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The rapid growth of OPEC's domestic oil consumption

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HIGHLIGHTS

- We analyze rapid growth of OPEC oil consumption (sevenfold since 1971: 5.1% annually).
- Panel co-integration econometric estimate of income elasticity about 1.0.
- Consensus projections (IEA, DOE/EIA) have consistently under projected OPEC consumption.
- Future oil market implications if OPEC consumption grows as fast as income (as in past).

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ABSTRACT

OPEC's domestic oil consumption has increased seven-fold in 40 years, to 8.5 million barrels per day (mbd). They consume almost as much oil as China. This constitutes one-fourth of their production. Such rapid growth in consumption (5.1% annually, faster than their income growth of 3.1%) will challenge OPEC's ability to increase their oil exports, which are relied upon in long-term world oil projections by the International Energy Agency (IEA), US Department of Energy (DOE/EIA) and British Petroleum (BP). However, these institutions assume unprecedented slowdowns in OPEC oil consumption – to less than 2% in the future – allowing them to project increases in OPEC oil exports with only modest increases in production. We analyze 1971–2010 data econometrically, with panel co-integration methods. We estimate that the income elasticity of consumption is about 1 for energy and oil. This means that OPEC's energy and oil consumption will grow as rapidly as their income. Hence, continued high growth rates for domestic oil consumption are more likely than the unprecedented slowdowns projected by IEA, DOE/EIA and BP – adding an extra 6 mbd of OPEC consumption in 2030. This will have major implications for OPEC production and export levels, and for world oil prices.

1. Introduction

This paper analyzes the rapid increase in OPEC's domestic oil consumption, from 1.2 in 1971 to 8.5 in 2010, in million barrels per day (mbd). Demand grew an average of 5.1% annually, much faster than the 3.1% rate of income growth. We also analyze the Middle East region, which has substantial overlap with OPEC, in order to analyze projections that are made for this region – but not for OPEC – by IEA, DOE/EIA and others. The countries and groups are as follows:

Total OPEC:

Middle East OPEC: Saudi Arabia, Iran, Iraq, Kuwait, UAE, Qatar; Other OPEC: Venezuela, Ecuador, Algeria, Libya, Angola, Nigeria.

Middle East:

Middle East OPEC: Saudi Arabia, Iran, Iraq, Kuwait, UAE, Qatar; Other Middle East (Non-OPEC): Bahrain, Oman, Yemen, Syria, Lebanon, Israel, Jordan.

We analyze the demand for total oil as well as for three groups of oil products: Transport Oil (gasoline, jet fuel, and light fuel oil including diesel oil); Residual Fuel Oil; and Other Oil (LPG, naphtha, and all other oil products). In addition, we analyze the demand for natural gas and for total energy.

The outline of this paper is as follows. Section 2 summarizes the 1971–2010 historical relationship between oil demand and income, as well as for energy and natural gas, for the OPEC countries and the Middle East. We also summarize the oil demand projections to 2030 for the Middle East that are made regularly by IEA, DOE/EIA, and other institutions. Section 3 summarizes the previous literature on oil demand, especially within the Middle

