Review of energy-growth nexus: A panel analysis for ten Eurasian oil exporting countries

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1. Introduction

The growth theories show that sustainability of economic growth is one of the key points, which, amongst other preconditions, depends on the effective use of production factors [114,123,124,16]. Energy, as one of the important factors of growth has attracted great attention in the last four decades [79,18,2]. Energy and growth are interrelated: on the one hand, energy is an important factor of production [113,130], on the other, economic growth results in higher living standards, which in turn boosts energy consumption [143,87,127]. Thus, a relationship between energy and growth has been a crucial topic in the literature over the last four decades since the pioneering study by Kraft and Kraft [76].

It is worth noting that most of the energy-growth nexus studies are devoted to the developed and developing oil importing countries [35–37,48,52,53,82,117,125,126]. The majority of the prior studies have examined the nexus in mixes of developing oil exporters and oil importers since their research aim was country group or region, but not the oil exporters specifically (see [6,22]). As [107,42], among others state, few studies have investigated the energy-growth nexus in a pure set of oil-exporting developing economies. Consequently, there is a gap in the literature on oil exporting developing economies. Many oil exporting developing economies are located in Eurasia, concentrated in the Middle East (ME) and Commonwealth of Independent States (CIS). However, we are not aware of studies investigating the energy-growth nexus for a pure set of oil exporting developing economies of Eurasia, including those from the CIS and ME.

Furthermore, there are only few studies [104,107,116] examining this nexus for a pure set of ME oil exporters to the best of our review. However, as discussed in the next section, oil exporters in ME and CIS...
Electricity Consumption-growth nexus implies that policymakers can find an evidence of growth hypothesis in the Primary Energy Consumption-growth nexus. Consumption can deter economic growth, as we find an evidence of growth hypothesis in the Primary Energy Consumption-growth nexus. Policymakers in the selected countries should consider that any policy implementations aimed at reducing the Primary Energy Consumption-growth nexus can deter economic growth, as we find an evidence of growth hypothesis in the Primary Energy Consumption-growth nexus. Conversely, validity of the neutrality hypothesis in the Residential Electricity Consumption-growth nexus implies that policymakers can pursue conservation policy by reconsidering the subsidies and or prices for Residential Electricity Consumption. Briefly note that this policy measure has been implemented in some countries, including Saudi Arabia, UAE, Kuwait and Azerbaijan in 2016 due to the drop in oil price and thus in government revenues.

2. Background

As mentioned in the section above, the ME and CIS oil exporters have some features, which make them an interesting case to study from the energy-growth perspective. In this section, we briefly discuss these features. The section describes first the role of the countries in the energy world and then the importance of oil (and gas) exports in these economies. It finally, illustrates how economic growth and energy consumption in these countries evolve over the last two decades.

It is worth mentioning that a number of oil-exporters in the region, especially GCC countries, as members of OPEC, play a decisive role in the dynamics and management of the world’s energy markets and their role will be more crucial in the future (inter alia). Yet, the CIS oil exporters have also become important players in the world’s energy markets as non-OPEC oil producers and distribution centers (among others). World Bank reports that the CIS oil exporters account for 15% of global oil production, while calculations based on the United States Energy Information Administration data show that they had an average 12% of the total world oil supply over the period 1992–2012 (141,136)]. Note that the six out of top ten countries over the world in terms of proven reserves and exports of crude oil were from the ME and CIS as reported in Table 1 [136,38].

Fig. 1 compares ME and CIS to other regions of the world in terms of proven reserves, production and exports of crude oil and natural gas using [136] data.5

The oil exporters of the ME and CIS held more than half of the global proven crude oil reserves in 2014 being about 55.7%. Saudi Arabia’s share of the world’s proven oil reserves amounts to a whopping 16.2%, which is higher than the North American region (13.3%) and the combined total of Africa, Asia & Oceania, Europe

| Country | Proven crude oil reserves in billion barrels | Country | Exports of crude oil including lease condensate in USD billions |
|---------|--------------------------------------------|---------|---------------------------------------------------------------|
| Venezuela | 297.74 (18.0) | Saudi Arabia | 133.30 (17.0) |
| Saudi Arabia | 268.35 (16.2) | Russia | 86.20 (11.0) |
| Canada | 173.20 (10.5) | Iraq | 52.20 (6.6) |
| Iran | 157.30 (9.5) | UAE | 51.20 (6.5) |
| Iraq | 140.30 (8.5) | Canada | 50.20 (6.4) |
| Kuwait | 104.00 (6.3) | Nigeria | 38.00 (4.8) |
| UEA | 97.80 (5.9) | Kuwait | 34.10 (4.3) |
| Russia | 80.00 (4.8) | Angola | 32.60 (4.1) |
| Libya | 48.47 (2.9) | Venezuela | 27.80 (3.5) |
| Nigeria | 37.14 (2.2) | Kazakhstan | 26.20 (3.3) |

Note: Proven crude oil reserves in Billion Barrels in 2014 are from US EIA International energy statistics. Exports of Crude Oil including Lease Condensate in USD Billions in 2015 are collected from the Central Intelligence Agency. Numbers in parentheses are percent shares in the world total.

4 We try to provide more information in terms of time while avoiding noise and being reader-friendly in our tables and figures. To this end, we present the last two decades’ data in 5-year averages.

5 US EIA brakes the entire world into seven regions, namely North America, Central and South America, Europe, Middle East, Eurasia, Africa, Asia and Oceania. For the purpose of this study, we modified Eurasia to CIS by excluding Estonia, Latvia, Lithuania and Georgia and then combined it with Middle East. In order to avoid confusion, note that definition of Eurasia in US EIA is different from the conventional definition of it. In this paper, we refer to the conventional definition of Eurasia, which covers 103 countries as mentioned in footnote 2.

3 To keep this section concise, we discuss the mentioned issues in Section 3 Literature Review.
Fig. 1. Shares of the regions in the world total, %. 

Table 2

| Country          | 1995–1999 | 2000–2004 | 2005–2009 | 2010–2014 |
|------------------|-----------|-----------|-----------|-----------|
| Azerbaijan       | 11.16     | 16.49     | 41.06     | 50.44     |
| Bahrain          | 2.07      | 2.03      | 1.89      | 2.25      |
| Iran             | 197.21    | 201.93    | 218.71    | 193.85    |
| Iraq             | 74.51     | 110.53    | 114.99    | 154.71    |
| Kazakhstan       | 27.32     | 50.95     | 73.23     | 84.45     |
| Kuwait           | 110.26    | 114.40    | 135.95    | 138.89    |
| Oman             | 48.09     | 47.05     | 41.00     | 49.21     |
| Qatar            | 30.46     | 41.41     | 58.89     | 81.67     |
| Russia           | 321.66    | 409.00    | 504.50    | 536.68    |
| Saudi Arabia     | 446.69    | 456.89    | 489.18    | 518.41    |
| Syria            | 31.86     | 27.12     | 22.18     | 10.75     |
| UAE              | 120.91    | 122.47    | 137.19    | 144.33    |
| Yemen            | 19.44     | 22.70     | 17.69     | 9.71      |
| World            | 3,508.62  | 3,734.53  | 3,963.76  | 4,099.13  |
| Share in the World, % | 41.09   | 43.46     | 46.84     | 48.19     |

Note: Calculated by the authors based on US EIA data. MTOE is Million Tons of Oil Equivalent.

The ME and CIS produced 48.1% of crude oil including lease condensate in 2014. This number is 2.5 times bigger than that of the world’s second producer, North America. In addition to these, as the figure shows, the ME and CIS provided 56.5% of the world’s total crude oil exports in 2012. Just for comparison purposes note that this number is 3.1, 6.0, 8.3, 10.1 and 17.5 times bigger than those of the Africa, North America, Central & South America, Europe and Asia & Oceania regions respectively. Note briefly that the ME and CIS countries also hold top ranks in terms of natural gas reserves, production and exports [107,136]. In fact, they held 71.6% of the world’s proved natural gas resources while produced 40.6% and exported 44.0% of it, as illustrated in Fig. 1.

Table 2 below details crude oil including lease condensate production of ME and CIS oil exporters.

The countries’ total production share in the World grows by average 2.3 percentage point over the period 1995–2014. The production increases in Iraq, Kuwait, Qatar, Saudi Arabia, UAE and the CIS countries, including Russia despite of sanctions over the period. 

The hugest growth of the production has been seen in Azerbaijan, which was 4.52 times increase from 1995–1999 to 2010–2014 and it was followed by another CIS country, i.e., Kazakhstan by 3.09 times increase. After restoring their independence, these two the former Soviet Union republics integrated into the world basically extracting and exporting their energy resources. 11.4% drop in the Iranian production in 2010–2014 relative to 2005–2009 most likely caused by the sanctions of US and European Union, i.e., imposed restrictions on cooperation with Iran in foreign trade, financial services, energy sectors and technologies among other things starting in 2012. Declines by 51.53% and 45.11% in the Syrian and Yemeni production, respectively from 2005–2009 to 2010–2014 are the consequences of the ongoing wars in these countries. 

