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Multivariate granger causality between electricity consumption, exports and GDP: Evidence from a panel of Middle Eastern countries

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ABSTRACT

This paper examines the causal relationship between electricity consumption, exports and gross domestic product (GDP) for a panel of Middle Eastern countries. We find that for the panel as a whole there are statistically significant feedback effects between these variables. A 1 per cent increase in electricity consumption increases GDP by 0.04 per cent, a 1 per cent increase in exports increases GDP by 0.17 per cent and a 1 per cent increase in GDP generates a 0.95 per cent increase in electricity consumption. The policy implications are that for the panel as a whole these countries should invest in electricity infrastructure and step up electricity conservation policies to avoid a reduction in electricity consumption adversely affecting economic growth. Further policy implications are that for the panel as a whole promoting exports, particularly non-oil exports, is a means to promote economic growth and that expansion of exports can be realized without having adverse effects on energy conservation policies.

1. Introduction

The relationship between energy consumption and gross domestic product (GDP) has attracted much attention in the literature. There are studies for several countries including countries in the Middle East. However, existing studies, including those for the Middle East, have failed to reach a consensus about causality. There are at least two possible reasons for disparate findings in the literature. First, until recently, most studies have focused on single countries with short spans of data. Many countries have only annual data with a maximum span of 20–30 years. The problem is that the power of traditional unit root tests, such as the augmented Dickey–Fuller test and traditional cointegration tests, such as the Johansen (1988) test, can be distorted when the span of data is short (Campbell and Perron, 1991; Perron, 1991).[1] Second, many studies, and particularly studies for the Middle East, suffer from omitted variable bias. A common view in the literature is that studies which focus on two-variable models may be biased due to the omission of relevant variables (see Chang et al., 2001; Stern, 2000). Some recent studies have included, in addition to energy and output, one or more other variables such as employment (Chang et al., 2001; Narayan and Smyth, 2005), energy prices (Masih and Masih, 1997) or capital and labour (Stern, 1993). Other studies, though, including quite recent studies, continue to use a bivariate model including only energy and output (see e.g. Mozumder and Marathe, 2007).

In light of the methodological problems that have plagued much of the literature in this area, further research on the causal relationship between energy consumption and GDP is important given its implications for energy conservation. This applies *a fortiori* to the Middle Eastern oil-exporting countries where the availability of cheap energy means that less attention has been given to the issue of energy conservation than in other parts of the world (Al-Iriani, 2006). The traditional lack of interest in energy conservation in the Middle East is concerning because over the two decades between 1980 and 2001 carbon dioxide emissions in the Middle East and North Africa (MENA) region grew 122 per cent overall or 3.9 per cent per annum. The only region in which carbon dioxide emissions grew faster over this period was developing Asia. The MENA region also has the world's second highest carbon dioxide intensity after developing Asia and, unlike developing Asia and other regions in the world, carbon dioxide intensity in MENA is actually increasing (EIA, 2002). The MENA region, similar to most developing countries, is not seriously concerned with global warming. As Khatib (2005, p. 3) notes: "While Kyoto may be ratified by an increasing number of MENA countries, it will become a different matter if emission commitments are to be enforced and imposed on developing countries".

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[1] There is a burgeoning literature on unit root analyses of energy data; for example, see Chen and Lee (2007), Hsu et al. (2008), Narayan and Smyth (2007) and Narayan et al. (2008).

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This paper examines the relationship between electricity consumption, GDP and exports for a group of Middle Eastern countries over the period 1974–2002 using panel unit root, panel cointegration, Granger causality and long-run structural estimation.[2] There are still relatively few studies that examine the energy–GDP nexus within a panel framework. The studies which use a panel framework are all recent (see Lee, 2005; Al-Iriani, 2006; Chen et al., 2007; Joyeux and Ripple, 2007; Mahadevan and Asafu-Adjaye, 2007; Mehrara, 2007; Lee and Chang, 2008; Narayan and Smyth, 2008). Most of these studies, including Al-Iriani (2006), which includes Middle Eastern countries as part of the panel, and Mehrara (2007), whose panel are oil-exporting countries, use a bivariate framework consisting of energy and GDP. The only panel studies, of which we are aware, that use a trivariate model are Lee (2005), Narayan and Smyth (2008) and Lee and Chang (2008), who use a trivariate model which also incorporates capital stock, and Mahadevan and Asafu-Adjaye (2007), who use a trivariate model which incorporates energy prices in addition to energy and GDP.