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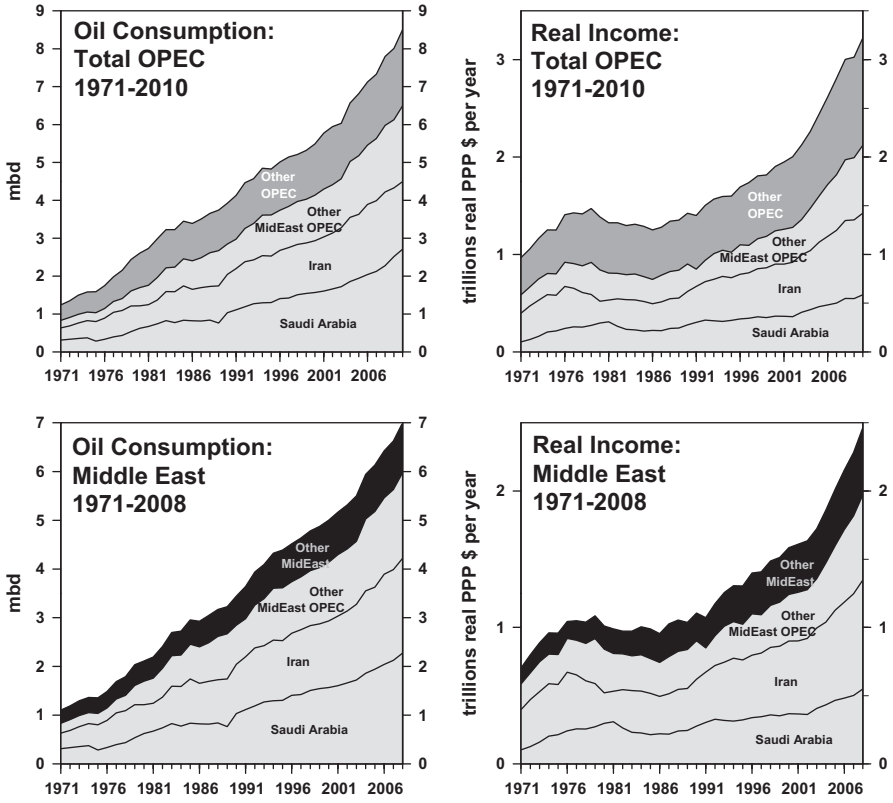

Fig.1. Oil Consumption and Real Income for Total OPEC and for Middle East, 1971–2010.
Data Sources: See Appendix A.

East. The econometric analysis in Section 4 utilizes panel co-integration methods, for each of the fuels separately. In Section 5 we compare our projections of oil demand with those of IEA and DOE/EIA, and in Section 6 we summarize our conclusions. Data sources are listed in Appendix A.

2. Background

Domestic oil consumption within OPEC has grown rapidly in the past four decades and is now about 10% of total world oil consumption. This is almost as large as the share of China. In per-capita terms, OPEC's oil consumption has grown rapidly, and is twice the average of other developing countries; but it is still only one-third the level of the OECD countries However, if Nigeria were not included with OPEC, then per-capita levels in OPEC would be comparable to those in the OECD (although the OECD uses much more non-oil energy).

Fig. 1 summarizes Total Oil Consumption and Real Income for OPEC and the Middle East. Middle East OPEC comprises about 80% of oil consumption for both OPEC and the Middle East, and more than two-thirds of income. Saudi Arabia plus Iran represent more than half of oil consumption and income, for both OPEC and the Middle East.

Table 1 summarizes the 1971–2010 levels and growth rates for income and the consumption of oil, natural gas, and energy. See Appendix A for the sources of data and description of all variables that we used. For all these groups of countries, consumption of both energy and natural gas has grown faster than income since 1971. Consumption of oil has grown faster than income for all country groupings except Other Middle East, where it has grown about as fast as income.

However, the IEA, DOE/EIA, and BP all project that Middle East oil consumption – and, by implication, OPEC consumption – in the next two decades will grow only half as fast as income. Moreover, they project that energy and natural gas consumption will also grow more slowly than income; only BP projects natural gas growing as fast as income.[1] OPEC (2010) projects that their own oil consumption will grow 1.7% annually, which is one-third their rate of the past 40 years and less than half their projected rate of income growth.