It is noteworthy that only these two countries hold on average 24% of the world production over the period.

Fig. 2 below illustrates how oil (and gas) exports is vital in the socio-economic life of the countries undertaken here.

It is noteworthy that the share of fuel export in total is around 90% for seven out of the 13 countries. Even, it is more than 95% for Iraq, Kuwait and Yemen in some sub-periods. The share is upward trending over time almost for all the countries, except for Yemen and UAE. As illustrated, the shares for Kazakhstan and Russia are around or below 70%. This is related to fact that these countries also export other mineral resources along with oil and natural gas. As documented by a number of empirical studies, the fiscal policy has a dominant position and oil (and gas) revenues are the main source of government revenues in oil-exporting developing economies, including the countries considered here (see [131] inter alia).

ME and CIS oil exporters are also characterized by tremendous records in economic growth and energy consumption. Seven out of 13 economies in the region are high-income countries and the rest are upper and lower middle-income nations as reported by the World Bank’s classification [140]. According to the World Bank statistics, Azerbaijan was ranked as the top economy in three consecutive years based on GDP growth of 26.4%, 34.5% and 25.0%, in 2005, 2006, and 2007, respectively. While the UAE was the highest ranked country in terms of GDP per capita in PPP measure in each year of 1990–1999, and then it was replaced by Qatar, another country from the region, over the period 2000–2015 [140].
Fig. 3 below portrays 5-year average real GDP growth rates of each country over the period 1995–2015. It can be seen that each country’s average growth rate was higher than the world average of 2005–2009, in which Azerbaijan and Qatar demonstrate drastic economic expansion by 21.23% and 16.25%, respectively. This is also true for the sub-period of 2000–2004 with an exception of Oman. Seven out of the 13, including all the CIS countries have lower growth rates than the world average in 1995–1999. Negative growth rates for Kazakhstan and Russia in this sub-period were mainly caused by socio-economic turmoil after collapsing the Soviet Union, which lasted until 1996 (See[57] among others). Obviously, negative growth rates of −1.38% and −5.57% for Syria and Yemen, respectively were results of ongoing wars as explained above. Another pattern that can be seen clearly from Fig. 3 is that the growth rates of the countries (see especially Azerbaijan, Iraq, Kazakhstan, Oman, and UAE) are very volatile across the sub-periods. This is one of the characteristics of oil-exporting economies, which shows that they heavily depend on oil-prices: the higher price, the higher economic growth and vice versa.

As for energy consumption, it is noteworthy that 12.5% of total primary energy consumption of the world came from these 13 oil exporters in 2012, while their average total primary energy consumption per capita was 3.9 times more than the world’s average in 2011[136].

Table 3 reports 5-year average primary energy consumption values of the countries over the period 1995–2014.

The first thing that can be noticed from the table is that the energy consumption of all the countries, except Azerbaijan and Syria, grows significantly over the period. Depending on the scale of economy and population (working age group) the countries have different energy demand. In this regard, Russia and Yemen are in the extremes. It is striking that Russian energy consumption was 52.23%, 33.11% and 5.40% more than the rest 12 countries’ consumption in the first three sub-periods, respectively. Growth pattern of the energy consumption is

9 Total Primary Energy Consumption in quadrillion Btu and per capita term of it measured in million Btu per person only available until 2012 and 2011 respectively in US Energy Information Administration, International energy statistics. That is why we were not able to report recent years (See: http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=44 & pid=44 & aid=2 & cid=AJ,BA,IR,IZ,KZ,KU,MU,QA,RS,SA,SY,TC,ww,YM, & syid=2010 & eyid=2012 & units=QBTOU and http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=44 & pid=47 & aid=2 & cid=AJ,BA,IR,IZ,KZ,KU,MU,QA,RS,SA,SY,TC,ww,YM, & syid=2010 & eyid=2011 & units=BTUPUSD).
also different across countries. It is interesting to note that except Azerbaijan, Kazakhstan, Iraq, Russia, and Syria, all the rest countries’ period average growth rates of energy consumption were above 24%. In this regard, Oman, Qatar and Iran demonstrated the highest period average growth rates, being 56.71%, 43.45% and 31.64%, respectively.

### 3. Literature review

The pioneering paper of [76] led to a huge number of studies investigating the energy-growth nexus in different countries with different time periods through the use of different methods and variables. Most of them are comprehensively reviewed in [106] classifying by country and group of countries.

Although [76] found a uni-directional causality running from GNP to energy consumption in the US, the literature on the energy-growth relationship is not conclusive in terms of a direction of causality [17,4,3,6,25,42].

Therefore, there are four hypotheses in the literature on the energy-growth nexus. The growth hypothesis assumes that causality runs from energy to growth. Therefore, any decline in energy consumption as a result of conservation policies will be negatively associated with economic growth. The conservation hypothesis, in contrast, emphasizes that growth is the main factor of energy consumption and in this regard economic growth will lead to an increase in energy consumption. The feedback hypothesis articulates a bi-directional causality: energy consumption will lead to an increase in energy consumption. The neutrality hypothesis indicates no causal relationship between energy consumption and growth [17,143,3,1,6,11,12,7,2,3,9,2,5,2,4,42].

All these types of causalities are empirically confirmed by the studies, and the nature of energy-growth nexus is mixed or conflicting. Mixed or conflicting results are explained with differences in the econometric methodologies applied, variables and specifications used, time period investigated and countries selected [105,106,138,143,17,22,33,42,6,8,95,3].

The energy-growth nexus literature mainly covers the developed and developing oil importing countries, and oil exporting developing countries are not studied sufficiently (see [6,17,11,12,22]). The empirical studies investigating the energy-growth nexus in the case of oil-exporting developing countries can be classified into either a single-country or a group-of-countries (panel) analyses. Some of the recent single-country studies include [5] for Nigeria; [144] for Indonesia; [133,9] for Malaysia; [22] for Algeria; [122] for Angola; [7] for Saudi Arabia; [145,61] for Iran; [70,91] for Bahrain. In line with the objective of our study, we should focus on the panel studies devoted to oil-exporting developing countries of ME and CIS in this section. As mentioned in the Introduction section, there are limited studies devoted to the pure set of ME oil exporters and very few studies on the pure set of CIS oil-exporting countries. Hence, in order to widen the scope of this section, we review two other types of studies as well: (a) devoted to the panel of oil-exporters from ME and CIS and other regions; (b) a mix of oil-exporters and oil importers. However, in order to not unduly inflate the Literature Review section, we do not review the papers, where only one oil-exporting country was included in the panel study and it is very small portion of given panel. Our point is that since such panel studies contain mainly other countries than our interested ones, their results should not be representative for the countries considered here. Table 4 summarizes the reviewed studies.

As [107,42,88,127,6] state, limited studies have investigated the energy-growth nexus in oil-exporting developing economies. Most of the prior studies have taken a mix of developing oil exporters and oil importers since their research aim was country group or region specific, but not the oil exporters. Moreover, we are aware of no studies investigating the energy-growth nexus for a pure set of oil exporting developed Eurasian economies, including the CIS oil exporters and only few studies (for example, [6,107] examining this nexus for a pure set of ME oil exporters. Even though ME and CIS oil exporters have a significant impact on world energy markets as mentioned in the section above. Consequently, there is a significant gap in the literature on oil exporting economies, especially for those from the ME and CIS.

Before proceeding to a discussion of shortcomings of the existing studies listed in Table 4, we must mention that these studies, particularly the first 12 papers in the table, are very valuable, as they are the only papers that constitute the literature of the energy-growth nexus for the oil-exporting developing countries.

The shortcomings related to the studies in the table above can be classified into common and individual ones. To be consistent with the aim of our study and being concise, we only discuss the common shortcomings of the reviewed studies here.

The literature on the energy-growth nexus assumes that different studies have concluded with different (mixed and even conflicting) findings because among others, they have used different measures of energy consumption. However, to the best of our knowledge, no earlier study have tested this assumption by conducting a robustness check: using more than one measures (variables) for energy consumption in the pure set of oil-exporting developing economies. It is worth mentioning that the issue we raise here was also underlined by [27] in the case of 65 countries, including Saudi Arabia and Iran as well as [30] in the case of USA. It is quite reasonable to think that different metrics of energy consumption may have different impacts on growth and vice versa. For example, energy consumption in industry and households may not have the same effect on growth due to the concept of alternative cost, i.e., consumption of energy in households makes it impossible to use in the industry, which would create more value added. Therefore, one may think that the energy consumption in households may have negative or no impact on growth.

