** (0.0021)	0.0199*** (0.0056)	0.0163*** (0.0039)	0.0017*** (0.0005)	0.0019*** (0.0004)
DPOP	-0.8283 (0.3153)	-0.0688 (0.3092)	-0.0307** (0.0131)	-0.0169 (0.0237)	-0.0419 (0.0214)	0.0183 (0.0312)	-0.0031 (0.0026)	0.0018 (0.0049)
OP_TRA	0.0532 (0.0331)	0.0434 (0.0312)	-0.0003 (0.0021)	0.0017 (0.0021)	0.0009* (0.0022)	0.0047** (0.00162)	0.0002 (0.0004)	0.00002 (0.0003)
FDI	0.0005 (0.0003)	0.0002 (0.0002)	0.00001 (0.00002)	0.00002 (0.00002)	0.00002 (0.00003)	-6.35e-06 (0.00002)	-2.95e-06 (3.69e-06)	-4.84e-07 (2.94e-06)
Constant	-4.3278 (8.5145)	-5.5894 (8.2173)	-0.2575 (0.4861)	-0.4707 (0.4263)	-0.4965 (0.7009)	-0.2926 (0.8541)	-0.0560 (0.0543)	-0.0365 (0.0527)
Trend		-0.008** (0.0038)		-0.0004* (0.0002)		-0.0008*** (0.0003)		-0.00003 (0.00005)
The EKC Holds	No	No	No	No	No	No	No	No
Turning Point	-	-	-	-	-	-	-	-
RMSE	0.0508	0.0468	0.0191	0.0183	0.0039	0.0035	0.0005	0.0005

Notes: *, **, *** indicate statistical significance at respectively 10%, 5% and 1% level.
Numbers in brackets refers to standard deviations.

Table 6. Estimation of long-run parameters with the Augmented Mean Group (AMG) method

Variables	(1) CO_2		(2) CH_4		(3) SO_2		(4) PM10	
	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend
GDP	-1.7235 (1.5739)	-1.5051 (1.3479)	0.0265 (0.0562)	-0.0080 (0.0426)	0.0448 (0.1096)	0.0436 (0.0921)	0.0117 (0.0173)	0.0044 (0.0177)
GDP^2	0.0754 (0.0793)	0.0710 (0.0680	-0.0023 (0.0031)	-0.0005 (0.0031)	-0.0021 (0.0063	-0.0028 (0.0051)	-0.0005 (0.0009)	-0.0003 (0.0009)
ENERG	0.8513*** (0.0787)	0.8038*** (0.0774)	0.0146*** (0.0037)	0.01002*** (0.0028)	0.0185*** (0.0050)	0.0164*** (0.0052)	0.0026*** (0.0006)	0.0026*** (0.0007)
DPOP	-0.2222 (0.2115)	-0.1189 (0.3015)	-0.0331** (0.0148)	-0.0241 (0.0246)	0.0481** (0.0235)	0.0494 (0.0338)	0.0016 (0.0019)	0.0045 (0.0046)
OP_TRA	0.0420 (0.0259)	0.0241 (0.0284)	0.0011 (0.0019	0.0010 (0.0018)	0.0047** (0.0020)	0.0055*** (0.00185)	0.0002 (0.0003)	-0.0002 (0.0003)
FDI	0.00019 (0.0002)	0.00002 (0.0002)	0.00003 (0.00002)	0.00002 (0.00002)	0.00003 (0.00002)	0.00001 (0.00003)	-1.43e-06 (2.32e-06)	1.75e-06 (2.33e-06)
Constant	2.6858 (8.7760)	0.2122 (7.9596)	-0.0355 (0.2806)	-0.2109 (0.3323)	-0.5784 (0.4685)	-0.4748 (0.4021)	-0.0895 (0.0777)	-0.0812 (0.0687)
Trend		-0.0041 (0.0035)		-0.0003* (0.0002)		4.02e-06 (0.00017)		-1.72e-06 (0.00005)
The EKC Holds	No	No	No	No	No	No	No	No
Turning Point	-	-	-	-	-	-	-	-
RMSE	0.0444	0.0421	0.0058	0.0056	0.0029	0.0028	0.0005	0.0004

Notes: *, **, *** indicate statistical significance at respectively 10%, 5% and 1% level.
Numbers in brackets refers to standard deviations.

