Renewable energy and economic growth in the MENA region: Empirical evidence and policy implications

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We estimate the impact of increasing electricity generation from renewable sources or, as alternative, increasing renewable generation capacity on economic growth in the MENA region, using a neoclassical growth function that includes capital, labor and energy use as additional input factors. We show that both generation and capacity impact growth positively for several countries and panels we considered, and never negatively. Our results hold for several robustness checks we performed. Our conclusion is that investing in renewables is beneficial for MENA countries, and that this could be an incentive to intensify the existing policy towards renewables in the region.

1 Introduction

With high solar irradiation and strong winds, large parts of the MENA region offer excellent potentials for generating electricity from renewable sources.[1,2] Yet, the use of those potentials for generating electricity remains low, although some countries made remarkable steps in recent years. In the region, Turkey has by far the highest share of electricity generation from renewable sources, with 28.8 per cent of total generation in 2013, reported in World Bank's World Development Indicators (WDI). Morocco showed a large increase, attaining a share of 15.3 per cent in 2013, an increase of more than 6 percentage points within only one year due to major investments in large-scale solar power plants and wind farms. But only one other country in the region, Syria, has a share of generation from renewable sources of more than 10 per cent, and

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[1] We included the following countries to our definition of the MENA region: Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine (West Bank and Gaza), Qatar, Saudi Arabia, Syria, Tunisia, Turkey, United Arab Emirates, Yemen

[2] The term renewable sources refers to biomass, hydro, geothermal, solar, wind, ocean thermal, wave action, and tidal action. This follows the definition of the US Energy Information Administration.

Table 1: Use of Renewables in the Electricity Sector of MENA countries, 2012

Country	Renewable Electricity Output			Installed Electricity Generation Capacity		
	total (GWh)	Share of total Electricity Generation	Percentage change since 2000	total (GW)	Share of total installed capacity	Percentage change since 2000
Algeria	616.00	0.0114	1,062.26	260.20	0.0200	−5.04
Bahrain	2.50	0.0002	n.c.	5.83	0.0015	n.c.
Egypt	14,721.00	0.0948	7.47	3,626.50	0.1231	28.14
Iran	12,553.00	0.0525	242.79	10,383.36	0.1326	293.76
Iraq	5,370.00	0.0922	787.60	2,516.00	0.2018	176.48
Israel	475.00	0.0080	1,432.26	298.00	0.0206	2,468.97
Jordan	69.00	0.0044	64.29	19.10	0.0056	67.54
Kuwait	0.00	0.0000	0.00	1.80	0.0001	n.c.
Lebanon	997.00	0.0713	124.04	222.00	0.0982	−18.53
Libya	0.00	0.0000	0.00	54.80	0.0077	n.c.
Morocco	2,343.10	0.0924	202.34	1,632.00	0.2413	29.63
Oman	0.00	0.0000	0.00	0.70	0.0001	n.c.
Qatar	0.00	0.0000	0.00	117.20	0.0147	n.c.
Saudi Arabia	1.00	0.0000	n.c.	35.50	0.0007	n.c.
Syria	3,205.00	0.1087	0.19	1,536.14	0.1715	28.01
Tunisia	310.00	0.0193	260.47	174	0.0414	131.08
Turkey	64,637.00	0.2831	109.19	22,267.00	0.3898	96.90
United Arab Emirates	19.00	0.0002	n.c.	45.50	0.0017	n.c.
Palestinian Territories	0.00	0.0000	0.00	0.00	0.0000	0.00
Yemen	0.00	0.0000	n.c.	1.50	0.0010	n.c.

n.c.: Non computable, as the value for 2000 is zero

Data source: US Energy Information Administration database; own calculations

there, this might be mainly a result of the civil war.[3] In contrast, 11 countries in the region reported a share of renewable electricity generation below 1 per cent or even zero for 2013. Table 1 gives some additional information on the use of renewables in the MENA region; as WDI mainly reports the shares, but no detailed data on generation and capacity, we present data from US Energy Information Administration database (EIA) in this table, which ends in 2012.

Among the renewable energy sources, hydro power has the highest share in generation; only ten MENA countries reported electricity generation from other renewable sources than hydro in 2012. Morocco stands out, as the first country in the region, to have passed the threshold of 5 per cent of electricity generation from non-hydro renewables in 2013, with a share of 5.3 per cent, according to WDI data. Turkey follows with 4.1 per cent, and Tunisia (2.0 per cent) is the

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[3] The share of renewable electricity generation in Syria increased from 5.6 per cent in 2011 to 11.6 per cent in 2013, but according to generation data from the US Energy Information Administration database (EIA), covering the years up to 2012, absolute generation from renewable sources remained in 2011 and 2012 around the average of the last pre-war years, indicating that the increase in shares is mainly a consequence of reduced electricity generation from other sources.

only other country in the region attaining a share of more than 1 per cent.

Regarding installed capacity, the shares of renewables are higher than for electricity generation, with Iraq, Morocco and Turkey reporting a share of more than 20 per cent and Egypt, Iran and Syria of more than 10 per cent. Once more, those numbers are mainly due to hydro power; only in Egypt, Israel, Morocco, Qatar, Tunisia and Turkey the share of non-hydro renewables exceeds 1 per cent of total installed capacity, with Morocco showing the highest share of 4.8 per cent.

Meanwhile, the MENA countries face rising energy demand, calling for a rapid expansion of their electricity generation capacity. The rich endowment with renewables opens opportunities for using these local resources to cover increasing demand. This might be advantageous for two reasons: First, dependency on fossil fuels makes the economy of energy-importing countries vulnerable, for example through rising energy prices, while for the energy exporting countries, higher domestic consumption means lower revenues from oil and gas exports. Secondly, COP21 targets require lower CO_2 emissions. The large potentials for renewables could offer the MENA countries a cheap way to meet those targets.[4] However, as for example El Fadel, Rachid, El-Samra, Bou Boutros and Hashisho (2013) point out when discussing the potential contribution of renewables to emission reduction in the region, the deployment of renewables might be constrained by relatively high initial investments, although lifetime costs of renewables are relatively low.