The main innovations in this study compared with the existing panel literature on causality between energy and GDP are twofold. First, we employ the Westerlund (2006) panel cointegration test which can accommodate structural breaks. It is well-known that erroneously omitted breaks can cause deceptive inference in time series testing and the effects of structural breaks do not disappear simply because one uses panel data. Several studies have examined the energy–GDP nexus accommodating a structural break for a single country (see Altinay and Karagol, 2004, 2005; Lee and Chang, 2005; Cetintas, 2007). However, Narayan and Smyth (2008), who examine the relationship between energy consumption and GDP in G7 countries, is the only existing study that accommodates a structural break in the panel cointegration model. In the context of the Middle East, the pace of economic development has been linked to surges in oil prices given the importance of oil as an export earner. Thus, events causing structural breaks in world energy markets, such as OPEC rationing from 1983 to 1993, could generate structural breaks in the energy–GDP nexus in the Middle East.

Second, we use a trivariate framework in which, in addition to GDP and energy, we incorporate exports. This marries the Granger causality literatures on the energy–GDP nexus and exports–GDP nexus. It is important to consider exports in the context of the Middle East because it is a region that has been criticized for being slow to globalize (Looney, 2005), with repeated calls for it to improve its export performance (World Bank, 2003). If the Middle East does improve its export performance, we need to know if this will exacerbate growing energy use and contribute to carbon dioxide emissions. Evidence on this point for the Middle East is lacking, but the energy intensity of exports and carbon dioxide emissions associated with growing exports has been considered for other countries such as China (Wang and Watson, 2007; Kahrl and Roland-Holst, 2008). Wang and Watson (2007) estimate that net exports accounted for 23 per cent of China's total carbon dioxide emissions in 2004. While China's exports, particularly manufacturing exports, far outstrip those of the Middle Eastern countries, this figure suggests a potentially important relationship between exports, energy consumption and economic development that is worth exploring.

[2] Granger causality assumes that the information relevant to the prediction of two variables, say electricity consumption and GDP, is contained solely in the time series of these variables. Since the future cannot predict the past, if electricity consumption Granger causes GDP, then changes in electricity consumption should precede changes in GDP. Therefore, in a regression of GDP on other variables (including its own past values) if we include past or lagged values of electricity consumption and it significantly improves the prediction of GDP, then we can say that electricity consumption Granger causes GDP. A similar definition applies if GDP Granger causes electricity consumption (see Gujarati, 1995, p. 621).

2. Electricity consumption, export performance and GDP in the Middle East

Economic development in the Middle East accelerated following the 1973 Arab–Israeli War and 1979 Iranian Revolution that led to a dramatic rise in the price of oil. As oil prices increased, most states in the Middle East benefited from increased revenue. Oil producing states, and especially the large producers such as Iran, Kuwait, and Saudi Arabia benefited directly in the form of higher export earnings. The resource poor Middle Eastern states such as Jordan, the Palestinian areas and Yemen benefited from the sharp increases in oil prices through transmission mechanisms from the oil producers including labour remittances and aid (World Bank, 2006b).

The high rates of economic growth in the 1970s and early 1980s started to fall following the gradual decline in oil revenues from 1983. Between 1980 and 2001, per capita income in the MENA region fell 5 per cent from US$5617 to US$5317 per person (EIA, 2002). In the 1980s and 1990s countries in the Persian Gulf suffered severe declines in real GDP per capita as a result of falling real oil prices and growing populations. In contrast to many of the Persian Gulf countries, Israel experienced significant growth in real GDP per capita. Between 1980 and 2001, Israel's real income per capita increased from US$12,858 per person to US$18,148 per person (EIA, 2002). Over the last few years, the MENA region as a whole has reversed the trend of the 1980s and 1990s and benefited from rising high oil prices and OPEC production increases. Between 2003 and 2005 real GDP in MENA (excluding war-ravished Iraq) grew at 6.2 per cent per annum, the highest 3-year average growth rate for the region in almost three decades (World Bank, 2006b). High regional growth in these years was a manifestation of high growth among the major oil producers which together accounted for 84 per cent of regional growth in 2005, compared with less than 70 per cent in the late 1990s (World Bank, 2006b).

The Middle East, as a whole, is highly dependent on revenue from oil exports. While it has benefited from growth in oil prices over the last few years, its export performance has generally been disappointing with considerable unfulfilled potential to expand investment and trade links with the rest of the world. Despite some liberalization efforts since the mid-1980s, MENA has the world's second highest rate of tariff and non-tariff barriers of the regions of the world after South Asia. High rates of protection not only impede imports, but hinder exporters through increasing the cost of imported inputs. During the 1990s, while world trade grew at almost 8 per cent, MENA's trade grew at only 3 per cent (World Bank, 2003). Quantitative analysis, reported by the World Bank (2003), suggest that its non-oil exports are one-third the level that would be expected from considerations of income and location.