Table 7. Estimation of long-run parameters with Common Correlated Effects Mean Group (CCEMG) method

Variables	(1) CO_2		(2) CH_4		(3) SO_2		(4) PM10	
	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend
GDP	-1.9744 (1.4521)	-1.2533 (1.1956)	0.0275 (0.0803)	0.0337 (0.0795)	0.1235* (0.0748)	0.1646* (0.0965)	-0.0036 (0.0074)	-0.0118 (0.0099)
GDP²	0.0994 (0.0739)	0.0649 (0.0622)	-0.0022 (0.0041)	-0.0011 (0.0040)	-0.0068* (0.0038)	-0.0091** (0.0046)	0.0004 (0.0004)	0.0007 (0.0006)
ENERG	0.8793*** (0.0812)	0.8455*** (0.0794)	0.0067** (0.0031)	0.00491 (0.0033)	0.0148*** (0.0044)	0.0145*** (0.0035)	0.0017*** (0.0006)	0.0023*** (0.0007)
DPOP	-0.5232** (0.2356)	0.3029 (0.3126)	-0.0351 (0.0154)	-0.0326 (0.0207)	0.0040 (0.0011)	0.0402 (0.0333)	-0.0013 (0.0023)	0.0042 (0.0050)
OP_TRA	0.00578 (0.0376)	0.01314 (0.0424)	0.0014** (0.0015)	0.0010 (0.0018)	0.0154*** (0.0205)	0.0046*** (0.0015)	-0.0002 (0.0002)	-0.0006*** (0.0002)
FDI	0.00003 (0.0003)	8.30e-06 (0.0004)	0.00004** (0.00002)	0.00004** (0.00002)	0.00004 (0.00003)	0.00002 (0.00003)	1.25e-06 (2.68e-06)	-2.94e-07 (2.55e-06)
Constant	18.7527** (8.8478)	10.2159 (8.1342)	-0.3209 (0.3955)	-0.4690 (0.3983)	-0.1385 (0.4113)	-0.3739 (0.4674)	-0.0346 (0.0525)	0.0011 (0.0556)
Trend		-0.0084* (0.0044)		-0.0004** (0.0002)		-0.0004 (0.0003)		-0.00001 (0.00004)
The EKC Holds	No	No	No	No	Yes	Yes	No	No
Turning Point	-	-	-	-	8785.7147	8467.2075	-	-
RMSE	0.0386	0.0365	0.0065	0.0064	0.0026	0.0024	0.0004	0.0004

Notes: *, **, *** indicate statistical significance at respectively 10%, 5% and 1% level.
Numbers in brackets refers to standard deviations.

Pollutant levels rise during the first phase of economic development, and beyond a turning point, economic growth reduces environmental pressures. The estimators of the parameters obtained by the PMG method are reported in Table 8. The assumption of existence on an EKC is verified for the emissions of CO_2 (main greenhouse gas) and SO_2 (local pollutant), the estimated impact of GDP and GDP² being respectively positive and negative and statistically significant. Turning points in US$2015 are respectively 1318.377 for CO_2, and 1753.5005 for SO_2. Furthermore, they are very similar to values obtained for developed countries in other existing studies[15]. They are reached by all the countries in our sample. Indeed, these points do not exceed the average GDP per capita for each UfM country (see appendix A3). In other words, with the improvement of per capita incomes in these countries, citizens are giving the environmental dimension a privileged place through the reduction of CO_2 and SO_2 emissions.

[15] See for instance Dijkraaf and Vollebergh (2005), or Galeotti *et al.* (2006).

In addition, the EKC is not verified and takes a U-shape for CH4 and PM10 emissions, the estimated impact of GDP and GDP^2 being respectively negative and positive (and statistically significant). Therefore, CH_4 and PM10 emissions will continue to increase in the UfM region.