Narayan and Smyth [95] criticize most of the existing studies examining the energy-growth nexus for employing a bivariate framework. They discuss that these studies are subject to the omitted variables bias problem and therefore, the findings and policy suggestions derived from these studies are potentially spurious. Note that the spurious results in the Granger-causality analysis caused by an omitted variable are deeply discussed and econometrically proven by [85,134],

### Table 3

| Country       | 1995–1999 | 2000–2004 | 2005–2009 | 2010–2014 |
|---------------|-----------|-----------|-----------|-----------|
| Azerbaijan    | 15.75     | 14.96     | 15.97     | 14.84     |
| Bahrain       | 8.13      | 9.92      | 12.97     | 15.69     |
| Iran          | 109.04    | 145.54    | 208.36    | 248.74    |
| Iraq          | 27.38     | 27.74     | 32.72     | 40.72     |
| Kazakhstan    | 45.51     | 49.31     | 58.11     | 65.64     |
| Kuwait        | 19.39     | 23.44     | 30.06     | 38.65     |
| Oman          | 6.92      | 9.00      | 15.69     | 26.63     |
| Qatar         | 14.98     | 14.95     | 25.72     | 44.21     |
| Russia        | 640.93    | 678.81    | 722.84    | 769.59    |
| Saudi Arabia  | 108.14    | 137.92    | 179.47    | 237.59    |
| Syria         | 17.57     | 20.36     | 22.44     | 19.39     |
| UAE           | 44.14     | 51.20     | 77.23     | 97.40     |
| Yemen         | 4.10      | 5.63      | 7.03      | 7.98      |

**Note**: Calculated by the authors based on the US, EIA data. MTOE is Million Tons of Oil Equivalent.
| Study                  | Period                  | Group of Countries                                           | Methodology Data                                                                 | Data                                                                 | Causality direction Method                                                                 | Long-run                          | Short-run                          |
|------------------------|-------------------------|----------------------------------------------------------------|---------------------------------------------------------------------------------|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-----------------------------------|------------------------------------|
| Al-Iriani [6]           | 1971–2002               | GCC countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) | GDP and EC per capita, GDP per capita, GDP per capita, GDP per capita, GDP per capita | Panel Mean Group Estimator, Panel VAR, Granger causality test          | GDP → EC                                                                                 | Investigated                     | GDP → EC                           |
| Osman et al. [104]      | 1975–2012               | All the GCC countries                                          | GDP per capita, GDP per capita, GDP per capita, GDP per capita, GDP per capita | Panel Mean Group Estimator, Panel VAR, Granger causality test          | GDP ↔ EC                                                                                 | Investigated                     | GDP ↔ EC                           |
| Ozturk and Al-Mulali [107] | 1980–2012            | All GCC countries                                              | GDP per capita, GDP per capita, GDP per capita, GDP per capita, GDP per capita | Panel Mean Group Estimator, Panel VAR, Granger causality test          | GDP ↔ EC                                                                                 | Investigated                     | GDP ↔ EC                           |
| Salahuddin and Gow [116] | 1980–2012              | All the GCC countries                                          | GDP per capita, GDP per capita, GDP per capita, GDP per capita, GDP per capita | Panel Mean Group Estimator, Panel VAR, Granger causality test          | GDP ↔ EC                                                                                 | Investigated                     | GDP ↔ EC                           |
| Issa [71]               | 1980–2011               | 17 Arab countries, including Bahrain, Egypt, Jordan, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, and Yemen | GDP per capita, GDP per capita, GDP per capita, GDP per capita, GDP per capita | Panel Mean Group Estimator, Panel VAR, Granger causality test          | GDP ↔ EC                                                                                 | Investigated                     | GDP ↔ EC                           |
| Solarin and Ozturk [121] | 1980–2012              | All GCC countries                                              | GDP per capita, GDP per capita, GDP per capita, GDP per capita, GDP per capita | Panel Mean Group Estimator, Panel VAR, Granger causality test          | GDP ↔ EC                                                                                 | Investigated                     | GDP ↔ EC                           |
| Hossein et al. [65]     | 1980–2008               | All the OPEC members                                           | GDP per capita, GDP per capita, GDP per capita, GDP per capita, GDP per capita | Panel Mean Group Estimator, Panel VAR, Granger causality test          | GDP ↔ EC                                                                                 | Investigated                     | GDP ↔ EC                           |
| Hossein et al. [64]     | 1980–2009               | All the OPEC members                                           | GDP per capita, GDP per capita, GDP per capita, GDP per capita, GDP per capita | Panel Mean Group Estimator, Panel VAR, Granger causality test          | GDP ↔ EC                                                                                 | Investigated                     | GDP ↔ EC                           |
| Tang and Aboseida [312]  | 2001–2009              | 24 MENA countries, including oil-exporters: Azerbaijan, Bahrain, Bangladesh, Botswana, Egypt, Iran, Iraq, Jordan, Kuwait, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, and Yemen | GDP per capita, GDP per capita, GDP per capita, GDP per capita, GDP per capita | Panel Mean Group Estimator, Panel VAR, Granger causality test          | GDP ↔ EC                                                                                 | Investigated                     | GDP ↔ EC                           |
| Squally [127]           | 1980–2003               | GCC countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) | GDP per capita, GDP per capita, GDP per capita, GDP per capita, GDP per capita | Panel Mean Group Estimator, Panel VAR, Granger causality test          | GDP ↔ EC                                                                                 | Investigated                     | GDP ↔ EC                           |
| Study | Period | Group of Countries | Methodology Data | Causality direction Method | Long-run | Short-run |
|-------|--------|--------------------|------------------|-----------------|--------|--------|
| Mehrara et al. [88] | 1971–2002 | 11 selected oil exporting developing countries: Iran, Oman, Saudi Arabia, Qatar, UAE, Argentina, Brazil, Venezuela, Ecuador, Mexico, and Norway | Per capita GDP and Per capita EC | Heterogeneous PCT and Panel VECM | GDP → EC | GDP → EC |
| Damotte and Slight [42] | 1990–2010 | Per capita GDP and Per capita EC | Per capita GDP and Per capita EC and Real Exports | Heterogeneous PCT and Panel VECM | GDP → EC | GDP → EC |
| For Iran, Nigeria, Qatar, Saudi Arabia | 1971–2002 | 11 selected oil exporting developing countries: Iran, Oman, Saudi Arabia, Qatar, UAE, Argentina, Brazil, Venezuela, Ecuador, Mexico, and Norway | Per capita GDP and Per capita EC | Heterogeneous PCT and Panel VECM | GDP → EC | GDP → EC |
| Narayan and Popp [10] | 1980–2006 | 93 countries, including Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, Syria, UAE and Yemen | Per capita GDP, Per capita EC, CO2, FDI all in per capita term | Common Correlated Effects | EC and GDP | GDP Not investigated |
| For entire panel in the case of both energy types | 1975–2007 | 85 countries, including Iran, Oman, Saudi Arabia, Syria and Yemen | Per capita GDP, Per capita EC and Real Exports all in per capita term and Urbanization, | Common Correlated Effects | EC and GDP | GDP Not investigated |
| As a panel | 1992–2012 | 65 countries, including Iran and Syria. EC, GDP per capita, FDI net inflows, GFCF, Labor force, Inflation, Trade Openness, Financial development, Population, and Real Exchange rate | EC and GDP | The Bootstrap Panel Causality Approach | EC and GDP | GDP Not investigated |
| Kayıkçı and Tang [13] | 1990–2007 | 80 countries, including Iran and Syria | GDP, Renewable Electricity Consumption, Non-Renewable Electricity Consumption, GDP, CO2, CO2, Real Exports all in per capita term | The English Granger causality tests and Granger causality tests | EC and GDP | GDP Not investigated |
| Kalyoncu et al. [73] | 1995–2009 | Azerbaijan, Georgia, Armenia | EC and GDP | The Bootstrap Panel Causality Approach | EC and GDP | GDP Not investigated |
| Cowan et al. [41] | 1990–2010 | BRIC countries: Brazil, Russia, India, China, and South Africa | EC, GDP, CO2 and GDP | The Bootstrap Panel Causality Approach | EC and GDP | GDP Not investigated |
| Study                              | Period           | Methodology Data                                                                 | Causality direction Method | Group of Countries                                                                 |
|-----------------------------------|------------------|-----------------------------------------------------------------------------------|----------------------------|------------------------------------------------------------------------------------|
| Yildirim et al. [142]              | 1971–2010        | 11 countries, including oil-exporting developing economies: Iran, Indonesia, Mexico | Granger non-causality test based on the distance between ARMA models              | Latin America and the Caribbean countries, developing economies of Mexico and Venezuela, Nigeria, Senegal, Sudan, Zimbabwe |
| Romero and Jesus [115]             | 1990–2011        | GDP, EC, and Real Capital for Mexico and Venezuela, Real GDP and EC for Brazil     | Granger causality based on ECM                                                  | Latin America and the Caribbean countries, including oil exporters of Mexico and Venezuela |
| Cheng [34]                         | 1949–1993        | GDP, EC, CPI, Government Expenditure                                              | Time-series Residual-Based Cointegration, Hsiao method, ECM and simple ARDL      | Brazil, Mexico and Venezuela                                                       |
| Akinlo [4]                         | 1980–2003        | GDP, EC, CPI, Government Expenditure                                              | Time-series Residual-Based Cointegration, Hsiao method, ECM and simple ARDL      | 11 countries in sub-Saharan Africa: Cameroon, Congo, Guinea, Malawi, Mozambique, Nigeria, Senegal, Sudan, Togo and Zimbabwe |
| Asafu-Adjaye [17]                  | 1971–1995        | GDP, Per capita EC, CPI                                                            | EC ↔ GDP                                                                     | 4 Asian countries, including oil-exporting developing economies of Indonesia and Thailand |
| Chen et al. [33]                   | 1971–2003        | 10 newly industrializing and developing Asian countries: China, Hong Kong, Indonesia, Singapore, Taiwan and Thailand | Time-series Johansen Cointegration test on ECM and Granger causality              | 10 newly industrializing and developing Asian countries: China, Hong Kong, Indonesia, Singapore, Taiwan and Thailand |
| Lee and Chang [81]                 | 1971–2002        | GDP, EC, and Real Capital for Mexico and Venezuela, Real GDP and EC for Brazil     | Time-series Johansen Cointegration test on ECM and Granger causality              | 16 Asian countries, including oil-exporting developing economies of Indonesia, Iran, Malaysia, Syria |
| Bozoklu and Yilanci [25]           | 1970–2011        | GDP and EC                                                                        | Time-series Johansen Cointegration test on ECM and Granger causality              | 20 OECD countries, including all exporters of Mexico, Norway and the Netherlands |