Economic development has been accompanied by strong growth in electricity consumption. MENA electricity demand is growing annually at a rate of around 5–6 per cent (double the world average of 2.7 percent) (Khatib, 2005). Rapid growth in electricity consumption across most of the MENA region has been prompted by several factors (see Khatib, 2005). First, the MENA countries, and the Gulf countries in particular, have experienced high population growth. Second, as part of a process of industrialization, most MENA countries have opted for energy intensive industries such as aluminium, cement, petrochemicals and steel. Third, electricity tariffs are highly subsidized and represent only a fraction of actual (market) cost. Moreover, in many cases electricity bills are uncollected or go unpaid. Fourth, conservation and demand side management practices have been given insufficient attention. These broad-brushed explanations for growth in electricity consumption across the Middle East conceal differences across countries (EIA, 2002). Growth in electricity consumption in Israel has reflected structural change with Israel's high-tech sector expanding significantly since the 1980s. In less-developed countries such as Iran and Saudi Arabia, growth in electricity demand reflects efforts to industrialize; rural electrification campaigns and greater commercial and residential power consumption.

3. Existing literature and hypotheses

There is a huge literature on Granger causality between GDP and energy use for a range of countries using various methodologies. Mehrara (2007) identifies four generations of studies. First generation studies used a traditional vector autoregression (VAR) methodology and Granger causality testing. The results from first generation studies are suspect because these studies assume the data are stationary. Second- and third-generation studies apply unit root and cointegration testing for single countries with various levels of sophistication. Fourth generation studies employ panel-based unit root and cointegration testing procedures. While the econometric techniques employed have become increasingly sophisticated, the results remain inconclusive. As Mehrara (2007, p. 2940) states, "when it comes to whether energy use is a result of, or a perquisite for, economic growth, there are no clear trends in the literature. Depending on the methodology used, and country and time period studied, the direction of causality between energy consumption and economic variables has remained empirically elusive and controversial". As a subset of this literature, a much smaller number of studies have considered the relationship between energy use and GDP in the Middle East. There are some single country studies (e.g. Zamani, 2007) and a panel-based study which includes Middle Eastern countries (Al-Iriani, 2006). The results from these studies have also been mixed. The panel-based study suggested strong unidirectional Granger causality running from economic growth to energy consumption, but Zamani (2007) reached conflicting results in a study of the relationship between energy consumption and myriad economic activities in Iran. Each of these studies use a bivariate framework with energy consumption and GDP being the only variables so there is a potential omitted variables bias problem.

As with the causal relationship between energy consumption and GDP, there is a sizable literature on Granger causality between exports and GDP. First generation studies that did not consider the stationarity of the data and used simple correlation methods found strong support for the export-led hypothesis; however, more recent studies which have taken stationarity into account have found mixed support for the export-led and handmaiden hypotheses (see Giles and Williams, 2000; Ahmad, 2001 for reviews). There are a small number of papers that have examined Granger causality between exports and GDP for MENA countries (see e.g. Jung and Marshall, 1985; Hutchison and Singh, 1992; Dodaro, 1993; Kugler and Dridi, 1993; Pomponio, 1996; Xu, 1996; Al-Mawali, 2004). The evidence on Granger causality from these studies has been mixed depending on the countries and methodology employed.

The gap in the literature is that there are no studies which examine the causal relationship between energy use, exports and GDP within the one multivariate model. This is a gap that we address in this study and, in so doing, we effectively marry the literature on the exports–GDP nexus and electricity consumption–GDP nexus. Thus, we test several hypotheses concerning the causal relationship between electricity consumption and GDP, exports and GDP and electricity consumption and exports.

The first set of competing hypotheses concerns the relationship between electricity consumption and GDP. The competing hypotheses are that there is unidirectional Granger causality running from electricity consumption to GDP; unidirectional Granger causality running from GDP to electricity consumption; bidirectional Granger causality between these variables or no Granger causality in either direction. These hypotheses, which have been considered in the energy use–GDP nexus literature, have important policy implications. If there is unidirectional Granger causality running from GDP to electricity consumption or no Granger causality in either direction, it may be implied that energy conservation policies, such as phasing out energy subsidies or elimination of energy price distortions have little or no adverse effect on economic growth. Phasing out energy subsidies and eliminating price distortions can be expected to conserve energy because, as discussed above in Section 2, energy subsidies and artificially low prices have led to excessive energy use in the Middle East. On the other hand, if unidirectional Granger causality runs from electricity consumption to GDP, reducing electricity consumption through bringing domestic electricity prices in line with the market could lead to a fall in income, while increases in electricity consumption contribute to economic growth.