This points to a potential trade-off between investing in renewables and economic growth, as shifting investments towards renewables could imply lower investments in other sectors, where the economic effect might be higher. On the other hand, increasingly studies discussed that investing in renewables might enhance growth, in the form of jobs and private sector development (see for example Kost (2015), de Arce, Mahía, Medina and Escribano (2012) or Supersberger and Führer (2011)).

With our paper, we want to contribute to the debate about the implications of renewable electricity deployment on economic growth from a macroeconomic perspective. Yet, the effects of renewable electricity generation on growth are widely discussed in academic literature in recent years, as one aspect of the energy-growth literature. However, only limited research on this relationship exists within the regional context of MENA (as we will discuss below). The existing studies on the renewable-growth nexus show different results, both for the question if the use of renewables and growth are linked and for the direction of this linkage, if existent. The only recent study we found that examines the relation between renewables and growth for more than one country in the MENA region, Farhani (2013), estimated different signs for the relationship between renewables and growth for different countries in the region.

We expand existing research on the renewable-growth nexus in two aspects: First, we consider not a bivariate setting of renewable energy and growth, but a multivariate one, that includes additionally capital, labor and energy use in the growth function. Secondly, we consider not only electricity generation from renewables, but also generation capacity. Our reason behind

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[4] Several studies exploring decarbonization strategies for the region point out that the use of renewables mean that "a near complete decarbonization of the power sector can be achieved at moderate costs" (Haller, Ludig and Bauer (2012), see as well for example Karakosta and Psarras (2013), Supersberger and Führer (2011) or German Aerospace Center (2005)).

this choice is the potentially negative impact on growth caused by shifting investments away from other sectors towards renewables. Thus, as increasing generation capacity is highly capital intensive, this effect—if it exists—should appear when capacity is expanded and not when generation increases, while capacity is constant.

We tackle our question concerning the renewables-growth nexus estimating the parameters of a growth function for a panel of initially 20 MENA countries and a time period from 1990 to 2012. Due to data limitations, only nine countries remain in the panel, and for some of them the time period is shorter. The most important loss of data arose as we had to exclude all countries that report zero generation from (or capacity of) renewables. We estimate the growth function individually for all countries with sufficient data, for a panel including all nine remaining countries and for several subpanels, as one could suppose that the effects of renewables on growth might be different with respect to economic development, geographic location or internal energy resources.

Our main finding is that an expansion of renewable generation capacity has a significant impact on growth only for one country (Algeria) and two subpanels (net oil exporting and North African countries). In all three cases, the estimated coefficient is positive. Generation significantly impacts growth in two countries (Morocco and Tunisia), and for all panels we considered, and this impact is always positive. So we can conclude that investing in renewables is beneficial for MENA countries.

The outline of the paper is as follows: In the next section, we give an overview on the literature relevant for our paper. Section 3 gives an overview on our data and methodology. In section 4, we present our estimation results, starting with unit-root testing, followed by estimating the impact of renewable capacity and renewable generation on growth and finishing with some robustness checks. We conclude with a discussion on policy implications.

2 Literature Review

The energy-growth literature has expanded rapidly during the last decades. As the ‘simple’ energy-growth nexus is not the focus of our paper, we do not discuss this literature in detail here; rather, we focus on studies that have examined this relationship in the MENA context. An overview on the different papers and their results for the energy-growth nexus can be found for example in Iyke (2015), a recent meta-study was conducted by Menegaki (2014).

For the MENA region, one of the newest studies on the energy-growth nexus is Kayıkçı and Bildirici (2015), assessing the nexus between output, electricity consumption and oil rents. They find that higher electricity consumption leads to higher GDP growth for most resource-rich countries in their sample, while the causality is reversed for most of the countries with low natural resources. Tang and Abosedra (2014) also show positive impact from energy consumption to economic growth, with tourism, gross capital formation and political stability as explanatory variables besides energy consumption. Their results hold for different estimation techniques (pooled OLS, random and fixed effects, fixed effects with panel corrected standard errors and one- and two-step dynamic GMM).

The nexus between renewable energy and growth has become one important branch of the energy-growth literature during the last years. In his meta-analysis, Sebri (2015) found 40 studies with 153 settings examining this topic up to December 2013, including working papers and some grey literature. He shows that the studies come to different conclusions with respect to the renewables-growth nexus and its direction. These differences are due to model specification, time frame, and the level of development of the countries taken into account. With regards to the latter, he shows that for both developed and developing countries the probability of finding a positive effect running from renewables to growth (the so called "growth hypothesis") is higher when countries are grouped into different panels based on their stage of development, compared to panels that combine countries in different stages of development.

For the MENA region, Farhani (2013) assesses the linkage between renewable energy consumption, growth and CO_2 emissions. He finds no causal linkage between renewables and GDP in the short run, while GDP growth has influence on renewable energy consumption in the long run; the sign, however, differs within the countries and is not significant for the overall panel.

On a single-country level in the MENA region, Dogan (2015) found no causality between renewable electricity consumption and economic growth in Turkey. For the same country, Ocal and Aslan (2013) showed that the impact of renewables on growth in negative, but causality is running from growth to renewables. The difference between both studies might be a result of the different variables they used: Dogan included non-renewable and renewable electricity consumption in absolute values, Ocal and Aslan combustible renewables and waste as share of total energy use. For Tunisia, Ben-Salha and Sebri (2014) found a bidirectional, positive relationship between renewable energy consumption and growth.

One problem of the energy-growth literature is that a large part uses bivariate settings, i.e. energy consumption or renewable energy consumption as sole explanatory variable for growth (see for example Mohammadi and Parvaresh (2014), Bouoiyour and Selmi (2013) or Damette and Seghir (2013)). This might lead to bias due to omitted variables. With respect to growth models, the missing variables are particularly capital and labor as widely accepted input factors to the growth function (which are, for example, used in Apergis, Payne, Menyah and Wolde-Rufael (2010)).

A second problem is how renewable energy variables are integrated in the model. Some studies replace energy consumption in the growth function by renewable energy consumption, renewable electricity generation or other renewable energy variables (see for example Ben Aïssa, Ben Jebli and Ben Youssef (2014), Farhani (2013) or Apergis et al. (2010)). This might be misleading as renewable energy consumption might then serve as proxy for total energy consumption. As a result, results might be misinterpreted: It could be that using renewables instead of conventional energy sources reduces growth, while expanding energy consumption increases it. If the second effect were stronger than the first, the results would show a positive impact from renewables to growth, although growth would be higher if other energy sources were used.