Fig. 2 graphs Total OPEC's oil consumption and real income, 1971–2010, for total oil and its three component products: transport oil, residual oil, and other oil. Residual Oil (heavy fuel oil) was a significant part of Total Oil consumption in the early 1970s, but its consumption has not increased much since then. It is used primarily in electricity generation, and it can be replaced by natural gas in some OPEC countries. In contrast, Transport Oil (gasoline, jet fuel, and light fuel oil including diesel oil) has grown faster than income for forty years, as has Other Oil (LPG, naphtha, and all other oil products). The axes in Fig. 2 are logarithmic; the diagonal lines indicate equi-proportional growth of oil consumption and income. Movement parallel to these lines indicates that oil consumption is growing as rapidly as income (income elasticity = 1); steeper/less steep movement indicates income elasticity greater than/less than 1. In the upper-left graph of Fig. 2, we see the following changes in Total Oil demand:

- 1971–75: Total Oil grows as fast as income;
- 1975–86: Total Oil increases despite stagnant or declining income;
- 1986–2010: Total Oil grows as fast as income.

[1] Exxon-Mobil (2010) projects that Middle East energy demand will grow only 2% annually to 2030. This is *much* slower than the 5.8% annual growth of the past 40 years.

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Table 1
Levels and growth rates of income and consumption of oil, gas, and energy in 1971–2010, with projections to 2030.
Data Sources: See Appendix A.

	History, 1971–2010						Projections to 2030			
			Average annual % growth				IEA	DOE/EIA	BP	OPEC Outlook
	1971 level	2010 level	1971–2010	1971–1975	1975–1986	1986–2010	New Policies scenario	Ref. Case scenario		
Total OPEC: Middle East OPEC+Other OPEC										
Total oil (mbd)	1.2	8.5	5.10%	6.40%	7.10%	3.90%				1.70%
Transport oil (mbd)	0.4	4.3	6.20%	14.00%	9.00%	3.80%				
Other oil (mbd)	0.3	3.1	6.40%	9.10%	6.30%	6.10%				
Residual oil (mbd)	0.6	1.6	2.70%	−2.20%	4.70%	2.60%				
Natural gas (mbdoe)	0.4	6.8	7.40%	7.70%	10.40%	5.90%				4.40%
Real income (B 2005$ PPP)	967	3223	3.10%	6.60%	0.00%	4.00%				3.50%
Ratio: % gr. Total Oil/% gr. Income			1.62	0.96	499	0.97				0.47
Middle East OPEC: Saudi Arabia, Iran, Iraq, Kuwait, Qatar, UAE										
Total oil (mbd)	0.8	6.5	5.40%	5.70%	8.00%	4.20%				
Transport oil (mbd)	0.2	2.9	6.90%	14.20%	11.30%	3.80%				
Other oil (mbd)	0.2	2.7	7.70%	12.50%	6.70%	7.30%				
Residual oil (mbd)	0.5	1.3	2.70%	−2.20%	4.80%	2.70%				
Natural gas (mbdoe)	0.2	5.5	8.80%	9.20%	11.90%	7.30%				
Real income (B 2005$ PPP)	585	2122	3.40%	8.20%	−0.70%	4.50%				
Ratio: % gr. Total oil/% gr. Income			1.61	0.69	−12	0.95				
Other OPEC: Venezuela, Ecuador, Algeria, Nigeria, Angola, Libya										
Total oil (mbd)	0.4	2	4.20%	7.80%	5.40%	3.00%				
Transport oil (mbd)	0.2	1.4	5.20%	13.70%	5.60%	3.70%				
Other oil (mbd)	0.1	0.4	3.10%	4.30%	5.50%	1.80%				
Residual Oil (mbd)	0.1	0.2	2.20%	−2.40%	4.60%	2.00%				
Natural gas (mbdoe)	0.2	1.3	4.70%	6.10%	8.60%	2.70%				
Real income (B 2005$ PPP)	382	1101	2.80%	4.20%	1.10%	3.30%				
Ratio: % gr. Total oil/% gr. Income			1.52	1.86	4.8	0.92				
Total Middle East: Middle East OPEC+Other Middle East										
Total oil (mbd)	1.1	7.7	5.10%	5.30%	7.20%	4.00%	1.40%	1.70%	1.80%	
Transport oil (mbd)	0.3	3.7	6.60%	13.20%	10.00%	3.80%				
Other oil (mbd)	0.2	2.9	6.40%	10.70%	6.20%	5.80%				
Residual oil (mbd)	0.6	1.8	2.80%	−2.10%	4.50%	2.90%				
Natural gas (mbdoe)	0.3	6.6	8.10%	10.10%	10.00%	7.00%	2.50%	2.70%	3.90%	
Real income (B 2005$ PPP)	703	2660	3.40%	8.00%	−0.04%	4.40%	3.90%	3.80%	3.90%	
Ratio: % gr. Total oil/% gr. Income			1.49	0.66	−187.5	0.92	0.36	0.45	0.46	
Other Middle East: Bahrain, Israel, Jordan, Lebanon, Oman, Syria, Yemen										
Total oil (mbd)	0.3	1.2	3.80%	4.10%	4.60%	3.40%				
Transport oil (mbd)	0.1	0.7	5.40%	10.70%	5.70%	4.40%				
Other oil (mbd)	0	0.2	3.40%	4.40%	3.50%	3.10%				
Residual oil (mbd)	0.1	0.5	3.40%	−1.70%	3.60%	4.10%				
Natural gas (mbdoe)	0.1	1.1	6.20%	11.70%	5.70%	5.50%				
Real income (B 2005$ PPP)	118	538	4.00%	7.40%	2.70%	4.00%				
Ratio: % gr. Total oil/% gr. Income			0.96	0.56	1.68	0.85				