The second set of competing hypotheses concerns the causal relationship between exports and GDP. These hypotheses have been considered in the exports–GDP nexus literature. The export-led hypothesis states that Granger causality runs from exports to GDP. There are several possible reasons why Granger causality might run from exports to GDP (Ahmad, 2001). At its most obvious level, exports increase GDP because exports are a component of GDP in national accounting. At a more subtle level, countries with a high export to GDP ratio are more open to outside influences and generate externalities, such as incentive to innovate. These efficiency gains increase GDP through increasing total factor productivity (TFP) in the Solow–Swan growth accounting framework. The competing hypothesis that Granger causality runs from GDP to exports is captured in variants of 'handmaiden' theories of trade (Kravis, 1970) or the argument that growth mechanisms that are 'internally generated' best explain the growth of exports (Jung and Marshall, 1985). For example, assume there is growth in TFP due to technological improvements that are independent of trade. It is plausible that the comparative cost structure of such an economy would evolve in a manner that is consistent with growing exports (Ahmad, 2001, p. 148).

The third set of competing hypotheses concerns the relationship between exports and electricity consumption. We are able to test these hypotheses because we examine electricity consumption, exports and GDP in the one model. The policy implications are as follows. If Granger causality runs from electricity consumption to exports, reducing electricity consumption could impede attempts to develop a diversified (non-oil) export sector. On the other hand, if there is Granger causality running from exports to electricity consumption or no Granger causality in either direction, energy conservation policies can be expected to have no adverse effect on export growth.

4. Data

The empirical analysis is based on six Middle Eastern countries; namely, Iran, Israel, Kuwait, Oman, Saudi Arabia, and Syria. We use annual time series data for the period 1974–2002. The sample is restricted to those countries for which data are available over this period. Per capita electricity consumption is measured in kWh, per capita GDP and exports are measured in US dollars at 1995 prices based on purchasing power parity. Data on GDP and electricity were obtained from the EIA (2003), while data on exports was obtained from the IMF (2003). All of the data were converted into natural logarithms prior to conducting the empirical analysis.

5. Econometric methodology and results

5.1. Panel unit root

We started through testing for the presence of a unit root in real income, electricity consumption and exports using the panel unit root test proposed by Breitung (2000). The reason for using the Breitung (2000) panel unit root test is that a recent large-scale Monte Carlo simulation study by Hlouskova and Wagner (2006) found that the Breitung (2000) panel unit root test generally had the highest power and smallest size distortions of any of the so-called first generation panel unit root tests.

The Breitung (2000) panel unit root test has the following form:

$$y_{it} = \alpha_{it} + \sum_{k=1}^{p+1} \beta_{ik} x_{i,t-k} + \varepsilon_t \tag{1}$$

In Eq. (1) the Breitung (2000) test statistic tests the following null hypothesis that the process is difference stationary: $H_0 : \sum_{k=1}^{p+1} \beta_{ik} - 1 = 0$ The alternative hypothesis assumes that the panel series is stationary; i.e., $\sum_{k=1}^{p+1} \beta_{ik} - 1 < 0$ for all i. Breitung (2000) uses the following transformed vectors to construct the test statistic:

$$Y_i^* = AY_i = [y_{i1}^*, y_{i2}^*, \ldots, y_{iT}^*]'$$

$$X_i^* = AX_i = [x_{i1}^*, x_{i2}^*, \ldots, x_{iT}^*]'$$

leading to the following test statistic:

$$\lambda_B = \frac{\sum_{i=1}^{N} \sigma_1^{-2} y_i^{*\prime} X_i^{*\prime}}{\sqrt{\sum_{i=1}^{N} \sigma_1^{-2} X_i^{*\prime} A' A X_i^*}} \tag{2}$$

which is shown to have a standard normal distribution.

The results of the Breitung (2000) panel unit root test are reported in Table 1. The test statistics for the log-levels of real income, electricity consumption and real exports each have a probability value greater than 1, implying that each of the three variables are panel non-stationary. However, when we apply the panel unit root test to the first difference of the log-levels variables we can reject the joint unit root null hypothesis for each of the three variables at the 5 per cent level of significance or better. Taken together, these results suggest the three variables contain a panel unit root.

Table 1
Panel unit root tests

Variables	Breitung t-test	Probability value
$\ln Y$	−1.0071	0.1569
$\Delta \ln Y$	−3.3619***	0.0004
$\ln El$	−0.4868	0.3132
$\Delta \ln El$	−2.0338**	0.0210
$\ln Ex$	0.0061	0.5024
$\Delta \ln Ex$	−6.1582***	0.0000

Notes: *** and ** denotes statistical significance at the 1 per cent and 5 per cent level.