In addition, in the long term, the estimated impact of energy consumption with the PMG method is positive and statistically significant for the two global pollutant emissions (CO_2 and CH_4). The elasticity of energy relative to CO_2 emissions in the long term is slightly higher than the one found in the short term (with PMG, M.G., AMG, and CCEMG). Therefore, energy consumption in UfM countries is strongly correlated with the environmental deterioration through the increase of CO_2 emissions in the long term. The estimated effect of energy consumption is also positive and statistically significant for the emissions of local pollutants (SO_2 and PM10). Nevertheless, the energy elasticity relative to SO_2 and PM10 emissions in the long term is nearly the same as that found in the short term (with PMG, M.G., AMG, and CCEMG). This implies that energy consumption does not cause an increase in SO_2 and PM10 emissions, and that the concentration levels of these two local pollutants remain stable over time in the UfM zone, where the 8 energy efficiency world leaders[16] in energy regulation are located (2016 statistics from ACEEE[17] on energy efficiency).

In the long term, with the PMG method, PM10 and SO_2 emissions are positively correlated with population density. On the other hand, the coefficient of the population density is negative and statistically significant for CO_2 and CH_4 (but not significant in the short run for these pollutants). This implies that emissions decrease in the long term with the increase in the population of the UfM: if population density increases by 1%, CO_2 and CH_4 emissions decrease respectively in the long term by 0.25% and 0.038%. This can be explained by the different modifications of lifestyles with the improvement of living standards, urbanization, and technical progress. Our results are in line with those of Bhattarai and Hammig (2001), according to which population growth leads to a decrease in deforestation in Latin America and Africa and those of Brajer *et al.* (2007), who find that population density favours the concentration of SO_2 in China. However, they differ from those of Martinez-Zarzoso *et al.* (2006), who report evidence that population density in European Union countries contributes to the increase of CO_2 emissions.

[16] Germany, Italy, France, Spain, United Kingdom, Netherlands, Poland, and Turkey
[17] American Council for an Energy-Efficient Economy.

Trade openness is positively correlated with CO_2 emissions and contributes to increasing the concentration of GHGs in the UfM. The levels of these pollutants increase when UfM countries are more open to the outside, which explains the effect of scale. The increase in exports to the rest of the world requires more production of goods in the UfM zone, which leads to increased emissions of pollutants, especially carbon dioxide. Our results are in line with those of Managi (2004), for whom trade opening leads to an increase in CO_2 emissions. However, CH_4, SO_2 and PM10 emissions are negatively correlated with trade openness, which confirms the results of Cole *et al.* (2004) and Magnani and Tubb (2007), who find that trade liberalization in OECD countries negatively affects pollutant emissions.

Finally, inward foreign direct investment flows contribute in the long term to the slight increase in CH_4 and PM10 emissions: a 1% increase in FDI inflows leads to a rise of 0.000071 % in CH_4 and of 0.0000065 % in PM10. These results are in line with those of Gharnit *et al.* (2019). On the other hand, an increase in these flows leads to a reduction in CO_2 and SO_2 emissions.

Table 8. EKC analysis based on the PMG method

Variables	(1) CO_2	(2) CH_4	(3) SO_2	(4) PM10
Long-Run Coefficients				
GDP	0.6012*** (0.0569)	-0.0443*** (0.0118)	0.1269*** (0.0099)	-0.01284*** (0.0022)
GDP^2	-0.0418*** (0.0032)	0.0023*** (0.0007)	-0.0077*** (0.0006)	0.0008*** (0.0001)
ENERG	1.1977*** (0.0139)	0.0159*** (0.0013)	0.0017** (0.0008)	0.0025*** (0.0002)
DPOP	-0.1431*** (0.0143)	-0.0384*** (0.0053)	0.0351*** (0.0014)	0.0003* (0.0008)
OP_TRA	0.1882*** (0.0057)	-0.0045*** (0.0010)	-0.0043*** (0.0005)	-0.0007*** (0.0003)
FDI	-0.0030*** (6.68E-05)	7.06E-05*** (1.96E-05)	-2.38E-05*** (6.22E-06)	6.58E-06** (3.71E-06)
The EKC Holds	**Yes**	**No**	**Yes**	**No**
Turning Point ($)	1318,3775	-	1753,5005	-
Short-Run Coefficients				
ECT	-0.5588** (0.2209)	-0.2414*** (0.0451)	-0.4674*** (0.1288)	-0.2600*** (0.0467)
D.GDP	17.0962** (7.0003)	2.0159 (1.7122)	0.6694*** (0.2424)	0.0947** (0.0406)
$D.GDP^2$	-0.9132** (0.4044)	-0.0983 (0.0826)	-0.0313*** (0.0115)	-0.0045** (0.0019)
D.ENERG	0.1148 (0.2927)	0.0006 (0.0047)	0.0165*** (0.0046)	0.0025*** (0.0006)
D.DPOP	-21.4467** (10.6912)	0.5899 (0.4206)	0.3820 (0.5470)	0.1564 (0.2110)
D.OP_TRA	-0.0190 (0.0398)	0.0040* (0.0022)	0.0007 (0.0033)	0.0009* (0.0005)
D.FDI	0.0015* (0.0008)	-0.0001 (0.0001)	-5.38E-05 (6.19E-05)	-1.08E-05** (5.48E-06)
Constant	-5.4021** (2.1433)	0.0731*** (0.0139)	-0.2860*** (0.0813)	0.0108*** (0.0022)