3 Data and Methods

To deal with the two problems described above, we use a growth model that includes capital, labor, energy and capacity for electricity generation from renewable sources or the generation from renewable sources.

Data on GDP, gross fixed capital and labor force comes from World Bank's World Development Indicators database (WDI). For GDP, we use the GDP in constant 2005 US$, for capital, gross fixed capital formation in constant 2005 US$[5], for the labor force the total labor force (number of people) and for the energy variable energy use in kilotons of oil equivalent. Our data on generation from renewables and available capacity is from the US Energy Information Administration's database (EIA): total renewable electricity net generation in billion kWh and electricity generation capacity from renewable sources in gigawatt (GW).

Our initial dataset covers the years 1990 to 2012. The year 1990 is set by the availability of data on the labor force, the year 2012 by the availability of detailed data on electricity generation and capacity. For several countries, the time span is shorter than the period 1990 to 2012 due to missing data for at least one end of our time frame (the available time period for each country is reported in table 2). This makes our panel unbalanced.

In addition, countries dropped out of the panel as data is not available for all variables, or only for a period that is too short for an estimation. As we are using logarithms of the variable, this affects all countries that report zero or missing data for their generation and capacity for renewables for all years from 1990 to 2012. Thus, we had to exclude Bahrain, Kuwait (renewable generation), Libya, the Palestinian Territories, Oman (renewable generation), Qatar (renewable generation), and Yemen. For some other countries, data on gross fixed capital is only available for 2005, which leads to their exclusion, as one data point is obviously not sufficient for a valid estimation; this is why Iraq, Libya, and Syria dropped out of the panel. Bahrain, Kuwait (renewable capacity), Oman (renewable capacity), Qatar (renewable capacity), and Saudi Arabia report non-zero values on renewable electricity for the most recent years, but for those years, either data on gross fixed capital formation or the labor force is not available, leading to their exclusion. For the United Arab Emirates, complete data is available only for 2009 to 2011, which is too less for valid estimations.

Ultimately, only nine countries remained in the panel: Algeria, Egypt, Iran, Israel, Jordan, Lebanon, Morocco, Tunisia, and Turkey.

We estimate a variation of the neoclassical growth model, explaining the output (Y) by a Cobb-Douglas function of the input factors, which are here capital (C), labor (L), energy (L), and, most important for us, electricity generated from renewable sources (RE_G) or the capacity available for generation from renewables (RE_C); in addition, there is a factor measuring total productivity (B_0):

$$Y = B_0 C^{\beta_C} L^{\beta_L} E^{\beta_E} RE^{\beta_{RE}} \tag{1}$$

The use of "renewable electricity" (RE) indicates that we consider both generation (RE_G) and installed capacity (RE_C) in this context.

For the estimations, we transform the equation to logarithms, obtaining therefore a linear

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[5] Data on the capital stock is not available in WDI. It is reported in Penn World tables, but only in current PPPs and constant 2011 US$; the necessary calculations to combine the capital stock from World tables with the WDI data on GDP in constant 2005 US$ would lead to inaccuracies. Due to this, we decided to follow the common way in the literature and to proxy the capital stock with gross fixed capital formation (see for example Omri, Daly, Rault and Chaibi (2015), Apergis and Payne (2012) or Apergis et al. (2010)).

function. Moreover, as unit-root testing shows that the logged variables are mostly—but not every time—integrated of order 1 (for our testing, see section 4.1 and table 2), we use the first differences, obtaining equation 2, where lower-case letters indicate logs and Δ indicate first differences:[6]

$$\Delta y = \beta_0 + \beta_C \Delta c + \beta_L \Delta l + \beta_E \Delta e + \beta_{RE} \Delta re \qquad (2)$$

The use of first differences due to the non-stationarity of our variables means that we are explaining the GDP growth rate by the growth of the inputs into the production function, so we are not estimating the elasticities of the growth function.

We estimate equation 2, completed with the error term (ϵ), individually for all countries with sufficient data in our sample. We then proceed with a panel estimation, using a random effects GLS model, as Hausman Specification testing did not result in rejecting the null hypothesis (H_0) that random effects are more appropriate than fixed effects. We do not use more advanced models—like VAR or VEC models—for two reasons: Firstly, the time series are not always integrated of order 1, which would violate a central assumption for VAR and VEC models. Secondly, investigating the direction of the causality discussed in the energy-growth literature that uses VAR or VEC models is not very important for our research question: In the energy-growth literature, a causality from energy to growth (the so-called "growth hypothesis", or, if causality is bidirectional, "feedback hypothesis") would mean that energy conservation policy might result in lower growth rates, while it would have no negative effect if causality is reverse (the "conservation hypothesis") or does not exist ("neutrality hypothesis") (see, among others, Apergis et al. (2010)). In our context, the impact of energy conservation policies on growth is not important, as we discuss the effects of shifting energy consumption from fossil to renewable sources on growth and not reducing energy consumption or its increase (although decoupling growth from increasing energy consumption might also be beneficial for MENA countries). In this setting, the direction of causality is a minor concern.

In addition to the panel including all countries, we set up several subpanels. As the results of Sebri (2015) or for example Kahsai, Nondo, Schaeffer and Gebremedhin (2012) indicate that the growth effect of renewables might depend on the level of development, we set up a panel that only includes countries classified as middle income countries by the World Bank (combining the upper middle and the lower middle income category); those are Algeria, Egypt, Iran, Jordan, Lebanon, Morocco, Tunisia, and Turkey. Only one high income country, Israel, reports sufficient data for an estimation, so a high income subpanel is meaningless, and no country in the region is classified as "low income".