5.2. Panel cointegration

On the basis of the panel unit root test results we proceed to testing for cointegration using the panel cointegration test suggested by Westerlund (2006). The cointegration test proposed by Westerlund (2006) can accommodate multiple structural breaks.

Consider the following long-run model:

$$\ln Y_{i,t} = \alpha_i + \beta_i \ln El_{i,t} + \phi_i \ln Ex_{i,t} + e_{i,t} \tag{3}$$

$$e_{it} = r_{it} + \mu_{it}$$

$$r_{it} = r_{it-1} + \phi_i \mu_{it}$$

where Y refers to real income, El refers to electricity consumption and Ex refers to exports. The index $j = 1,\ldots,M_i+1$ denotes structural breaks. One can allow for at most M_i breaks or M_i+1 regimes that are located at dates $T_{i1}, \ldots, T_{iM_i}$, where $T_{i0} = 1$ and $T_{iM_i+1} = T$. The location of the breaks are specified as a fixed fraction $\lambda_{ij} \in (0,\ 1)$ of T such that $T_{ij} = [\lambda_{ij} T]$ and $\lambda_{ij-1} < \lambda_{ij}$ for $j = 1,\ldots M_i$. Westerlund (2006) determines the structural breaks endogenously using the Bai and Perron (1998) technique, which globally minimizes the sum of squared residuals to obtain the location of breaks:

$$\hat{T}_i = \arg \min_{T_i} \sum_{j=1}^{M_i+1} \sum_{t=T_{ij-1}+1}^{T_{ij}} (y_{it} - z'_{it} \hat{\gamma}_{ij} - x'_{it} \hat{\beta}_i)^2 \tag{4}$$

where $\hat{T}_i = (\hat{T}_{i1}, \ldots, \hat{T}_{iMi})'$ is a vector of estimate break points, $\hat{\gamma}_{ij}$ and $\hat{\beta}_i$ are the estimates of the cointegration parameters based on the partition $T_i = (T_{i1}, \ldots, T_{iMi})'$ and τ is the trimming parameter such that $\lambda_{ij} - \lambda_{ij-1} > \tau$. To ensure that the break date estimator works properly we set the minimum length of each sample segment equal to 0.15 T and follow the advice of Bai and Perron (1998, 2003) and use the Schwartz Bayesian criterion. The maximum number of allowable breaks is set equal to one.

The null hypothesis for all countries of the panel is

$$H_0 : \phi_i = 0 \text{ for all } i = 1, \ldots, N$$

versus

$$H_1 : \phi_i \neq 0 \text{ for } i = 1, \ldots, N_1 \text{ and } \phi_i = 0 \text{ for } i = N_1 + 1, \ldots, N$$

The alternative hypothesis allows ϕ_i to differ across the cross-sectional units.

The panel LM test statistic is defined as follows:

$$Z(M) \equiv \sum_{i=1}^{N} \sum_{j=1}^{M_i+1} \sum_{t=T_{ij-1}+1}^{T_{ij}} (T_{ij} - T_{ij-1})^{-2} \hat{\omega}_{i1.2}^{-2} S_{it}^2 \tag{5}$$

where $\hat{\omega}_{i1.2}^{-2} = \hat{\omega}'_{i1.1} - \hat{\omega}'_{i21} \hat{\Omega}_{i22}^{-1} \hat{\omega}_{i21}$ and $S_{it} = \sum_{k=T_{ij-1}+1}^{t} \hat{e}_{ik}^*$, where $\hat{e}_{ik}^*$ is any efficient estimate of e_{it}. We use the fully-modified ordinary least-squares (FMOLS) estimator (Phillips and Hansen, 1990) to estimate e_{it}, where the test statistic is written as a function of breaks. As Westerlund (2006) pointed out, the results for the $Z_{FM}(M)$ test statistic are sensitive to cross-sectional correlation. To ensure the results in this study are robust to cross-sectional correlation we used bootstrapped critical values based on 5000 bootstrap replications. The 5 per cent critical value obtained from the bootstrap distribution for the FMOLS-based test is 2.155. We obtain a $Z_{FM}(M)$ statistic equal to 0.676 when we allow for one structural break, meaning that real income, exports and electricity consumption are cointegrated around a broken intercept.

5.3. Panel Granger causality

Next we examine the direction of causality between the variables in a panel context. Engle and Granger (1987) show that if two non-stationary variables are cointegrated, a VAR in first differences will be misspecified. Given that we found a long-run equilibrium relationship between exports, real income and electricity consumption, when testing for Granger causality, we specify a model with a dynamic error-correction representation. The VAR model is augmented with a one-period lagged error-correction term that is obtained from the cointegrated model.