(continued on next page)
| Study | Period | Methodology | Data | Causality direction Method | Long-run | Short-run |
|-------|--------|-------------|------|---------------------------|----------|-----------|
| Lee and Chang [80] | 1965–2002 | Per capita GDP, Per capita EC | 22 developed and 18 developing countries, including oil-exporting countries of Indonesia, Malaysia, Mexico, Venezuela | Panel OLS-based VAR | GDP ↔ EC | GDP ↔ EC |
| Dedeoğlu and Kaya [48] | 1980–2010 | Per capita GDP, Per capita EC | 25 OECD members, including oil exporting countries of Mexico, Norway and the Netherlands | Heterogeneous PC-T, Panel FMOLS, Panel EMOLS (Panel ECM) | GDP ↔ EC | GDP ↔ EC |
| Ozturk et al. [105] | 1971–2005 | Per capita GDP, Per capita EC | 51 countries, including oil-exporting developing economies of Nigeria, Mexico, Oman, Venezuela, Indonesia, Iran | Heterogeneous PCT, Panel VECM and Panel and Time Series FMOLS and DOLS | GDP ↔ EC | GDP ↔ EC |
| Ahmed and Azam [2] | Different periods for different countries | GDP and EC | 119 high, medium and low income economies, including oil-exporters of ME and CIS | Granger causality test in frequency domain context | All four hypotheses across the globe | All four hypotheses across the globe |
| Narayan [96] | 1984–2010 | Per capita GDP and Per capita EC | 135 high, medium and low income economies, including oil-exporters of ME and CIS | The panel data predictive regression model | GDP ↔ EC | GDP ↔ EC |

**Notes:** GDP=Real Gross Domestic Product, EC=Energy consumption, EC → GDP indicates that the causality runs from energy consumption to growth, EC → GDP indicates that the causality runs from growth to energy consumption. ME=Middle East and North African Countries, CIS=Commonwealth of Independent States, OPEC=Organization of Petroleum Exporting Countries and Development, ASEAN=Association of South East Asian Nations, MENA=Middle East and North African Countries, PCT=Panel Cointegration Test, LO=Dynamic Ordinary Least Squares, VAR=Vector AutoRegressive model, VECM=Vector Error Correction Model, PMG=Panel Mean Group estimators, GMM=Generalized Method of Moments, FMOLS=Fully Modified Ordinary Least Squares, ARDL=Autoregressive Distributed Lag, FE=Fixed Effect, RE=Random Effect.
among others. From this point of view, one can argue that many studies listed in Table 4, including [6,8,9,12,17,42,143,105,25,43,33,39,80,34,121,23,2,96], potentially suffer from the mentioned problem as they have employed a bivariate framework. Unfortunately, all of the studies focusing pure set of developing oil-exporters, except [107,64,65], are among them.

Based on Monte Carlo simulations, [62] show that the [26] panel unit root test (PURF) has the highest power and smallest-size distortions amongst the first generation PURTs. However, other than [95], we are not aware of energy-growth studies for oil-exporting developing countries applying this test. Furthermore, to the best of our knowledge, none of the first 12 studies has applied the [58] PURT to panel data of oil exporting developing economies.\(^{12}\)

The number of studies in the table examines the energy-growth nexus for groups or regions containing the mixture of oil exporters and oil importers (For example, [80,81,11,12,105,43,23,2,96]). These studies have suggested common policy recommendations for both types of countries without considering that a set of countries are heterogeneous. However, as [6] emphasizes, the policy implications of studies devoted to oil importing economies would not be applied to oil exporting countries because their structure, functioning and energy policies are different. Similarly, the policy suggestions derived from the panel of mix countries would not be applicable for both types of countries in the same extent. Apart from that, [88] argues that there is a large potential for energy savings in oil exporting developing countries. However, policy makers in these countries are reluctant to cancel energy subsidies, as they are fearful that an increase in domestic energy prices may deter economic growth. Refs. [6,42] state that oil-exporting countries pay less attention to energy conservation policies and the future of the energy-growth relationship because they enjoy cheap energy. All these three above-mentioned issues require further and more detailed investigation of the energy-growth nexus for oil exporting developing countries.

The last issue is related to the theoretical underpinnings that prior energy-growth studies set up for their analysis. As the bivariate framework may lead to misleading results, some studies include control variable(s) into econometric analysis to overcome this problem without having enough theoretical justification for that. For example, Asafu-Adjaye [17] and Mahadevan and Asafu-Adjaye [87] use CPI, Akino [4] employs CPI and government expenditure, Cheng [34] utilizes capital and Narayan and Smyth [95] and Azam et al. [18] consider exports. It is noteworthy that inclusion of any control variable in the analysis should be based on an economic theory or concept. In this regard, production function concept seems relevant multivariate framework, as labor and capital are theoretically predicted determinants of growth and they have a certain impact on energy consumption (see [129,130,99,100,11,12,143,81,107,120]). Moreover, Ozturk et al. [105] state the importance of capital and labor variables in the analysis of the energy-growth nexus. Furthermore, Lee et al. [79] show that omitting capital in the empirical analysis of the energy-growth relationship results in an overestimation of the influence of energy consumption. Additionally, Yoo [143] emphasizes the importance of investment in increasing energy supply and additionally, suggests including employment, among other macroeconomic factors, in the energy-growth relationship analysis.

However, we are not aware of prior studies using a production function framework for a pure (not mixed) set of oil exporting developing economies where Azerbaijan, Kazakhstan and Russia are also included.\(^{13}\)

In this paper, we address all the mentioned issues which, have been missed by the prior studies listed in the table.

4. Methodological framework

4.1. Theoretical background

In this study, we use a multivariate rather than a bivariate framework. [85] econometrically shows that in the bivariate system, to omit relevant variable(s) may lead to a spurious finding of Granger-causality. He also states that non-causality in a bivariate system may theoretically be a result of the omitted variable(s). Moreover, [134] proves that non-causality in the bivariate system may stem from the omitted variable. On the other hand, [98] indicates that including a third variable in the energy-growth analysis may not only change the sign and magnitude of the coefficients but can also alter the direction of causality [31,32,97].

Unlike most prior studies devoted to oil-exporting developing economies, we employ a modified production function framework because of its advantages discussed in Section 3.

A relationship between energy and production has two competing views in the literature. According to the neoclassical approach, energy has a minor effect on production as it has a very small share in the creation of value added. Even the growth concepts, such as the Harrod-Domar and Solow-Swan models, argue that energy cannot be considered an element of a production function [30,81,119]. However, despite the assumptions of the neoclassical concepts, internal growth models of public spending [20] and human capital [84]-both with the contributions of the neoclassical economists of [59,28]-have demonstrated that energy may be an important factor of production. Similarly, the energy economists emphasize that energy is a crucial factor of production [128]. Industrialization with increasing infrastructure investment brings high and constant energy consumption. An increasing amount and role of the energy in industrial production makes it one of the important inputs alongside labor and capital. It can even substitute the labor force in the technological process [50,51].