One other aspect discussed in the literature is that the impact of renewable electricity on growth might depend on the country's resources, particularly on oil (see for example Mohammadi and Parvaresh (2014) or Damette and Seghir (2013)). For this, we differ in our subpanels between net oil exporting and net oil importing countries (in terms of crude oil). The net oil exporting countries in the panel are Algeria, Egypt, Iran, and Tunisia, the net oil importing

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[6] Note that including a constant, β_0, in equation 2 means that there is a time trend in the output if β_0 is significant. This is a result of differencing, as a non-time dependent constant would drop out (as $\beta - \beta$ is obviously zero), while a time-dependent coefficient remains with factor 1 (as $\beta t - \beta(t-1) = \beta$). This time trend might for example be explained with an increase of total productivity.

countries thus Israel, Jordan, Lebanon, Morocco, and Turkey.[7]

A third aspect might be geography, so we set up a subpanel including the North African MENA countries (Algeria, Egypt, Morocco, Tunisia). Once more, we cannot show estimations for other geographic subpanels like the Gulf region due to limited data.

For comparability, we estimated all subpanels with a random-effects GLS model. As the Hausman specification test leads to the rejection of H_0 of random effects being more appropriate for the subpanel of net oil exporting countries (both for renewable generation and renewable capacity) and the middle income countries (only for renewable capacity), we also estimated for those subpanels a fixed effects model.

4 Empirical results

4.1 Unit root tests

Table 2 shows the results of augmented Dickey-Fuller unit root tests for all variables and for each of the countries in our panel and the respective time period for which data is available for all variables. GDP and energy are always integrated of order 1. Renewable generation and renewable capacity is integrated of order 1 in most cases, but on a significance level of 10 percent, we could reject H_0 of non-stationarity already for the levels for Algeria (renewable generation) and Turkey (renewable capacity). For Algeria, Israel and Morocco, capital is stationary only in the second difference, the same is true for the labor force in Iran. For Israel, the labor force is not even stationary in the second difference, and for Algeria, Jordan, Morocco and Tunisia, it is already stationary in levels. Those results were confirmed by the Phillips-Perron unit root test we also performed.[8]

Thus, we cannot conclude that all our variables are integrated of order 1, and therefore, we cannot apply cointegration analysis to discuss the question of causality. This is why we decided to “fall back” on the simpler concept of regression analysis.

A second crucial decision we made is to use LS estimations in first difference although we have some countries where one variable is non-stationary in the first difference. Our consideration is that the assumption of a $I(1)$ process is true for most of our variables, and that we want to apply the same model to all countries. However, we stress that one should read the estimation results carefully, particularly for regarding the magnitude of the estimated coefficients.

The unit root test for our panel and the different subpanels are much less complicated. With two exceptions, the Im-Pesaran-Shin (IPS) tests which we report in table 3 shows that all series contain a unit root in levels, and that in first differences, at least one group is stationary, when we use a significance level of five per cent. The two exceptions are the labor force for the net oil exporters, where the IPS test suggests that the first difference contains only series with a unit root and for North Africa, where we should reject H_0 that all series contain a unit root already in levels. On a significance level of 10 per cent, we could reject H_0 that all series contain a unit root for renewable generation in the North Africa subpanel. Here, we again decided to rely

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[7] We classify a country as “net crude oil exporter” when exports exceeded imports for the majority of years between 1990 and 2012. For example, Egypt was a net importer of crude oil from 2005 to 2007, but net exporter for all other years, so we included the country to the panel of net oil exporting countries.

[8] We decided not to report the results of the Phillps-Perron test as it do not give additional information.

Table 2: Results of unit root testing for individual countries (augmented Dickey-Fuller test)

Country	Time series		y	c	l	e	re_C	re_G
Algeria	1990 to 2009	level	1.303	3.907	***−9.373	1.781	−2.236	*−2.689
		first difference	*−2.587	−1.161		**−3.461	**−3.958	***−6.327
		second difference		***−5.771				
Egypt	1990 to 2011	level	1.161	0.176	1.285	0.461	1.068	−1.477
		first difference	**−3.013	**−3.205	***−4.618	***−4.189	***−4.221	***−6.976
Iran	1990 to 2007	level	0.743	−0.642	0.531	−0.645	1.951	−0.508
		first difference	*−2.825	**−3.011	−0.78	***−6.729	**−3.140	**−2.871
		second difference			**−3.121			
Israel	1995 to 2012	level	−0.401	0.848	1.521	−0.824	0.536	0.933
		first difference	***−7.031	−2.558	−2.386	***−6.893	***−4.057	**−3.062
		second difference		***−3.504	−1.826			
Jordan	1990 to 2011	level	−0.513	−1.04	***−5.021	−1.303	−0.424	−1.165
		first difference	***−4.291	***−4.105		***−4.725	***−4.487	***−5.655
Lebanon	1994 to 2011	level	1.58	0.106	0.443	−2.118	−1.891	−2.275
		first difference	*−2.712	**−3.188	−1.42	***−3.584	***−3.559	***−3.909
		second difference			**−3.111			
Morocco	1990 to 2011	level	0.307	0.889	*−2.652	0.104	−1.44	−1.925
		first difference	***−10.236	−2.551		***−5.758	***−5.034	***−4.835
		second difference		***−5.129				
Tunisia	1990 to 2005	level	−0.214	−1.411	***−6.069	−0.724	−0.563	−1.319
		first difference	***−4.784	**−3.556		***−10.765	***−3.506	***−4.013
Turkey	1990 to 2005	level	0.146	−1.129	−1.394	−0.494	*−2.715	−2.038
		first difference	***−4.666	***−4.541	***−5.285	***−5.327	−2.069	***−4.396

Missing countries: Insufficient data for estimations

*, **, *** mark significance for rejecting H_0 of a unit root on a significance level of 10, 5 or 1 per cent, respectively

on estimations in first differences, with the same underlying considerations presented for the individual estimations

4.2 Renewable capacity and growth

Table 4 reports the results of our estimations for the model including renewable capacity and for individual countries, while table 5 reports the model for the panel and the subpanels.

For individual countries, the impact of renewable generation capacity on growth is significant (on a level of 5 per cent) only for Algeria, and here, it is positive. For the panel and the subpanels, we also only find evidence for a positive impact of renewable capacity on growth, specifically for the net oil exporting countries (regardless whether we use random or fixed effects) and for the North African countries. You should notice that both subpanels include Algeria, the only country where renewable capacity has a significantly positive impact on growth.

Those results point out that we can reject our hypothesis that investing in renewable generation capacity might hinder economic growth. Quite in contrary, there is some evidence that investing in renewable generation capacity even enhances growth.