The growth of Transport Oil and Other Oil has been similar to that of Total Oil: increasing as fast as income when income was increasing in 1971–75 and 1986–2010 (moving parallel to the diagonal lines), and increasing even when income was stagnant or declining in 1975–86. Only Residual Oil has grown more slowly than income (movement less steep than the diagonal lines).

Similar graphs to Fig. 2 for the individual members are shown in Appendix B. These are generally similar to the aggregate OPEC graph, except for countries with disruptions, such as Iraq and Kuwait, or countries with stagnant or uneven economic growth, such as Libya and Nigeria.

Similar graphs of Total Oil consumption versus Income are plotted in Fig. 3 for each of the three main groups of countries: Total OPEC, Middle East, and Middle East OPEC. Their paths are all similar, which is not surprising because Middle East OPEC comprises such a large fraction of income and oil consumption for both Total OPEC and the Middle East. Since 1986, oil consumption has grown about as rapidly as income; movement is roughly parallel to the diagonal, equi-proportional growth lines.

We plot in Fig. 4 similar graphs for Total Energy, Total Oil, and Natural Gas consumption versus Income, for 1986–2010. For all three country groups, energy consumption has grown slightly faster than income: movement has been slightly steeper than the diagonal lines. Oil consumption has grown about as fast as income (parallel to the diagonals), and natural gas has grown *much* faster than income (much steeper than the diagonals).

Table 2 shows data for individual countries in OPEC, the Middle East and in the OECD: oil consumption levels in 1971 and 2010, oil share of energy consumption, oil product prices for diesel and gasoline in 2008, and vehicle ownership levels in 2010. These data will help to inform three aspects of the discussion about OPEC and the Middle East: (1) the prospects for oil demand reduction, in comparison with OECD oil demand reductions since 1971; (2) the role of oil product prices; and (3) the likely growth of vehicle ownership.

Oil demand reductions achieved by the OECD countries were primarily due to fuel-switching in electricity generation (away from Residual Oil to natural gas, coal, hydro and nuclear) and in residential and commercial heating (to natural gas and electricity, away from "Other Oil"). Efficiency improvements played a much smaller role. See Dargay and Gately (2010). Between 1971 and 2010, OECD demand for Residual Oil fell by two-thirds,