The following is an example of studies employing an augmented production function framework in the energy-growth nexus: Streimikiene and Kasperowicz [120] for European Union countries; Ozturk and Al-Mulali [107] for GCC states, Oh and Lee [99,100] for Korea; Stern [129,130] for US; Ghali and El-Sakka [51] for Canada; Apergis and Payne [11], for Central American economies; Apergis and Payne [12] for CIS countries; and Lee and Chang [81] for Asian countries.

The augmented production function in the case of panel data can be expressed as follows:

$$ Y_{ij} = f(L_{ij}, K_{ij}, EC_{ij}) $$

(1)

Where, \( Y \) is real GDP, \( L \) and \( K \) are the labor input and real capital stock, respectively, \( EC \) is the energy input. \( i \) and \( t \) define number of cross sections and time, respectively.

In the empirical analysis, for the purpose of econometric estimation, (1) can be written as follows:

$$ Y_{ij} = a_{ij} + \beta_{ij} L_{ij} + \gamma_{ij} K_{ij} + \lambda_{ij} EC_{ij} + \epsilon_{ij} $$

(2)

Where, \( y, l, k \) and \( ec \) are the natural logarithm of \( Y, L, K \) and \( EC \), respectively; \( \epsilon \) is the error term.

4.2. Data

We use annual data of Eurasian oil-exporting developing countries, i.e., Azerbaijan, Bahrain, Iran, Kazakhstan, Kuwait, Oman, Qatar, Russia, (footnote continued)
Saudi Arabia and the UAE over the period of 1997–2014. Selection of the countries and period were based upon the data availability.

As mentioned above, we use two measures of energy consumption. The first variable is a Primary Energy Consumption (PEC) in million tons of oil equivalent (MOTE) while the second is a Residential Electricity Consumption (REC) in thousand tons of oil equivalent (KOTE). Data on both variables are collected from United States Energy Information Administration Database [136].

We measure economic growth with real Gross Domestic Product (GDP) in millions of Purchasing Power Parity based international dollars at constant 2011 prices. The data is retrieved from the World Bank Development Indicator database [140].

To be consistent with the production function framework, we employ Employment (EMP) and real Foreign Direct Investment (FDI) inward stocks as a control variables. The EMP is in thousand persons and available from the International Labor Organization database [68]. Foreign Direct Investment inward stocks in nominal million USD is obtained from United Nation’s database [135]. It is deflated by United States GDP Deflator, 2011=100, retrieving from [140], to get the real values. There are four reasons why we use FDI. First, FDI is one of the important determinants of economic growth in developing countries, including oil-exporting ones [24,29,44,54]. Second, there has been a massive FDI inflow into the oil sector of the above-mentioned Eurasian oil-exporting developing countries ([21,46,49,40,112,67]). Third, it is a common practice to proxy capital stock with investment in the empirical studies of energy-growth nexus. For example, [107,142,18,1294,139], have used investment as a proxy for capital stock. Moreover, Sari and Soytas [117] show that any variance in capital stock. Therefore, our purpose for using FDI in this study is to empirically test its role in the growth of the selected economies.

Note that we use per, rec, gdp, emp and fdi, which are the natural logarithm of PER, REC, GDP, EMP and FDI, respectively, in the empirical analysis.

4.3. Econometric methodology

As Guttormse [56] and Mehrara [88] note, the energy-growth literature can be divided into four generations in terms of the applied econometric methodology. In this study, we employ the fourth generation’s methodology, which is panel cointegration and error correction modelling. Oshat [103] discusses a number of advantages of the panel estimation, which induces us to employ it in our empirical analysis. First, by combining the time series and cross-sectional dimensions, the panel data provide more information. Second, this type of data reduces colinearity among the explanatory variables, increases degrees of freedom, and thereby yields more efficient estimation results. Third, the panel estimation allows us to control the individual heterogeneity. Finally, it identifies the effects that cannot be detected in the time series or cross-section data.

The following is the steps of our empirical estimations. We will first check for stationarity of our variables, i.e., Primary Energy Consumption and Residential Electricity Consumption, GDP growth, Foreign Direct Investments and Employment. After we find that all of the variables are integrated in the same order, we will perform the PCTs. If we find that the variables are cointegrated, the next step will be estimation of the long-run elasticities and error correction models. Finally, we will perform tests for the long-run and short-run Granger causality. If we do not find a cointegrating relationship among the variables, we will estimate a VAR of stationary variables and test for short-run Granger causality.

To obtain robust results and to address some methodological issues missing in prior studies, we use different methods in our empirical analysis. More precisely, we use the [83,69], Fisher-ADF and Fisher-PP of Maddala and Wu [86] as well as Breitung [26] and Hadri [58] PURTs to test the integration properties of our data. We check for the existence of cointegration using both the [108,74] PCTs. Long-run elasticities are estimated by using the FMOLS and DOLS. Finally, we employ the FIML (Full Information Maximum Likelihood) and the GMM system methods to estimate the error correction models and/or short-run dynamic models and then to check for short-run and long-run Panel Granger-Causality.

For the convenience of readers, description and discussion of the mentioned methods are placed in the Appendix.

5. Results

We first check the integration properties of the variables by applying a variety of the PURTs. The test results are reported in Table 5.

Note that we run the tests in the two cases, i.e., (a) individual intercept and trend and (b) individual intercept only where possible. The results are reported Panels A and B, respectively. For the all variables, expect pec and emp, it is straightforward to conclude that they have a unit root at the log level.

We investigate the integration properties of pec and emp in detail to make a proper decision. In the case of pec, most of the tests, except [58], are in favor of trend stationarity of the variable. However, in the case of the Individual Intercept, all tests are in favor of the non-stationary of pec. Moreover, we conduct the ADT test on pec time series of individual countries in our panel. The test results clearly indicate that a unit root is a part of the data-generating process of rec time series in all countries, except Kazakhstan, Russia and Bahrain, where the series appear as trend-stationary process, although their graphical illustrations do not suggest so. Thus, we conclude that the panel of pec has a unit root and it is stationary at the first difference.

Regarding emp, three, including [26], out of six PURTs suggest that the variable is a unit root process. The LLC results is confusing in the sense that it indicates stationarity of emp in both cases, i.e. with and without trend. Additionally, in the case of Individual Intercept, the test results given the upper part of the Panel B clearly indicate that emp is non-stationary. Furthermore, we conduct the ADT and PP test on the individual countries’ emp time series and after a careful examination (graphical analysis, comparing the tests results, analyzing the UR parameters), we conclude that only Saudi Arabian emp can be considered a trend stationary process. Thus, we conclude that the panel of emp has a unit root rather than a deterministic linear trend.

The tests results reported in the bottom part of Panels A and B, with a very few exceptions, indicate that the variables are stationary at their first difference of the log level, i.e., in their growth rates.

Thus, as a final decision of the PURT exercise, we conclude that all the variables are non-stationary at the level and their first difference is a stationary process. In other words, they are integrated in the order of one, i.e., 1(1).

After concluding that all the variables are integrated in the same order of one, we can proceed to testing the cointegration among them.

Before proceeding to examine that whether the variables are cointegrated, the following points should be considered: Our panel contains only oil-exporters, but not a mix of the exporters and importers. Additionally, all the countries in the panel are developing countries rather than a mix of developing, developed and or less-developed. Thus, it can be considered that our panel is quite homogenous. Therefore, we should focus more on the [74] PCT results than [108,110] as discussed in the methodological section. Nonetheless, we also perform [108,110] for a comparison purposes. According to the methodological discussion in the Appendix, Panel-ADF and Group-

14 All econometric estimations are performed in EViews 9.5 econometric package and covers from 1997 to 2014.

15 The ADT test results and graphs for pec time series by country can be obtained from the authors upon request.

16 The ADF test results and graphs for the time series of emp by country are available upon request.
ADF statistics of the Pedroni test outperform other test statistics. Therefore, we only report these two statistics of the Pedroni test in order to make the paper concise.

Note that as in the case of PURTs, we perform PCTs in two cases: individual intercept and trend as well as individual intercept only.\(^{17}\) Note also that because we have two proxies for energy consumption, \(pec\) and \(rec\), the PCTs are run in two versions: (a) \(gdp, fdi, emp, pec\) and (b) \(gdp, fdi, emp, rec\). The purpose of having the versions is a robustness check. Table 6 reports the Panel cointegration tests results.