Regarding the other variables in our growth model, capital has a positive impact on growth for almost all countries (exceptions are Algeria and Morocco), as well as in the panel and all subpanels. By contrast, growth of the labor force and of energy use do not have any significant impact on economic growth for individual countries; for the panels of net oil importing countries and of middle-income countries, the impact of the latter is positive. The constant is significant for almost all estimations (with the exception of Algeria and Morocco, the latter being by far the worst model), indicating that in levels, there is a time trend influencing growth.

4.3 Renewable generation and growth

By comparison to the renewable capacity model, there is more evidence for a positive impact of renewable generation on growth: The estimations show significant and positive coefficients for the panel and all subpanels, as table 7 shows. In addition, we can identify a positive impact for two countries, reported in table 6: for Morocco (with a high value of 0.064) and Tunisia (0.0235, close to the estimated coefficients for the panels). Within the panels, the coefficient for renewable electricity generation varies only slightly. The results could suggest that the impact of renewables on growth might be smaller in net oil exporting countries, as the coefficient is only at 0.0150, compared to 0.0196 for the overall panel. However the confidence intervals overlap to a large extend, so we cannot conclude a significant difference.[9]

The coefficients for all other variables and the intercept remain almost unchanged when we replace renewable capacity with generation. For Algeria, the intercept is higher and becomes significant on a 10 per cent level, and for Jordan, the coefficient for energy use turns significant on the same level, although it is almost unchanged (for the capacity case, the probability for rejecting that the coefficient is zero was at 0.11, so that the slight change in its magnitude and standard error was sufficient to show significance).

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[9] The 95 per cent confidence interval for the overall panel and renewable generation spans from 0.0105 to 0.0287, while it covers 0.0048 to 0.0252 for the net oil exporting countries.

Table 3: Results of unit-root testing for panel data (Im-Pesaran-Shin test)

Country		y	c	l	e	re_C	re_G
Panel	level	-0.0534	0.1156	-2.3344	-0.6455	-0.4695	-1.5558
	first difference	***-4.5600	***-3.2161	***-2.7023	***-6.0009	***-4.0651	***-4.9668
Net oil exporting countries	level	0.225	0.32	-3.407	-0.127	0.194	-1.7412
	first difference	***-3.3867	***-2.8125	-1.98	***-6.5264	***-3.7796	***-5.1126
	second difference			***-4.7741			
Net oil importing countries	level	-0.2894	-0.0275	-1.4461	-1.2164	-0.9848	-1.418
	first difference	***-5.4907	***-3.5676	***-3.2378	***-5.7761	***-4.2696	***-4.8042
Middle income countries	level	0.2422	0.024	-2.7841	-0.6067	-0.6084	-1.8768
	first difference	***-4.7184	***-3.2984	***-2.7621	***-5.8906	***-4.0571	***-5.2045
North African countries	level	0.436	0.774	**-4.2023	0.078	-0.753	*-2.1223
	first difference	***-5.4413	***-2.8175	**-2.4218	***-6.2760	***-4.2977	***-5.6268

*, **, *** mark significance for rejecting H_0 that all panels contain a unit root on a significance level of 10, 5 or 1 per cent, respectively

Table 4: Estimation results for individual countries, including renewable electricity generation capacity

	Algeria	Egypt	Iran	Israel	Jordan	Lebanon	Morocco	Tunisia	Turkey
β_C	0.0939	**0.0873	***0.2177	**0.2305	***0.1373	***0.2139	0.0256	*0.1679	***0.2352
	(0.0817)	(0.0353)	(0.0363)	(0.0873)	(0.0384)	(0.0370)	(0.2237)	(0.0761)	(0.0342)
β_L	−0.3370	0.1342	−0.3002	−0.0068	0.0231	0.1014	−0.9859	0.0206	−0.0596
	(0.7006)	(0.1567)	(0.2129)	(0.2076)	(0.1533)	(0.3973)	(0.7343)	(0.4648)	(0.1311)
β_E	0.0887	−0.0766	−0.0754	0.0906	0.1931	0.0432	0.1633	0.1541	0.1980
	(0.1654)	(0.0691)	(0.0963)	(0.1089)	(0.1167)	(0.0511)	(0.3630)	(0.1102)	(0.1170)
β_{RE_C}	**1.0735	0.0848	0.0602	0.0031	−0.0598	−0.4822	0.1567	0.0805	−0.0227
	(0.4638)	(0.1827)	(0.0464)	(0.0107)	(0.0548)	(0.5347)	(0.1342)	(0.0562)	(0.0587)
β_0	0.0334	***0.0391	***0.0415	***0.0294	***0.0433	*0.0314	0.0428	**0.0311	***0.0222
	(0.0266)	(0.0048)	(0.0105)	(0.0095)	(0.0098)	(0.0149)	(0.0265)	(0.0111)	(0.0060)
Observations	19	21	17	17	21	17	21	15	22
Adjusted R^2	0.6693	0.5969	0.7991	0.6910	0.7313	0.8473	0.3334	0.8744	0.9220
F statistic	2.88	3.00	11.14	2.44	6.92	10.41	0.94	3.29	68.07

Numbers in parantheses: Standard Errors

*, **, *** mark significance for rejecting H_0 that the estimated coefficient is zero on a significance level of 10, 5 or 1 per cent, respectively

Table 5: Estimation results for panels, including renewable electricity generation capacity