The Granger causality test is based on the following regressions:

$$\Delta \ln Y_{it} = \pi_{iY} + \sum_{p} \pi_{11ip} \Delta \ln Y_{it-p} + \sum_{p} \pi_{12ip} \Delta \ln El_{it-p} + \sum_{p} \pi_{13ip} \Delta \ln Ex_{it-p} + \psi_{1i} ECT_{t-1} + \varepsilon_{it}, \tag{6}$$

$$\Delta \ln El_{it} = \pi_{iEl} + \sum_{p} \pi_{21ip} \Delta \ln El_{it-p} + \sum_{p} \pi_{22ip} \Delta \ln Y_{it-p} + \sum_{p} \pi_{23ip} \Delta \ln Ex_{it-p} + \psi_{2i} ECT_{t-1} + \varepsilon_{it} \tag{7}$$

$$\Delta \ln Ex_{it} = \pi_{iEx} + \sum_{p} \pi_{31ip} \Delta \ln Ex_{it-p} + \sum_{p} \pi_{32ip} \Delta \ln Y_{it-p} + \sum_{p} \pi_{33ip} \Delta \ln El_{it-p} + \psi_{3i} ECT_{t-1} + \varepsilon_{it} \tag{8}$$

Here *Y*, *El* and *Ex* are as previously defined, Δ denotes the first difference of the variable, *ECT* is the error-correction term, and *p* denotes the lag length. The lag length in each case was selected using the two-stage procedure suggested in Abdalla and Murinde (1997). Following Abdalla and Murinde (1997) the optimal lag length was selected through maximizing the value of the R^2. The Granger causality results are reported in Table 2. There is short-run Granger causality running from electricity consumption to real income and from real income to exports. There is also long-run Granger causality relationship running from exports and electricity consumption to real income and from exports and real income to electricity consumption.

This result differs from Al-Iriani's (2006) findings for the six countries of the Gulf Cooperation Council and Mehrara's (2007) results for a panel of 11 oil-exporting countries. Both of these studies found unidirectional causality running from energy to GDP. The difference could reflect the different sample of countries, but most likely also reflect the fact that these earlier panel studies suffer from omitted variable bias. While both these studies use a bivariate framework, we find evidence of reverse causality when exports are added as an additional channel through which causation can run. The long-run results for exports and GDP are consistent with the export-led hypothesis. This finding is consistent with some previous studies for the MENA region; notably, Dutt and Ghosh (1996) for Israel and Turkey; Pomponio (1996) for Turkey and Tunisia and Riezman et al. (1996) for Algeria, Egypt and Tunisia.

Table 2
Panel Granger causality test results

	$\Delta\ln Y$	$\Delta\ln El$	$\Delta\ln Ex$	ECM_{t-1}
$\Delta\ln Y$	–	2.8379*	1.2431	−0.0474***
		(0.0617)	(0.2914)	[−3.6718]
$\Delta\ln El$	1.2891	—	2.1303	−0.0733***
	(0.2786)		(0.1224)	[−10.8895]
$\Delta\ln Ex$	4.6141***	2.2396	—	−0.0011
	(0.0114)	(0.1100)		[−0.1270]

Notes: *, **, and *** denote statistical significance at the 10 per cent, 5 per cent and 1 per cent levels, respectively. The *t*-statistics are shown in parenthesis and square brackets.

5.4. Panel long-run estimates

Having established cointegration as well as the direction of Granger causality in the long-run we proceed to estimation of the long-run structural coefficients using Phillips and Hansen's (1990) FMOLS. The long-run elasticities of the impact of electricity consumption and exports on real income for each of the six Middle Eastern countries and for the panel of Middle Eastern countries based on the FMOLS estimator are reported in Table 3. Beginning with the country specific results, we find that electricity consumption has a positive and statistically significant impact on real income in Israel, Oman and Syria. The magnitude of the impact ranges from 0.12 in the case of Syria to 0.49 in the case of Israel. However, for Saudi Arabia, the impact of electricity consumption on real income is negative and statistically significant at the 1 per cent level, implying that a 1 per cent increase in per capita electricity consumption reduces real per capita income. This result reflects the fact that over the period of the study, consumption of electricity increased considerably while real income fell in per capita terms in Saudi Arabia. Saudi Arabia's per capita income fell from over US\$20,900 per person in 1980 to about US\$12,200 per person in 2001 (EIA, 2002). Saudi Arabia experienced especially rapid per capita electricity demand growth during the early 1980s on the back of rising incomes from the 1970s oil price increases and after oil prices fell in the mid-1980s, electricity consumption patterns were only partially affected. In terms of energy consumption as a whole, per capita energy demand in Saudi Arabia increased from 178 million Btu in 1980 to 234 million Btu in 2001 (EIA, 2002). Saudi Arabia's electricity intensity increased from less than 100 kWh in 1980 to 444 kWh in 2001 (measured in \$1995 PPP) (EIA, 2002).