According to the Kao test results, the null hypothesis of no cointegration can be rejected in both versions. In other words, there is cointegrating relationship among the variables.

The results from the [108,110] test indicates that the null hypothesis of no cointegration can be rejected for \(gdp, fdi, emp, pec\) at the 10% significance level, whereas it cannot be rejected for \(gdp, fdi, emp, rec\).

Thus, it can be concluded that, based on the PCTs results, there is a stronger evidence of cointegration among the variables when energy consumption is represented by Primary Energy Consumption. Likewise, there is a weak evidence of the cointegration when the energy consumption is represented by Residential Electricity Consumption.

Since the variables are cointegrated, it is meaningful to estimate long-run coefficients, i.e., elasticities. For this purposes, two specifications of \(gdp\) are estimated: \(gdp, fdi, emp, pec\) and \(gdp, fdi, emp, rec\). We employ both panel FMOLS and DOLS to obtain much more robust results as discussed in the methodological section. Note that, we select degree of freedom correction version in the FMOLS and DOLS estimations to avoid possible small sample bias. Table 7 reports the estimation results.

As the table presents, there are statistically significant positive impacts of \(fdi\) and \(emp\) on \(gdp\) in both the FMOLS and DOLS estimations regardless of whether \(pec\) or \(rec\) are used as a measure of energy consumption. Moreover, Panel A indicates that there is a statistically significant positive long-run impact of \(pec\) on \(gdp\) and the elasticities from the FMOLS and DOLS are quite close to each other. However, the long-run impact of \(rec\) on \(gdp\) is not statistically significant either in FMOLS or DOLS estimations, as reported in Panel B of the table. It is noteworthy that the long-run estimation results support PCTs results in the sense that \(rec\) does not have any statistically significant impact on \(gdp\) in the long run.

Thus, based on the results of the long-run estimations, we can conclude that there is no long-run effect of \(rec\) on \(gdp\). Therefore, in the next step, Panel VECM of \(gdp, fdi, emp\) and \(pec\) is estimated to produce

\(^{17}\) As Lee and Chang [81] state, the trend effects are assumed to capture any disturbances that are common for the countries in our panel, such as changes in global energy markets and international business cycles.
short-run coefficients and speed of adjustments and Panel VAR of gdp, fdi, emp and rec is estimated to obtain just short-run coefficients. We will then examine short-run and long-run Granger causalities.

We apply the two-step procedure of Engle-Granger [47] method to examine the short-run and long-run Granger causalities. In the first step, we estimate the Eq. (A.9) for each of 10 countries in our panel and calculate the long-run residuals, i.e., error correction terms, ECT. In the second step, by using the error correction terms, we estimate Eq. (A.10), i.e., Panel VECM, a Granger causality model consisting system of error correction equations.

Note that most of the existing studies, particularly those listed in Table 4, either use a Maximum Likelihood (ML hereafter) estimator developed by Pesaran et al. [111] or GMM estimator suggested by Arellano and Bond [15]. Unlike these studies, we use both of these methods in estimating (A.10) or (A.10) employing ML as a robustness check. We estimated (A.10) employing ML. We set maximum lag order to two, as we did in PURT and PCT analyses, since our data is in the annual frequency and the sample is not long.\(^{16}\) Optimal lag order is selected based on satisfying classical assumptions on the residuals while providing smaller values for the Schwarz and Akaike information criteria. After a careful examination, we find that both of the information criteria prefer to the lag order of one, in which the residuals of (A.10) do not have any problems, especially a serial correlation.\(^{20}\) For the GMM case, as in the ML estimation, we again estimate (A.10) with maximum lag order of two and try to find an optimal lag order. We find that one lag is appropriate for the equations in terms of classical assumptions of the error term and saving the degree of freedom. Hence, we use the lag order of one for the right-side variables. As the instrument, we use the lag order of two for the dependent variable and the lag order of one for the other variables in each equation.

By following the methodology described in the Appendix, we then conduct the Granger-causality analysis on the estimated (A.10). Table 8 reports the short-run, long-run and strong Granger causality results\(^{21}\):

In general, the table demonstrates that the speed of adjustment coefficients and other numerical values derived from the ML and GMM estimations are quite close to each other and indicate that there is no short-run causal relationship from the ML and GMM estimators and follow the same procedures.\(^{22}\) We find that the lag order of one is relevant for both the ML and GMM estimations. We then perform the short-run Granger causality test. Table 9 presents the test results.

In terms of energy consumption economic growth nexus, the results from the ML and GMM estimations, reported in Table 9, are close to each other and indicate that there is no short-run causal relationship between Δgdp and Δpec.

Thus, summing up all the results of this section, we can conclude that the Primary Energy Consumption is cointegrated with GDP and it has a statistically significant positive impact on GDP in the long run. Moreover, the former Granger causes the latter in both the short run and long run, but not vice versa. On the other hand, we find that Residential Electricity Consumption is not cointegrated with GDP and it does not have any significant impact on the latter in the long run. Furthermore, there is no short-run causal relationship between the growth rates of Residential Electricity Consumption and GDP.

### 6. Conclusion and discussion

#### 6.1. Discussion

The PCT results show that GDP, Foreign Direct Investments, Employment and Primary Energy Consumption are cointegrated. In other words, they move together in the long run. Any deviation from this long-run equilibrium path is temporary and will be corrected towards it. The finding that energy consumption is cointegrated with the production function variables is in line with findings by [107,11,12,143,99,100,130,129]. On the other hand, there is a weak evidence that Residential Electricity Consumption is cointegrated with GDP.

Moreover, the FMOLS and DOLS estimations for the long-run coefficients yield similar results that the explanatory variables have a statistically significant and positive impact on GDP in the long run. More specifically, a 1% increase in Foreign Direct Investments, Employment and Primary Energy Consumption leads to a 0.1%, 0.2–0.3% and 0.2–0.3% increase in GDP, respectively, in the panel of 10 Eurasian oil-exporting developing countries. Unlike, a statistically significant impact of Residential Electricity Consumption on GDP is not found.

### Table 8
Test results for short- and long-run panel causality.

| Dependent variable | Source of causation (independent variable) | Long-run | Strong |
|--------------------|-------------------------------------------|----------|--------|
|                    |                                            | ECT      | ECT and Δgdp | ECT and Δpec | ECT and Δfi | ECT and Δemp |
| Panel A: ML estimation |
| Δgdp               | –                                         | 0.450 (0.000) | –          | 20.174 (0.000) | 20.250 (0.000) | 20.153 (0.000) |
| Δpec               | 0.023 (0.880)                             | 0.171 (0.589) | 0.300 (0.861) | –          | 0.834 (0.659) | 0.293 (0.864) |
| Panel B: GMM estimation |
| Δgdp               | 3.346 (0.067)                             | 0.436 (0.000) | –          | 16.539 (0.000) | 17.036 (0.000) | 17.087 (0.000) |
| Δpec               | 0.329 (0.566)                             | 0.175 (0.122) | 2.583 (0.275) | –          | 4.071 (0.131) | 2.648 (0.293) |

Note: The values in the table, except those in ECT columns, are Chi-square statistics from the Wald test. The Values in ECT columns are speed of adjustment coefficients. Probabilities are in parentheses.

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\(^{18}\) Note that since rec does not have statistically significant impact on gdp in the long-run, we use pec as a measure of energy consumption in (A.9). Also note that in order to avoid potential bias, we estimate (A.9) by FMOLS with degree of freedom adjustment instead of using OLS.

\(^{19}\) Panel VECM estimation period is 2000–2014, as the first three years are consumed by taking difference of the variables and then two lags.

\(^{20}\) The estimation and residuals diagnostic tests results can be obtained from the authors upon request.

\(^{21}\) Note that, since fdi and emp are not our main interest, we do not report the Granger causality results for them and they are available from the authors under request.
Finally, we conducted the Granger causality test. The results suggest that there is a unidirectional Granger causality running from Primary Energy Consumption to GDP. This result supports the Growth hypothesis emphasizing that energy consumption is one of the determinants of economic growth. Hence, a reduction in energy consumption caused by conservation policies among others would be harmful for economic growth. Our finding is consistent with those of [121,122], the studies examining the energy-growth nexus either in GCC or CIS oil-exporting developing countries. Furthermore, we did not find any causal relationship between Residential Electricity Consumption and GDP in the short run. This finding is in line with the Neutrality hypothesis meaning that energy consumption and growth are mutually independent and thus do not exert any impact on each other. Therefore, some measures aiming at conservation of Residential Electricity Consumption can be implemented. Ref. [88] states that there is a large potential for saving energy in the oil-exporting developing countries. Note that, Cheng [34], Akino [4], Oztukur et al. [105] among others also found similar result for the oil-exporting developing economies.