Notes: *, **, *** indicate statistical significance at respectively 10%, 5% and 1% level.
Numbers in brackets refers to t-statistics.

5. Conclusions and policy implications

The aim of this paper is to examine the relationship between economic growth and emissions of four pollutants (two global and two local), and its robustness for 28 countries of the Union for the Mediterranean (UfM) over the 1970-2020 period. The econometric strategy relied on recent methods of non-stationary panel data, which accounts for parameter heterogeneity, and for some of them, possible cross-sectional dependence among countries [Mean Group (M.G.) of Pesaran and Smith (1995), Augmented Mean Group (AMG) of

Eberhardt and Teal (2010), Common Correlated Effects Mean Group (CCEMG) of Pesaran (2006), and Pooled Mean Group (PMG) of Pesaran, Shin and Smith (1999)]. The results can be summarized as follows:

First, whether the hypothesis of the existence of an environmental Kuznets curve (EKC) holds or not, crucially depends on the estimation method considered. Specifically, results based on the M.G., AMG, and CCEMG techniques lead to the rejection of the EKC for pollutants (except for SO_2 if we consider the CCEMG estimator and a model without trend), while those obtained by the PMG confirms the existence of an inverted U-shape for CO_2 and SO_2 emissions.

Then, the signs of the estimated coefficients (β_1 and β_2) satisfy the EKC assumptions for CO_2 and SO_2 emissions, turning points not exceeding the average GDP per capita for each country.

In addition, the results obtained with the four estimation methods reveal a positive impact of energy consumption on CO_2, SO_2, and PM10 emissions (the energy coefficient for CH_4 emissions provided by PMG is positive and statistically significant, although, in the short run, the coefficients of this pollutant are positive and not significant, as it is also the case with the CCEMG technique with model including a trend.

In the long run, SO_2 emissions don't increase over time because of the establishment of more stringent European standards in terms of product quality and safety, which have reduced the gasoline sulfur, diesel, heavy fuel oil, and heating oil. In Europe, SO_2 pollution fell sharply during the 1990-2008 period following the use of domestic heating and natural gas for energy production. In addition, PM10 emissions, which come mainly from the transport sector through exhaust gases or the fuel combustion from vehicles, remain relatively stable over time despite the increase in traffic. This can be explained by the technological improvement of the engines by catalysts installation allowing the toxic exhaust gas oxidation contributing to better protect the environment: indeed, the catalyst invented by General Motors in 1974 became compulsory on new cars in 1995.

The impact of energy consumption on the emissions of the two local pollutants (SO_2 and PM10) in line with activities of road or sea transport remains relatively stable over time in the UfM zone. Consequently, to work together for the de-pollution of the Mediterranean, UfM countries must be more engaged in a significant reduction in the emissions of these two local pollutants, as well as in the improvement of the transport sector, which is the most important contributor to GHG emissions.