Turning to the effect of exports on real income, we find that for Kuwait, Saudi Arabia and Syria, exports have a positive and statistically significant impact on real income. The magnitude of the impact ranges from 0.18 in the case of Syria to 0.43 in the case of Kuwait. For Israel, exports have a negative and statistically significant effect on real income, although the magnitude of the impact is relatively small (0.01). Finally, the panel long-run elasticities reported in the last row of Table 3 suggest that electricity consumption and exports have a positive and statistically significant effect on real income. A 1 per cent increase in

Table 3
FMOLS long-run elasticities (income as the dependent variable)

	ln *El*	ln *Ex*
Iran	−0.05	0.01
	(−0.25)	(0.14)
Israel	0.49***	−0.01**
	(13.66)	(−2.32)
Kuwait	−0.21	0.43***
	(−1.64)	(3.98)
Oman	0.15***	0.14
	(3.27)	(1.49)
Saudi Arabia	−0.25***	0.28***
	(−5.76)	(2.93)
Syria	0.12***	0.18***
	(4.25)	(4.37)
Panel	0.04***	0.17***
	(5.52)	(4.32)

Notes: ** and *** denote statistical significance at the 5 per cent and 1 per cent levels, respectively.

Table 4
FMOLS long-run elasticities (electricity consumption as dependent variable)

	ln *Ex*	ln *Y*
Iran	−0.29	−0.15
	(−5.33)	(−0.32)
Israel	0.01	1.85***
	(0.96)	(13.57)
Kuwait	0.45	−1.32**
	(1.20)	(−1.99)
Oman	0.15	3.86***
	(0.37)	(4.48)
Saudi Arabia	0.85***	−3.07***
	(2.53)	(−7.38)
Syria	−0.66	4.50***
	(−1.40)	(3.11)
Panel	0.08	0.95***
	(0.69)	(4.68)

Notes: ** and *** denote statistical significance at the 5 per cent and 1 per cent levels, respectively.

electricity consumption increases income by 0.04 per cent while a 1 per cent increase in exports increases income by 0.17 per cent, with both coefficients being statistically significant at the 1 per cent level.

The long-run elasticities of the impact of exports and real income on electricity consumption for each of the six Middle Eastern countries and for the panel of Middle Eastern countries based on the FMOLS estimator are reported in Table 4. The results suggest that a 1 per cent increase in exports generates a 0.85 per cent increase in real income in Saudi Arabia, but the coefficient on exports is statistically insignificant for the other five countries and for the panel as a whole. The coefficient on real income is positive and statistically significant for Isreal, Oman and Syria with a 1 per cent increase in real income generating between a 1.85 per cent increase in electricity consumption in Israel and a 4.5 per cent increase in electricity consumption in Syria.

The coefficient on real income is negative and statistically significant in Kuwait and Saudi Arabia, where a 1 per cent increase in real income generates a 1.32 per cent and 3.07 per cent decrease in electricity consumption, respectively. These results are consistent with the findings of Mahadevan and Asafu-Adjaye (2007). These authors note (at p. 2486), "developing countries such as Kuwait [and] Saudi Arabia .... that are net energy exporters enjoy cheap energy domestically as prices are kept artificially low as a result of low government tariffs and high consumer subsidies. This has resulted in waste and inefficient use and hence energy consumption has not translated to GDP growth". As supporting evidence of this observation, both countries experienced rapid growth in per capita electricity consumption and falling per capita income over the period of the study. Saudi Arabia is discussed above in the context of Table 3. The coefficient on electricity consumption for Kuwait in Table 3 was also negative, but statistically insignificant. While Kuwait has undergone a big increase in electricity consumption, GDP per capita (in constant 2000 $US) fell from $30,625 in 1974 to $20,286 in 1980 and $17,103 in 2002 (World Bank, 2006a). For the panel as a whole, the coefficient on real income is significant and a 1 per cent increase in real income generates a 0.95 per cent increase in electricity consumption.

6. Non-technical summary of results and policy implications

The main findings from this study are that for the panel of Middle Eastern countries there is that Granger causality between electricity consumption and real income runs in both directions and that Granger causality runs from exports to real income and from exports to electricity consumption. This result means that electricity consumption and real income improve the predictive power of each other's time series and that exports improve the predictive power of the time series of electricity consumption and real income. The results from the FMOLS long-run estimates indicate that for the panel as a whole, an increase in electricity consumption and exports has a positive and statistically significant effect on real income, while an increase in real income has a positive and statistically significant effect on electricity consumption. To summarize the practical implications: a 1 per cent increase in electricity consumption increases GDP by 0.04 per cent, a 1 per cent increase in exports increases GDP by 0.17 per cent and a 1 per cent increase in GDP generates a 0.95 per cent increase in electricity consumption. The findings for the panel as a whole are also true for several of the individual countries, although in Saudi Arabia and Kuwait electricity consumption and real income are inversely related and in Israel an increase in exports has a small negative effect on real income.