Moreover, we find a positive impact of Foreign Direct Investments and Employment on GDP, which is in line with the earlier studies and consistent with economic growth theories.

We conclude that, unlike Residential Electricity Consumption, Primary Energy Consumption has certain short-run and long-run effects on GDP in Eurasian oil-exporting developing countries. Our explanation for these findings is that Primary Energy Consumption, as one of the inputs of the production, can lead to economic growth. However, Residential Electricity Consumption is about usage of energy in households, which first, does not directly contribute to production of goods and services, and second, like opportunity costs, usage electricity in residential sector make it impossible to use in industry and or commercial sectors. Finally, the electricity price is highly subsidized in the countries undertaken here and this leads to an inefficient use of electricity by the residential sector and thus, less possibility of saving it for industry and or commercial usage. This also limits its contribution to economic growth.

6.2. Conclusions and policy implication

In this paper, we investigate the energy-growth nexus in 10 Eurasian oil-exporting developing countries, namely Azerbaijan, Bahrain, Iran, Kazakhstan, Kuwait, Oman, Qatar, Russia, Saudi Arabia and UAE, over the period 1997–2014. We are motivated by a number of issues related to the countries considered, energy measures used, methodologies applied and theoretical frameworks employed, which were not sufficiently addressed in previous studies. We perform panel integration, cointegration and error correction analysis as well as the Granger causality in the augmented production function framework. We employ different alternative methods and use two different measures of energy consumption in the empirical analysis for a robustness check.

We find that the Primary Energy Consumption has a significant impact on growth in both the short run and long run. It supports validation of the growth hypothesis for the selected countries. However, we do not find any significant nexus between economic growth and Residential Electricity Consumption, another measure for energy consumption, either in the short run or long run. This finding confirms evidence of the neutrality hypothesis.

Furthermore, it is revealed that the Foreign Direct Investments and Employment are the main determinants of growth in the selected countries, which is in line with the production function concept.

The study has some policy implications. Policymakers in these economies should consider that the growth hypothesis is valid in the nexus of the Primary Energy Consumption-GDP. The main policy message is that since the Primary Energy Consumption is one of the important factors of production, any policy measures aimed at conserving it would undermine economic growth in the selected countries. On the other hand, no nexus between Residential Electricity Consumption and GDP, which is a confirmation of the neutrality hypothesis, implies that policymakers in these countries can pursue conservation policies. In particular, they can reconsider the size of subsidies and or cheaper prices of electricity for households. Among other usefulness, this measure would help the governments to improve their budgets revenues in the backdrop of huge decline in oil revenues caused by the collapse in oil prices. In fact, policy makers in some countries undertaken here have implemented this measure. For example, electricity price increased twice in Azerbaijan by 17% in July and 57% in December 2016. Similarly, price of electricity and also refined oil products were increased by about 50% in January 2016 in Saudi Arabia.

Addressing a number of issues, which have not been explored sufficiently by the prior studies and filling the gap in the case of the Eurasian oil-exporting developing countries, especially those from ME and CIS region, this study contributes to the energy-growth literature.

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Appendix. Econometric methodology

**PUR**T: As mentioned in the text, to obtain robust results, we use both common root tests such as Levin, Lin and Chu (LLC, [83,26,58]) and individual root tests of Im, Pesaran and Shin (IPS, [69]), Fisher-Augmented Dickey Fuller (F-ADF) and Fisher-Phillips Perron (F-PP).

In general, a PURT equation can be expressed as the following:

| Dependent variable | Source of causation (independent variable) |
|--------------------|---------------------------------------------|
| Δgdp               | Δrec Δfhi Δemp                               |
| Δrec               | 0.406 (0.524) 1.149 (0.284) 0.328 (0.567) 0.105 (0.745) |
| Δfhi               | 0.000 (0.982) 1.223 (0.269) 0.352 (0.553) 0.386 (0.122) 0.072 (0.789) 0.691 (0.406) |
| Δemp               | 0.010 (0.922) 4.965 (0.026) 4.386 (0.122) 0.072 (0.789) 0.691 (0.406) |
| Note: The values in the table are Chi-square statistics from the Wald test. Probabilities are in parentheses. |
\[ \Delta y_{i,t} = \phi y_{i,t-1} + \sum_{j=1}^{p} \mu_j \Delta y_{i,j-1} + X_i' \beta_i + \xi_{i,t} \]  
(A.1)

Where, \( y \) is a variable to be tested, as in (1), \( X \) is a set of exogenous variables such as fixed effects and/or individual trends; \( i \) and \( t \) are as defined in (1). \( \xi \) is error term, which is assumed to have mutually independent idiosyncratic disturbance; \( \Delta \) stands for first difference operator;

If \( \phi = 0 \) then \( \chi \) has a unit root. If \( \phi < 0 \), then \( \chi \) is weakly stationary.

In common unit root tests (LLC, Breitung and Hadri), as the name indicates, it is assumed that \( \phi = \phi \) for all \( i \) in (A.1). Hence, the null hypothesis of the unit root in LLC and Breitung tests is: \( H_0: \phi = 0 \).

The alternative hypothesis of no unit root is: \( H_1: \phi < 0 \).

It is important to note that unlike LLC and Breitung, in Hadri test, the null hypothesis is a no unit root: \( H_0: \phi = 0 \) while alternative is unit root: \( H_1: \phi < 0 \).

Detailed discussion on these tests can be found in [83,26,58].

Unlike common root tests, \( \phi \) is not restricted to be the same and thus it may vary across sections. Therefore, the null hypothesis (\( H_0 \)) of unit root and the alternative hypothesis (\( H_1 \)) of no unit root in IPS, F-ADF and F-PP are as follows:

\[
H_0: \phi = 0, \quad \text{for all } i = 1, 2, \ldots, N_i \\
H_1: \phi < 0, \quad \text{for all } i = N_i+1, N_i+2, \ldots, N
\]

After estimating the (A.1) separately for each cross section, the average of the t-statistics (\( \bar{T}_{i}^{CT} \)) for \( \phi \) is calculated:

\[
\bar{T}_{i}^{CT} = \frac{\sum_{i=1}^{N} T_{i}}{N}
\]

To save space, we will not describe the IPS, F-ADF and F-PP tests here in detail. One should look at [69,86] for a detailed discussion.

**PCT:** If the PURT analysis shows that the variables are integrated in the same order of one, then a cointegration analysis can be conducted to determine whether a long-run relationship exists among the variables.\(^{23}\) The cointegration analysis here can be divided into three stages: (a) test for cointegration, i.e., long-run relationship(s) among the variables; estimation of (b) long-run coefficients and (c) short-run coefficients and speed of adjustments.

To obtain much more robust results, we employ two single equation-based PCTs: [74,108,110].

Note that Wagner and Hlouskova\(^{137}\) comprehensively compare the single equation-based and system-based PCTs and show that the system-based tests generally underperform. They are very poor when the number of time series observations is small. In particular, they are prone to over-estimation of the cointegrating space.\(^{24}\) Moreover, Wagner and Hlouskova\(^{137}\) discuss that Pedroni\(^{108}\) PCT outperforms the system-based tests such as [78], which is based on [72] in the case of no cointegration. Hence, we do not employ system-based PCTs, especially considering that we have a small number of time series observations.

1. **Kao** [74] PCT: Kao’s test considers a homogenous cointegration relationship by allowing heterogeneity only in intercept and ruling out trend.

To be precise, this test restricts \( \beta_i = \beta \) and \( \delta_i = 0 \) for all \( i \) in (A.1) and uses the following regression:

\[
\chi_{i,t} = \alpha_i + \beta y_{i,t-1} + \delta_i + \epsilon_{i,t} \quad (A.2)
\]

In the second stage, the stationarity of the residuals from (A.2), i.e., \( \hat{\epsilon}_{i,t} \), is tested by using one of the following equations:

\[
\hat{\epsilon}_{i,t} = p \hat{\epsilon}_{i,t-1} + \theta_{i,t} \quad (A.3)
\]

Again, the augmented version of (A.3) should be used, if values of \( \theta_{i} \) are correlated.

\[
\hat{\epsilon}_{i,t} = p \hat{\epsilon}_{i,t-1} + \sum_{j=1}^{q} s_j \Delta \hat{\epsilon}_{i,j-1} + \xi_{i,t} \quad (A.4)
\]

In (A.3) and (A.4), it is assumed that \( p = q \) for all \( i \). In other words, an autoregressive coefficient does not vary across sections.

The null hypothesis of no cointegration (\( H_0 \)) and the homogenous alternative hypothesis (\( H_1 \)) are as follows. \( H_0: p = 1 \) and \( H_1: p = 1 \).

Kao has calculated four Dickey-Fuller and one Augmented Dickey-Fuller type test statistics to check the hypotheses. All of these test statistics and critical values are comprehensively discussed in [74].