	Random Effects					Fixed Effects	
	All countries	Net oil exporting countries	Net oil importing countries	Middle income countries	North African countries	Net oil exporting countries	Middle income countries
β_C	***0.1752	***0.1482	***0.1869	***0.1711	***0.0764	***0.1496	***0.1724
	(0.0191)	(0.0245)	(0.0280)	(0.0204)	(0.0449)	(0.0236)	(0.0200)
β_L	−0.0537	−0.1890	0.0442	−0.0103	−0.3434	−0.0884	−0.1011
	(0.0907)	(0.1325)	(0.1175)	(0.0958)	(0.2134)	(0.1341)	(0.1058)
β_E	***0.0773	−0.0106	**0.1272	***0.0756	0.0928	−0.0224	***0.0752
	(0.0398)	(0.0531)	(0.0578)	(0.0434)	(0.0896)	(0.0537)	(0.0432)
β_{RE_C}	0.0084	***0.0953	0.0047	0.0481	**0.1320	**0.0826	0.0410
	(0.0113)	(0.0348)	(0.0133)	(0.0313)	(0.0572)	(0.0384)	(0.0329)
β_0	***0.0321	***0.0362	***0.0296	***0.0302	***0.0372	***0.0343	***0.0329
	(0.0042)	(0.0046)	(0.0053)	(0.0040)	(0.0069)	(0.0047)	(0.0042)
Observations / series	163/9	72/4	90/5	146/8	76/4	72/4	146/8
Overall R^2	0.4005	0.4327	0.4321	0.4071	0.1604	0.4270	0.4033
Wald Chi^2 statistic (F statistic for fixed effects)	111.62	51.10	64.68	96.83	13.57	12.50	25.47

Numbers in parantheses: Standard Errors

*, **, *** mark significance for rejecting H_0 that the estimated coefficient is zero on a significance level of 10, 5 or 1 per cent, respectively

Table 6: Estimation results for individual countries, including renewable electricity generation

	Algeria	Egypt	Iran	Israel	Jordan	Lebanon	Morocco	Tunisia	Turkey
β_C	0.0681	***0.0940	***0.2132	**0.2396	**0.1034	***0.2227	0.1383	**0.1729	***0.2488
	(0.0861)	(0.0295)	(0.0369)	(0.0834)	(0.0393)	(0.0380)	(0.1737)	(0.0639)	(0.0373)
β_L	−0.9321	0.0589	−0.2995	0.0127	0.1423	0.0170	−0.4161	−0.0268	−0.0306
	(0.7020)	(0.1618)	(0.2122)	(0.2013)	(0.1575)	(0.4243)	(0.5567)	(0.3948)	(0.1292)
β_E	−0.0656	−0.1055	−0.1111	0.0220	*0.2092	0.0299	0.4503	**0.2434	0.1957
	(0.1847)	(0.0669)	(0.0909)	(0.1144)	(0.1114)	(0.0505)	(0.2634)	(0.0996)	(0.1143)
β_{RE_G}	0.0128	0.0425	0.0240	−0.0117	0.0228	−0.0023	***0.0640	**0.0235	−0.0180
	(0.0078)	(0.0330)	(0.0181)	(0.0126)	(0.0164)	(0.0131)	(0.0174)	(0.0092)	(0.0203)
β_0	*0.0555	***0.0416	***0.0469	***0.0331	***0.0347	*0.0336	0.0173	**0.0282	***0.0208
	(0.0270)	(0.0049)	(0.0095)	(0.0087)	(0.0089)	(0.0161)	(0.0213)	(0.0095)	(0.0045)
Observations	19	21	17	17	21	17	21	15	22
Adjusted R^2	0.5520	0.6016	0.7360	0.6413	0.7718	0.8385	0.6498	0.9041	0.9056
F statistic	2.01	3.63	11.22	2.78	7.40	9.59	4.42	5.42	70.78

Numbers in parantheses: Standard Errors

*, **, *** mark significance for rejecting H_0 that the estimated coefficient is zero on a significance level of 10, 5 or 1 per cent, respectively

Table 7: Estimation results for panels, including renewable electricity generation

	Random Effects					Fixed Effects
	All countries	Net oil exporting countries	Net oil importing countries	Middle income countries	North African countries	Net oil exporting countries
β_C	$^{***}0.1674$	$^{***}0.1596$	$^{***}0.1691$	$^{***}0.1648$	$^{**}0.0889$	$^{***}0.1589$
	(0.0181)	(0.0241)	(0.0269)	(0.0186)	(0.0421)	(0.0227)
β_L	-0.0512	-0.1633	0.0586	-0.0550	-0.3146	-0.0876
	(0.0862)	(0.1310)	(0.1104)	(0.0937)	(0.1994)	(0.1300)
β_E	$^{**}0.0828$	-0.0280	$^{***}0.1502$	$^{***}0.0725$	0.1027	-0.0523
	(0.0375)	(0.0527)	(0.0544)	(0.0397)	(0.0830)	(0.0510)
β_{RE_G}	$^{***}0.0196$	$^{***}0.0150$	$^{***}0.0253$	$^{***}0.0235$	$^{***}0.0265$	$^{***}0.0146$
	(0.0046)	(0.0052)	(0.0076)	(0.0050)	(0.0065)	(0.0049)
β_0	$^{***}0.0315$	$^{***}0.0373$	$^{***}0.0280$	$^{***}0.0321$	$^{***}0.0366$	$^{***}0.0363$
	(0.0040)	(0.0045)	(0.0048)	(0.0045)	(0.0065)	(0.0045)
Observations / series	$163/9$	$72/4$	$90/5$	$146/8$	$76/4$	$163/9$
Overall R^2	0.4566	0.4381	0.4969	0.4745	0.2677	0.4337
Wald Chi^2 statistic (F statistic for fixed effects)	141.55	52.25	83.97	137.89	25.95	14.26

Numbers in parantheses: Standard Errors

*, **, *** mark significance for rejecting H_0 that the estimated coefficient is zero on a significance level of 10, 5 or 1 per cent, respectively

4.4 Robustness checks

The results discussed in the previous two sections show that there is evidence for an influence of renewable electricity on growth, especially in the case of renewable electricity generation. However, the question remains if our models really report an effect of renewable electricity, or if renewable electricity serves as proxy for another, not included effect. We control for this possibility with two robustness checks.