Bidirectional Granger causality between electricity consumption and real income implies that electricity consumption and economic growth are jointly determined and affected at the same time. On the one hand, an expansion in real GDP increases electricity consumption in Israel, Oman and Syria and for the panel as a whole. There are at least two reasons for this. First, economic growth has resulted in an expansion in the commercial and industrial sectors where electricity is a basic input. Second, higher disposable income increases demand for electronic gadgets for entertainment and comfort for households. This pattern is similar to what has occurred in Asia (see Chen et al., 2007; Mahadevan and Asafu-Adjaye, 2007). On the other hand, an increase in electricity consumption results in higher real income for the panel as a whole as well as for the individual country results for Israel, Oman and Syria. In addition to the direct effect of electricity used for commercial use which contributes to GDP, the increase in electricity consumption results in an increase in electricity production, which implies an expansion in electricity employment and infrastructure.

The findings suggest that, for the panel as a whole, these countries should adopt the dual strategy of increasing investment in electricity infrastructure and stepping up electricity conservation policies to reduce unnecessary wastage of electricity, in order to avoid a negative effect on economic growth of reducing electricity consumption. One problem is that, as discussed above, while some energy conservation programs exist in the Middle East, such as the National Energy Efficiency Program in Saudi Arabia, implemented in conjunction with UNDP, they are still in their infancy (Al-Iriani, 2006). The related problem is that at this point, due to subsidies, low tariffs and weak collection mechanisms, few Middle Eastern power stations are able to provide a reasonable measure of self-financing to power extension (Khatib, 2005). Faced with poor financial performance and capital shortages, many Middle Eastern countries, particularly in the Gulf, are looking for IPPs to construct and operate new power facilities. To this point, success has been limited. In short, what are needed are reforms which lead to efficient use and provide utilities with a measure of self-financing. Such reforms could include the following (see Khatib, 2005): an unsubsidized or limited subsidy tariff structure; 100 per cent collection of bills by a privately owned distribution company and creating a regulatory environment that will create confidence in the power sector that will attract domestic and foreign capital.

The support for the export-led hypothesis for the panel as a whole and for Kuwait, Saudi Arabia and Syria backs the claims of the World Bank (2003) that expanding exports, particularly non-oil exports, in the Middle Eastern countries will increase economic growth. The main problem is that many Middle Eastern countries have had policies that are not conducive to export expansion; namely, a combination of overvalued exchange rates and a high level of tariff and non-tariff barriers. As the World Bank (2003) has proffered, further liberalization of trade in goods in the Middle Eastern countries is needed to expand exports. One advantage of focusing on export growth is that our finding there is unilateral Granger causality running from exports to electricity consumption implies that exports *per se* can be boosted without adverse effects on energy conservation, which differs from GDP more broadly.

7. Conclusion: limitations and directions for future research

There are large literatures that examine the causal relationship between energy use and GDP on the one hand and exports and GDP on the other. These studies have been often plagued by methodological limitations that have undermined the reliability of the relevant policy implications. These limitations include focusing on a single country with a short span of data and omitted variable bias due to the omission of relevant variables. This study has adopted a panel approach to address the problem of a short span of data and examined the relationship between electricity consumption, exports and GDP to address omitted variables bias. The latter effectively marries the two literatures on the exports–GDP nexus and electricity consumption–GDP nexus. Our study has been for the Middle East, which is a region where thus far little attention has been given to the issue of energy conservation because of the traditional ready cheap supply of energy and more needs to be done to promote exports. Thus, it makes sense to consider exports, electricity consumption and GDP in the one model. One solid conclusion from the study is that promoting exports is a good approach to expanding growth without adverse environmental effects. The recommendation to focus on export growth is consistent with that of the World Bank (2003).

One of the limitations of this study is that the analysis is at an aggregated level. Different industries have different intensities of energy, and over time the importance of a specific industry will change. To this point, there are few studies that examine the relationship between energy use and GDP at a disaggregated level. Such a study which also examines exports is one direction for future study. Another direction for future research could be to examine the relationship between energy use, exports and GDP in other regions of the world. One obvious candidate would be the newly industrialized countries of Asia including China which consume large amounts of energy and generally have had high rates of export-led economic growth.

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