2. **Pedroni** [108] PCT: This is a heterogeneous PCT. In the first stage of Pedroni’s method, the following panel regression, which allows for heterogeneity across sections, is estimated as:

\[
\chi_{i,t} = \alpha_i + \delta_i + \beta y_{i,t-1} + \beta_2 x_{i,t-1} + \ldots + \beta_k x_{i,t-1} + \mu_{i,t} \quad (A.5)
\]

\( y \) and \( x \) are assumed to be I(1). \( \alpha_i, \delta_i \) are individual and trend effects and they can be set to zero if needed.

In the second stage, the stationarity of the calculated/estimated residuals of (A.5), i.e., \( \hat{\epsilon}_{i,t} \), is tested by using the following regressions:

\[
\hat{\epsilon}_{i,t} = p \hat{\epsilon}_{i,t-1} + u_{i,t} \quad (A.6)
\]

If values of \( u_{i} \) are correlated, then augmented version of (A.6) should be used.

\[
\hat{\epsilon}_{i,t} = p \hat{\epsilon}_{i,t-1} + \sum_{j=1}^{q} s_j \Delta \hat{\epsilon}_{i,j-1} + \nu_{i,t} \quad (A.7)
\]

---

\(^{23}\)It is important to note that some variables might be I(1) while others are I(0). In such cases, Pooled Mean Group Estimators by Pesaran et al. [111] should be performed.

\(^{24}\)In fact, we ran the Fisher (Combined Johansen) system-based cointegration test, and it indicated three cointegrating relationships among the variables, which is hard to explain/interpret theoretically and identify econometrically.
The null hypothesis of no cointegration is: \( H_0: \beta = 1 \). There are two alternative hypotheses. The homogenous (between dimension) alternative hypothesis: \( H_1: \beta < 1 \) for all \( i = 1, \ldots, N \) and the heterogeneous (within dimension) alternative hypothesis is: \( H_1: \beta = \rho < 1 \) for all \( i = 1, \ldots, N \). The first one is tested by the between-dimension test or group test statistics and assumes common values for \( \beta = \rho \) while the second one is tested by the within-dimension test or panel test statistics. To test the null and the alternative hypotheses, Pedroni has developed seven test statistics. Four of them (i.e., Panel v-Statistic, Panel rho-Statistic, Panel PP-Statistic and Panel ADF-Statistic) are for a within-dimension test. The rest three (i.e., Group v-Statistic, Group rho-Statistic, Group ADF-Statistic) are for a between-dimension test. A detailed discussion of these tests statistics and the relevant critical values are provided in [108,110].

Ref. [108] states that the Panel-ADF and Group-ADF test statistics outperform other test statistics because they have better small-sample properties. Additionally, Pedroni [110] shows that \( \rho \) and \( \rho \) tests are prone to under-reject the null of no cointegration in small samples. Orsal [102] goes one step further and proves that Pedroni’s Panel-ADF has the best size and size-adjusted power properties especially when the time series observations and number of cross section are small by conducting Monte Carlo simulations and empirical example. Therefore, it outperforms Pedroni’s other PCTs.

**Estimation of long-run coefficients:** In the PCTs of Kao and Pedroni, if the null hypothesis of no cointegration can be rejected, then it can be concluded that the variables are cointegrated and therefore, coefficients in (A.2) and (A.5) can be interpreted as the long-run coefficients (elasticities). Note that Pedroni [109] shows that if the variables are cointegrated, then the panel OLS estimator is biased and hence, the panel FMOLS should be used. Additionally, Kao and Chang [75] show that in the finite sample, the DOLS outperforms the OLS and the FMOLS in terms of smaller size distortions and more correct inferences. On the other hand, Apergis and Payne [12] refer to Banerjee [19] and emphasize that if the number of observations is more than 60, then the panel FMOLS and DOLS are asymptotically equivalent.

Thus, by considering all of the above-mentioned issues, we use both the panel FMOLS and DOLS estimators in estimating our long-run coefficients. Because the FMOLS and DOLS methods are well established and widely discussed in the prior studies, to save space, we do not describe them here again.

**Estimation of short-run coefficients and speed of adjustments—Panel VAR/VECm:** Note that PCTs do not provide short-run coefficients and speed of adjustments. However, without estimating them one cannot perform tests for long-run and short-run causality, which are one of the main exercises in this study. Thus, if the variables are cointegrated, then we will use Panel VECM for estimating the short-run coefficients and speed of adjustment. Panel VAR model will be employed to estimate only the short-run coefficients if the variables are not cointegrated. To conserve space, we describe only Panel VECM here, considering that Panel VAR is a restricted version of the former, where the error correction term is absent.

Panel VECM is an extension of a well-known time series VECM for panel analysis. The Panel VECM method is widely discussed in [8,55,63,77], among others. Based on these comprehensive discussions, we can briefly describe the method here as below:

\[
\Delta y_{it} = \delta d_{it} + \Pi y_{i,t-1} + \Gamma \Delta y_{i,t-1} + \epsilon_{it} \tag{A.8}
\]

where, \( y_{it} = (y_{i1t}, y_{i2t}, \ldots, y_{in_t})' \) is \( mx1 \) vector of non-stationary variables for cross-section \( i \) in period \( t \). \( \Pi = -I_m + \sum_{j=1}^{k} \Phi_j \); \( \Gamma = -\sum_{j=1}^{k} \delta_j \Phi_j \) for \( j = 2,3,\ldots, (k-1) \); \( \Phi_j \) is a \( m \times m \) coefficient matrix; \( i = 1,2,\ldots, T; \) \( i = 1,2,\ldots, N; \) \( e_{it} \) is a \( m \times 1 \) vector of disturbances; \( d \) is a vector of deterministic components; that is, \( d_{it} = 1 or (1, t); \) \( \delta_j \) is a \( m \times 1 \) or \( m \times 2 \) matrix of parameters; \( k \) denotes lag length and \( m \) is number of variables.

Note that, \( \Gamma \) is the matrices of short-run coefficients. If \( \Pi \) has a reduced rank, then it can be decomposed as:

\[ \Pi = \Gamma \beta \]  

Thus, Panel VECM in our case can be expressed as below:

\[
\begin{bmatrix}
\Delta gd_{it} \\
\Delta ec_{it} \\
\Delta fdi_{it} \\
\Delta pec_{it}
\end{bmatrix} = \begin{bmatrix}
c_{1i} \\
c_{2i} \\
c_{3i} \\
c_{4i}
\end{bmatrix} + \begin{bmatrix}
\Gamma_{11i} & \Gamma_{12i} & \Gamma_{13i} & \Gamma_{14i} \\
\Gamma_{21i} & \Gamma_{22i} & \Gamma_{23i} & \Gamma_{24i} \\
\Gamma_{31i} & \Gamma_{32i} & \Gamma_{33i} & \Gamma_{34i} \\
\Gamma_{41i} & \Gamma_{42i} & \Gamma_{43i} & \Gamma_{44i}
\end{bmatrix} \begin{bmatrix}
\Delta gd_{i,t-1} \\
\Delta ec_{i,t-1} \\
\Delta fdi_{i,t-1} \\
\Delta pec_{i,t-1}
\end{bmatrix} + \begin{bmatrix}
f_{1i} \\
f_{2i} \\
f_{3i} \\
f_{4i}
\end{bmatrix} ECT_{i,t-1} + \begin{bmatrix}
f_{1j} \\
f_{2j} \\
f_{3j} \\
f_{4j}
\end{bmatrix} \tag{A.10}
\]

The definitions of the variables are as before. \( c \) is vector of intercepts; \( \tau \) is vector of the speed of adjustment coefficients which indicate how fast deviations from the long-run equilibrium are corrected; \( \Gamma \) is matrix of the short-run coefficients; \( \epsilon \) is vector of serially independent residuals with mean zero and finite covariance matrix.

### Panel Causality Test: The F or Wald test is applied on the short-run coefficients of (A.10) to examine the direction of a short-run causal relationship (if any) between the variables. For example, in the growth equation, \( \Delta ec \) does not Granger cause to \( \Delta gd \) in the short run if and only if all the coefficients of \( \Gamma_{14i} \) are not significantly different from zero in (A.10). This is short-run non-causality. Long-run causality can be examined by testing that statistical significance of \( \tau \) in (A.10). For example, if \( \tau \) is statistically significant, it means that energy consumption, \( ec \), does Granger cause to the GDP, \( gd \) in the long run. Note that we also test strong causality. For example, energy consumption has strong causality on growth if jointly all of \( \Gamma_{14i} \) and \( \tau \) are significantly different from zero in the Wald test.

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\[25\] Note that \( ec \) is representative for \( pec \) and \( rec \).
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