One concern might be that we used both energy use and renewable electricity in our estimations. We did this to separate the impact of renewable electricity on GDP from the overall—and widely agreed—effect of energy on GDP, but one might argue that the parallel use split the effect of energy on two variables. To check for this, we run our estimations without the renewable electricity variable, i.e. explaining GDP growth only with the growth of capital, labor and energy use. When we do this for our panel estimations, the coefficients for the remaining variables change only slightly, and particularly the coefficient for energy use remains almost unchanged and do not turn significant for one panel or subpanel where it was not significant when we included renewable electricity. In addition, the parameters for model quality, the overall R^2 and the Wald-Chi^2 statistic, fell remarkably. On the country level, the estimated coefficients change a little stronger than in the panel (but mainly for non-significant coefficients), and energy use becomes significant in Jordan when we omit renewable electricity capacity, while for Tunisia, it becomes insignificant for the case of omitting renewable generation. With the exception of Turkey, adjusted R^2 is lower when we do not include renewable electricity; in Turkey, the adjusted R^2 for the model without renewable electricity is slightly higher than for the model including it (0.9154 to 0.9056). The values for the F statistics are mostly higher in the smaller model, but this might be a result of the low degrees of freedom for individual countries. In total, we can conclude that our check suggests strongly that renewable electricity measures an effect on growth not covered by energy use.

A second argument might be that renewable electricity does not has an effect itself, but is a proxy for an (unknown) effect of electricity use in general. We tested for this by replacing renewable electricity generation with total electricity generation and renewable capacity with total capacity. For the capacity case in the panels, total electricity capacity has a significant effect in net oil exporting and North African countries (the only both subpanels where the effect of renewable capacity was significant as well), but deviating from the renewable case, it is negative for both subpanels. With respect to generation, total generation is significant in the overall panel and the subpanel of net oil exporters, with a coefficient that is significantly higher than for renewable generation. However, in both cases, the coefficient for energy use becomes lower and turns insignificant for the overall panel (for the net oil exporters subpanel, it is insignificant in both cases). This suggests that the estimated higher impact of total electricity generation than for renewable generation is a result of taking over a part of the coefficient of the energy use variable. On the country level, total electricity capacity is significant only for Algeria (where renewable capacity is significant as well) but once more, the sign is negative. Regarding electricity generation, total generation has a significant and remarkable high effect in Jordan (the estimated coefficient is 0.3197), but once more, it rules out energy use, and we did not have evidence that renewable electricity generation influences GDP in first differences in this country.

Both robustness checks delivered no evidence that the positive impact from renewables on growth—in some subpanels and one country with respect to renewable capacity expansion, in the panel, all subpanels and for two countries, when we regard renewable generation—is a mismeasurement due to any unobserved factor proxied by renewable electricity. Therefore, we can conclude that renewable electricity is in fact enhancing growth in the MENA region.

5 Conclusions and policy implications

Our results show that renewable electricity generation has a significant and positive effect on economic growth. We could show this effect only for two countries (Morocco and Tunisia), but it holds for the panel of all eight MENA countries reporting sufficient data and for all subpanels we considered. Renewable capacity expansion impacts growth positively in Algeria and in the subpanels for net oil exporting and North African countries.

These results suggest that increasing investments in renewable energy technologies and expanding their deployment (i.e. enlarging the market for renewable energy) might enhance growth in the MENA region. Although evidence for single countries is weak, the large positive effect of increasing renewable generation on growth in Morocco, one of the countries in the region investing most strongly in renewables, suggests that a positive effect of renewable generation exists for single countries, but cannot be shown for most other countries due to their very low level of renewable energy deployment.

The positive effect we showed in our estimations might be a result of sizable socio-economic effects that could be captured when investing in renewables, in the form of jobs and private sector development. As we already mentioned in the introduction, recent studies have shown that that such effects can be sizable over a longer period of time and following consistent investments in renewables (see for example Kost (2015); de Arce et al. (2012)). Therefore, our results suggest that in spite of high investment costs in renewables, policy makers should continue efforts to expand the share of renewables in energy generation, as positive effects on the economy are to be expected.

Further, increasing energy demand, expected to reach an average yearly rate of 5 to 6 per cent in the MENA region in the coming two decades (International Energy Agency (2014)), will call for further solutions to diversifying the energy mix. These positive effects from renewable electricity generation materialize in our results both for net oil importing and net oil exporting countries, although the effects might be smaller for the latter. This might be a result of their smaller vulnerability to rising energy prices, and thus lower urgency to invest in renewables in the short term. Yet, the impact in the net oil exporting countries is significantly positive, suggesting that investing in renewable electricity generation is profitable for them as well.

Therefore, it is not surprising to see that fossil fuel rich countries, such as Saudi Arabia, the UAE, or Qatar, are currently investing heavily in renewable energy generation and in knowledge development (Al-Saleh and Vidican (2013); Vidican, McElvaney, Samulewicz and Al-Saleh (2012)). For them, investing in renewables may be a way to reduce domestic fossil fuel consumption—or to meet increasing energy demand without an increase of domestic fuel consumption—, to increase fuel exports and thus for higher revenues. Thus, renewable electricity generation reduces the opportunity costs of domestic energy consumption and increases welfare. Also, by investing in renewable energy, the Gulf countries are seeking to maintain their global competitive advantage in the energy sector. As investing in renewables in this region started heavily after 2007 and our data ends in 2012, we could not yet capture the effects of those investments on growth in the respective countries in our study.

Countries with smaller or no oil and gas reserves have been primarily to address energy security concerns by reducing their dependency on fossil fuel imports. Given that worldwide the demand for oil and gas is increasing and the costs for further resource exploration are rising, this once more leads to the suggestion that additional investments in renewable generation capacity might be a contribution to a positive economic future, reducing their vulnerability with regard to changes of fossil-fuel prices on the world market. That currently oil prices have stabilized at a low level and are not expected to increase at previous levels will probably not undermine current investments in alternative energy technologies. History has shown us that, especially as fossil-fuel reserves originate from countries with fragile political systems, vulnerabilities in oil prices are likely to persist on the world market.

Summing up, our results suggest that MENA countries do stand to profit from investments in renewables. This might be a stimulus for governments in the region to continue and intensify policies enhancing the use of renewables, as the potential for renewable energy deployment in the MENA is enormous. To enhance the positive economic effects on growth, policy-makers should also actively use industrial policy tools to support local manufacturing and service provision associated with renewables and to expand technology transfer, creating opportunities for spillover effects on the larger economy.

Yet, detailed empirical estimation of these effects remains challenging due to available data. We see more research needed in identifying ways to deal with missing data and in performing more in-depth analyses at country-level where these effects can be specified more precisely.