The effect of energy on CO_2 emissions increases over time, which confirms the findings of Hamit-Haggar (2012), and Atasoy (2017). Thus, governments of UfM countries must put in place international cooperation policies to reduce environmental degradation and control energy efficiency, especially since 8 UfM countries (Germany, Italy, France, Spain, United Kingdom, Netherlands, Poland, and Turkey) are ranked among the most advanced in the world in terms of energy regulations. The energy sector in the UfM zone is facing major challenges: a strategic challenge in line with the increase in the share of renewable energies, the energy mix diversification, and energy demand control by strengthening energy efficiency; an economic challenge related to subsidies and pricing and an environmental one related to investment in clean technologies. It should be noted that despite real investment in flagship projects, efforts to develop renewable energies in the UfM zone remain modest, and their consumption only represents 17.08% of final energy consumption.

The coefficient of population growth is negative and highly significant in the long run, which suggests that CO_2 emissions (PMG) in the UfM decrease as population growth increases in the long run. This finding is in line with Hassan and Salim (2015) and Atasoy (2017).

Trade openness leads to an increase in CO2 emissions. Ferrantino (1997), and Grether, *et al.* (2007) reached a similar conclusion. Besides, we find trade openness to be negatively related to CH4, SO2 and PM10 emissions (PMG). If trade increases by 1% in the long term, these three pollutants (CH4, SO2 and PM10) will decrease by respectively 0.004%, 0.004% and 0.0007%. As a result, even though CO2 emissions are positively correlated with trade openness, the creation of a UfM free trade zone is not beneficial to the environment, as there is essentially an increase in the emissions rate of the second GHG (CH_4). These findings are consistent with those of Nasir and Rehman (2011), and Jalil and Feridun (2011).

In the long term, FDI have a positive impact on CH_4 and fine particle emissions, which confirms the validity of the pollution haven hypothesis. These results are in accordance with those of He *et al.* (2020), and Assamoi *et al.* (2020). However, FDI causes the decrease in CO_2 and SO_2 emissions. This can be explained by the respect of international standards and environmental regulations by investors for CO_2, which gives room for the support of the pollution haven hypothesis. These results are in line with those of Ahmad *et al.* (2021), Shao *et al.* (2019), and Jiang *et al.* (2018). Consequently, the contributions of foreign investors remain harmful to the environment with the increase in CH_4 the second GHG emissions for the UFM zone.

In the light of our results, various orientations can be drawn up in terms of policy implications. Considering the systemic nature of the problem, both ecological and economical, it follows that policymakers must provide operational and holistic responses. Our findings suggest that improving environmental quality in the Mediterranean countries, especially low-income economies, requires additional policies that complement conventional instruments. These policies could include both interventions to: (i) strengthen investments for a sober energy transition. This is precisely the establishment of innovative financing mechanisms for both energy efficiency projects (*e.g.,* energy renovation) and green energies; (ii) improve governance and existing regulatory instruments. This objective is achievable by adopting a shock of the existing regulatory framework simplification and by strengthening the skills of the territories in the transition, as well as accounting for regional specificities. Another prerequisite would be to support policies adaptation to the maturity and competitiveness degree of the various sectors by promoting energy production at the regional level and aiming for energy autonomy for non-interconnected areas; (iii) strengthen innovation and R&D investments in the energy sector. The same goes for the strengthening and structuring of research potential, scientific cooperation, and entrepreneurial dynamics.

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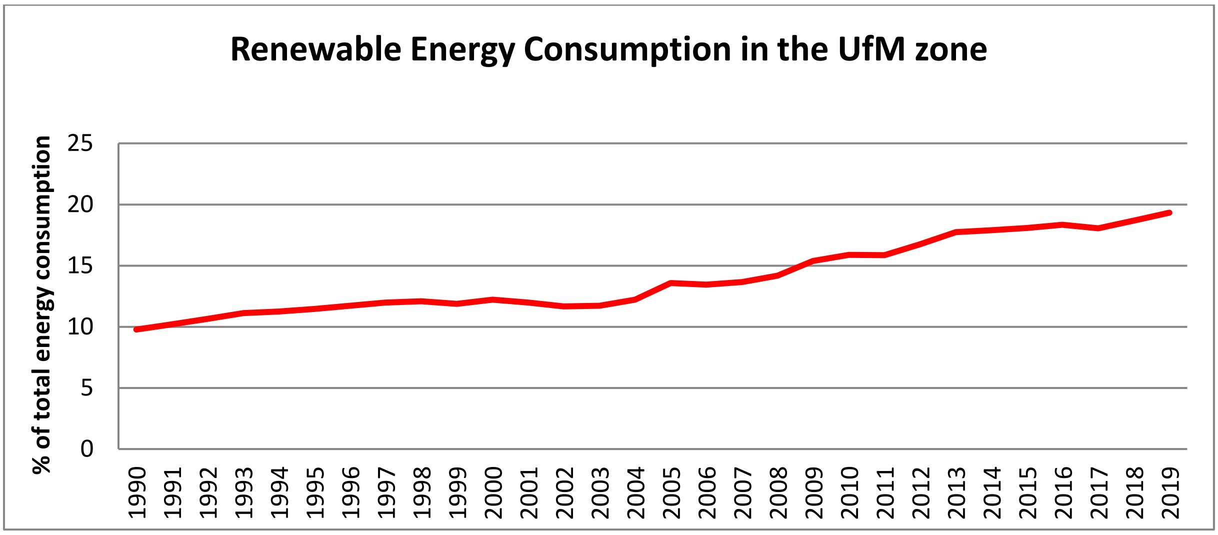
APPENDICES

A1. List of Member States on the Union for the Mediterranean and overview of their economic and environmental situations.

	Member States	Organisation	GDP (constant 2010 US $)			CO_2 (metric ton per capita)		
			2010	2016	Evolution %	2010	2016	Evolution %
Northern shore	Germany	EU	41785.56	46 167.83	10.49	9.88	9.47	-4.15
	Austria	EU	46858.04	48 300.95	3.079	8.93	8.47	-5.15
	Belgium	EU	44380.18	45 598.74	2.75	9.95	8.31	-16.48
	Bosnia and Herzegovina *	CEFTA	4635.52	5 591.03	20.61	5.90	7.29	23.56
	Bulgaria	EU	6843.27	7966.88	16.42	6.57	7.14	8.68
	Cyprus	EU	30818.48	29081.82	-5.64	7.16	5.87	-18.02
	Croatia*	EU	13937.14	14718.93	5.61	4.82	4.61	-4.36
	Denmark	EU	58041.41	61370.79	5.74	8.71	6.66	-23.54
	Spain	EU	30736.63	31539.51	2.61	6.03	5.44	-9.78
	Estonia*	EU	14638.61	18387.77	25.61	13.96	17.1	22.49
	Finland	EU	46202.42	46438.82	0.51	12.35	9.31	-24.62
	France	EU	40638.33	42054.53	3.48	5.99	5.12	-14.52
	Greece	EU	26917.76	22666.29	-15.79	7.84	6.06	-22.7
	Hungary	EU	13092.23	15032.14	14.82	5.19	5.23	0.77
	Ireland	EU	48711.95	70298.66	44.32	9.01	8.26	-8.32
	Italy	EU	35849.37	34397.65	-4.05	7.04	6.03	-14.35
	Latvia*	EU	11326.23	14713.02	29.90	4.04	4.14	2.48
	Lithuania*	EU	11984.87	15944.63	33.04	4.37	4.7	7.55
	Luxembourg	EU	104965.3	107479.51	2.39	21.94	17.61	-19.74
	Malta*	EU	21087.79	26510.07	25.71	5.95	5.26	-11.6
	Monaco *	EU	150585.49	193745.57	28.66	1.58	1.63	3.16
	Montenegro*	CEFTA	6682.28	7492.86	12.13	-	-	-
	Netherlands	EU	50950.03	52727.10	3.49	10.60	9.61	-9.34
	Poland	EU	12599.53	15101.36	19.86	8.41	7.77	-7.61
	Portugal	EU	22538.65	22511.73	-0.11	4.88	4.82	-1.23
	Romania	EU	8209.92	10236.86	24.69	4.04	3.98	-1.49
	UK	EU	39079.84	42201.64	7.99	7.73	5.59	-27.68
	Slovakia *	EU	16600.61	19298.07	16.25	7.59	6.77	-10.8
	Slovenia*	EU	23437.47	24445.56	4.30	8.38	7.08	-15.51
	Sweden	EU	52132.92	56195.88	7.79	5.52	4.54	-17.75
	Czech Republic*	EU	19808.07	21863.64	10.38	11.44	10.55	-7.78
	Turkey	EU	10672.39	14062.73	31.77	4.26	4.63	8.69
	Israel		30659.13	33839.83	10.37	9.48	7.96	-16.03
South shore	Albania	CEFTA	4094.36	4683.74	14.39	1.38	1.78	28.99
	Algeria	Arab League. AMU and A.U.	4480.79	4834.23	7.89	3.18	3.85	21.07
	Egypt	Arab League and AU	2644.82	2761.39	4.41	2.50	2.29	-8.4
	Jordan	Arab League	3656.46	3241.25	-11.36	2.88	2.41	-16.32
	Lebanon*	Arab League	7756.74	6330.42	-18.38	4.74	3.64	-23.21
	Libya*	Arab League, AMU and AU	12064,78	5669,73	-53,01	10.49	8.38	-20,11
	Morocco	Arab League, AMU and A.U.	2839,91	3214,92	13,20	1,58	1,63	3,16
	Mauritania*	Arab League, AMU and AU	1241,41	1336,99	7,70	0.60	0.59	-1,67
	Palestine*	Arab League	-	-	-	-	-	-
	Syria*	Arab League	-	-	-	2.92	2.07	-29,11
	Tunisia	Arab League, AMU and AU	4140,15	4265,37	3,02	2,42	2,58	6,61