References

Al-Saleh, Y. & Vidican, G. (2013). Innovation dynamics of sustainability journeys for hydrocarbon-rich countries. *International Journal of Innovation and Sustainable Development*, *7*(2), 144–171. doi: 10.1504/IJISD.2013.053320

Apergis, N. & Payne, J. E. (2012). Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. *Energy Economics*, *34*(3), 733–738. doi: 10.1016/j.eneco.2011.04.007

Apergis, N., Payne, J. E., Menyah, K. & Wolde-Rufael, Y. (2010). On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. *Ecological Economics*, *69*(11), 2255–2260. doi: 10.1016/j.ecolecon.2010.06.014

Ben Aïssa, M. S., Ben Jebli, M. & Ben Youssef, S. (2014). Output, renewable energy consumption and trade in Africa. *Energy Policy*, *66*, 11–18. doi: 10.1016/j.enpol.2013.11.023

Ben-Salha, O. & Sebri, M. (2014). A Multivariate Analysis of the Causal Flow between Renewable Energy Consumption and GDP in Tunisia. *Economics Bulletin*, *34*(4), 2396–2410.

Bouoiyour, J. & Selmi, R. (2013). The Nexus between Electricity Consumption and Economic Growth in MENA Countries. *Energy Studies Review*, *20*(2), 24–44.

Damette, O. & Seghir, M. (2013). Energy as a driver of growth in oil exporting countries? *Energy Economics*, *37*, 193–199. doi: 10.1016/j.eneco.2012.12.011

de Arce, R., Mahía, R., Medina, E. & Escribano, G. (2012). A simulation of the economic impact of renewable energy development in Morocco. *Energy Policy*, *46*, 335–345. doi: 10.1016/j.enpol.2012.03.068

Dogan, E. (2015). The relationship between economic growth and electricity consumption from renewable and non-renewable sources: A study of Turkey. *Renewable and Sustainable Energy Reviews*, *52*, 534–546. doi: 10.1016/j.rser.2015.07.130

El Fadel, M., Rachid, G., El-Samra, R., Bou Boutros, G. & Hashisho, J. (2013). Emissions reduction and economic implications of renewable energy market penetration of power generation for residential consumption in the MENA region. *Energy Policy*, *52*, 618–627. doi: 10.1016/j.enpol.2012.10.015

Farhani, S. (2013). Renewable Energy Consumption, Economic Growth and CO2 Emissions: Evidence from Selected MENA Countries. *Energy Economics Letters*, *1*(2), 24–41. Retrieved from `http://ssrn.com/abstract=2294995`

German Aerospace Center. (2005). *Concentrating Solar Power for the Mediterranean Region. Final Report.* Stuttgart. Retrieved from `http://www.dlr.de/Portaldata/1/Resources/portal_news/newsarchiv2008_1/algerien_med_csp.pdf`

Haller, M., Ludig, S. & Bauer, N. (2012). Decarbonization scenarios for the EU and MENA power system: Considering spatial distribution and short term dynamics of renewable generation. *Energy Policy*, *47*, 282–290. doi: 10.1016/j.enpol.2012.04.069

International Energy Agency. (2014). *Morocco 2014: Energy policies beyond IEA countries.* Paris.

Iyke, B. N. (2015). Electricity consumption and economic growth in Nigeria: A revisit of the energy-growth debate. *Energy Economics*, *51*, 166–176. doi: 10.1016/j.eneco.2015.05.024

Kahsai, M. S., Nondo, C., Schaeffer, P. V. & Gebremedhin, T. G. (2012). Income level and the energy consumption–GDP nexus: Evidence from Sub-Saharan Africa. *Energy Economics*, *34*(3), 739–746. doi: 10.1016/j.eneco.2011.06.006

Karakosta, C. & Psarras, J. (2013). Understanding CDM potential in the Mediterranean basin: A country assessment of Egypt and Morocco. *Energy Policy*, *60*, 827–839. doi: 10.1016/j.enpol.2013.05.078

Kayıkçı, F. & Bildirici, M. E. (2015). Economic Growth and Electricity Consumption in GCC and MENA Countries. *South African Journal of Economics*, *83*(2), 303–316. Retrieved from `http://onlinelibrary.wiley.com/doi/10.1111/saje.12061/epdf`

Kost, C. P. (2015). *Renewable energy in North Africa: Modeling of future electricity scenarios and the impact on manufacturing and employment* (Vol. 7). Dresden.

Menegaki, A. N. (2014). On energy consumption and GDP studies; A meta-analysis of the last two decades. *Renewable and Sustainable Energy Reviews*, *29*, 31–36. doi: 10.1016/

j.rser.2013.08.081

Mohammadi, H. & Parvaresh, S. (2014). Energy consumption and output: Evidence from a panel of 14 oil-exporting countries. *Energy Economics*, *41*, 41–46. doi: 10.1016/j.eneco.2013.11.002

Ocal, O. & Aslan, A. (2013). Renewable energy consumption–economic growth nexus in Turkey. *Renewable and Sustainable Energy Reviews*, *28*, 494–499. doi: 10.1016/j.rser.2013.08.036

Omri, A., Daly, S., Rault, C. & Chaibi, A. (2015). Financial development, environmental quality, trade and economic growth: What causes what in MENA countries. *Energy Economics*, *48*, 242–252. doi: 10.1016/j.eneco.2015.01.008

Sebri, M. (2015). Use renewables to be cleaner: Meta-analysis of the renewable energy consumption–economic growth nexus. *Renewable and Sustainable Energy Reviews*, *42*, 657–665. doi: 10.1016/j.rser.2014.10.042

Supersberger, N. & Führer, L. (2011). Integration of renewable energies and nuclear power into North African Energy Systems: An analysis of energy import and export effects. *Energy Policy*, *39*(8), 4458–4465. doi: 10.1016/j.enpol.2010.12.046

Tang, C. F. & Abosedra, S. (2014). The impacts of tourism, energy consumption and political instability on economic growth in the MENA countries. *Energy Policy*, *68*, 458–464. doi: 10.1016/j.enpol.2014.01.004

Vidican, G., McElvaney, L., Samulewicz, D. & Al-Saleh, Y. (2012). An empirical examination of the development of a solar innovation system in the United Arab Emirates. *Energy for Sustainable Development*, *16*(2), 179–188. doi: 10.1016/j.esd.2011.12.002