Notes: GDP and CO2 indicate respectively the gross domestic product (income) and the carbon dioxide emissions per capita. Some UfM countries had to be eliminated from the sample during estimations due to the unavailability of data and geopolitical wars in some regions which suspended their membership, or if countries have had the observer status.

A2. Renewable energy consumption in the UfM zone (% of total energy consumption)



Source: World Development Indicators (World Bank). (Monaco and Palestine had to be eliminated from the sample due to the unavailability of data).

A3. The average of GDP per capita for the UfM zone over the 1970-2020 period.

Country (UPM)	Average of GDP per capita 1970-2020 (Constant 2015 US $)
Germany	31077,70
Austria	33980,52
Belgium	31573,72
Bulgaria	4870,001
Cyprus	18447,73
Denmark	42844,40
Spain	20370,09
Finland	32994,93
France	29596,23
Greece	10927,07
Hungary	33850,80
Ireland	27073,64
Italy	3636,60
Luxembourg	75043,20
Netherlands	34939,68
Poland	6909,89
Portugal	15287,26
Romania	5526,56
UK	34110,81
Sweden	37981,78
Albania	3376,57
Algeria	3329,29
Egypt	2349,58
Israel	25191,48
Jordan	3636,60
Morocco	1803,60
Tunisia	2696,90
Turkey	6545,10

A4. Methods for estimating parameters of the econometric specifications

We briefly review here the 4 methods implemented to estimate the short-run and long-run parameters of our 4 econometric specifications.

A4.1 The Correlated Common Effects Mean Group estimator (CCEMG)

It was proposed by Pesaran (2006)) and Kapetanios *et al.* (2011). It is based on the Mean Group (M.G.) estimator and accounts for the dependence in cross sectional units and parameters heterogeneity. The model is static and does not include the lagged dependent variable as an explanatory variable, as it is the case in Chudik and Pesaran (2013). Pesaran (2006) approximates common correlated effects by the cross-sectional means of the dependent variable and the explanatory ones. The model is specified as:

$$y_{it} = \alpha_i + \beta_i x_{it} + \varphi_i f_t + \varepsilon_{it} \quad \textbf{(1)}$$

, where y_{it} and x_{it} are respectively the dependent variable and the vector of explanatory variables. α_{1i} is the coefficient for country specificities, f_t denotes a common unobservable factor, and ε_{it} is the error term.

Equation (1) is augmented by the cross-sectional means of the dependent and independent variables and can be rewritten as:

$$y_{it} = \alpha_{1i} + \beta_i x_{it} + \delta_i \bar{y}_{it} + \theta_i \bar{x}_{it} + \varphi_i f_t + \varepsilon_{it} \quad \textbf{(2)}$$

, with $\bar{y}_t = \frac{1}{N}\sum_{i=1}^{N} y_{it}$ and $\bar{x}_t = \frac{1}{N}\sum_{i=1}^{N} x_{it}$.

The CCEMG estimator is given by:

$$\hat{b}_{CCEMG} = \frac{1}{N}\sum_{i=1}^{N} \hat{b}_{it}$$

It is convergent under certain assumptions (*e.g.*, Vogel, 2013).

A4.2 The Mean Group estimator (MG)

It was introduced by Pesaran and Smith (1995) and assume independence in cross-sectional units, which implies the absence of common correlated (unobservable) factors between countries. The M.G. estimator is calculated in two steps: first, a separate estimate is made for each country. Then, the average of the estimated coefficients is computed. This estimator can be obtained in a static model, or in a dynamic one. Under certain regularity conditions it is convergent (*e.g.*, Pesaran and Smith, 1995, for more details).

A4.3. The Augmented Mean Group estimator (AMG)

It was proposed by Eberhardt and Bond (2009), and by Eberhardt and Teal (2010). Like the CCEMG estimator, it accounts for possible cross-sectional dependence among countries and parameters heterogeneity. The difference between them lies in the method for approximating common unobservable factors. The CCEMG estimator is based on linear combinations of the observed common effects cross-sectional means and the dependent and explanatory variables. The AMG estimator is obtained from the equation below, which is augmented by time dummies:

$$\Delta y_{it} = \alpha_{1i} + \beta_i \Delta x_{i,t} + \varphi_i f_t + \sum_{t=2}^{T} \tau_t \, DUMMY_t + \varepsilon_{it} \qquad \textbf{(3)}$$

The AMG estimator is computed in the same way as CCEMG, *i.e.*

$$AMG = N^{-1} \sum_{i=1}^{N} \tilde{\beta}_i .$$

, where $\tilde{\beta}_i$ refers to the OLS estimators of the coefficients β_i of equation (3).

A4.4. The Pooled Mean Group estimator (PMG)

It was introduced by Pesaran, Shin and Smith (1999). It relies on the estimation of an ARDL model which allows short-run and long-run parameters to be estimated. Besides, it accounts for individual heterogeneity, and permits to deal with economic series integrated of different orders (I (0) and I (1)).

Specifically, the PMG estimator is obtained from the following ARDL model (p, q):

$$y_{i,t} = \sum_{j=1}^{p} \lambda_{i,j}\, y_{i,t-j} + \sum_{j=0}^{q} \tau'_{i,j}\, x_{i,t-j} + \mu_i + u_{it} \quad \textbf{(4)}$$

$$\text{, with } u_{it} = \rho' f_{it} + \varepsilon_{it}$$

, where $x_{i,t}$ is a (k*1) matrix of explanatory variables, μ_i are individual fixed effects, f_{it} *is* a vector of common unobservable factors, ε_{it} is a white noise uncorrelated with regressors and common unobservable factors.

Equation (4) is equivalent to:

$$\Delta y_{i,t} = \phi y_{i,t-1} + \beta' x_{i,t} \sum_{j=1}^{p-1} \lambda^{*}_{i,j}\, \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta^{*\prime}_{i,j}\, \Delta x_{i,t-j} + \mu_i + u_{it} \quad \textbf{(5)}$$

, where $\phi_i = -(1 - \sum_{j=1}^{p} \lambda_{ij})$, $\beta_i = \sum_{j=0}^{q} \delta_{ij}$, $\lambda^{*}_{ij} = -\sum_{m=j+1}^{p} \lambda_{im}$

, and $\delta^{*}_{ij} = -\sum_{m=j+1}^{q} \delta_{im}$

Equation (5) is stable if $\phi < 0$.

The cointegrating relationship is then given by

$$y_{i,t} + \left(\frac{\beta_i'}{\phi_i}\right) x_{i,t} + \eta_{i,t}$$

, since long-run coefficients are assumed to be homogeneous across countries, *i.e.*

$$\theta = \theta_i = \left(\frac{\beta_i'}{\phi_i}\right)$$

, where ϕ_i refers to the speed of adjustment.
The existence of a long-run relationship is rejected if $\theta = 0$.

The PMG estimator assumes equal long-run coefficients for all countries, but short-run parameters may differ from a country to another.