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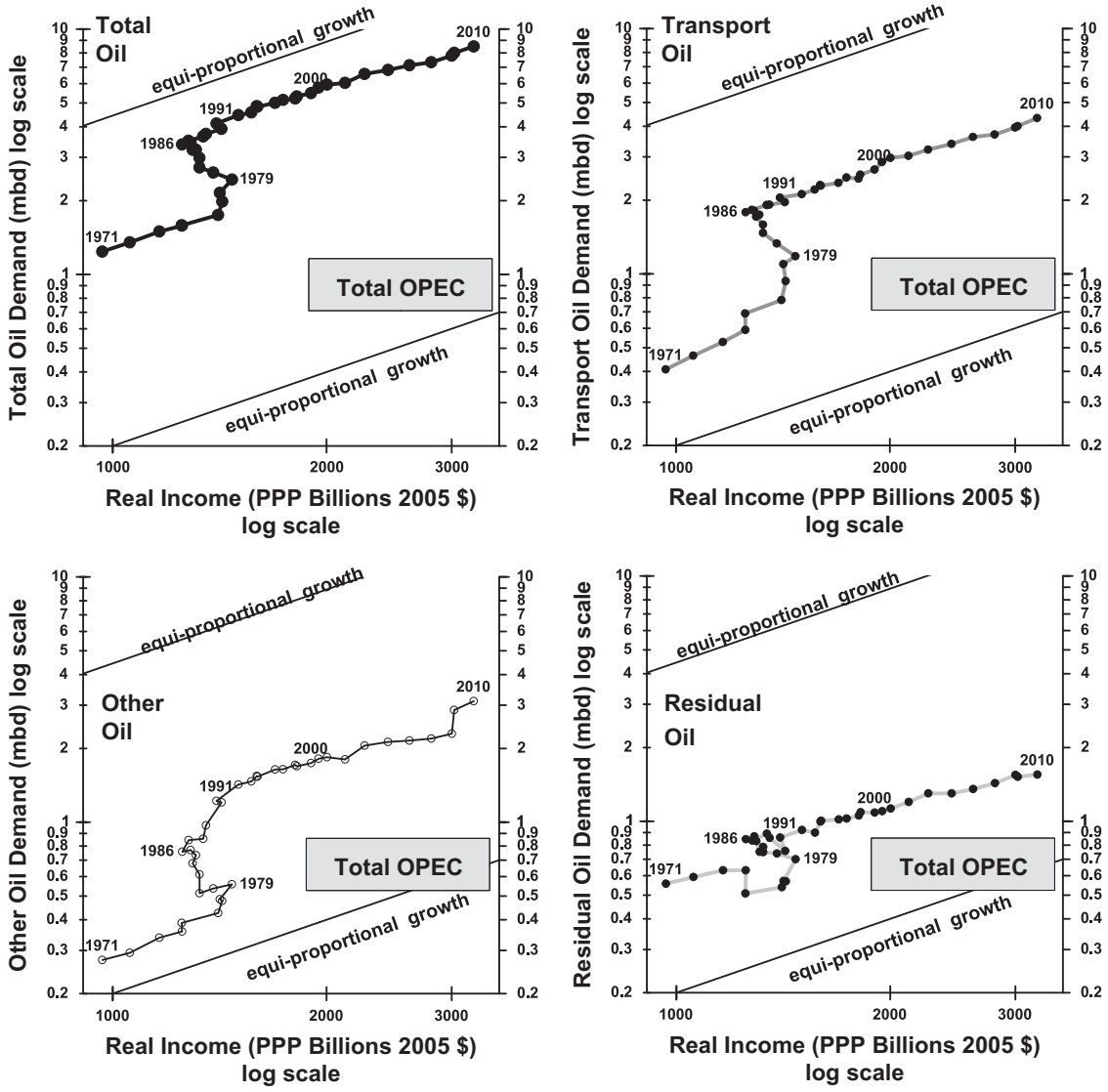

Fig. 2. Oil Demand (Total, Transport, Residual, Other) and Real Income, 1971–2010: Total OPEC.
Data Sources: See Appendix A.

from nearly 10 mbd to less than 4 mbd. Over that same period, OECD Transport Oil demand more than doubled and Other Oil increased by nearly 20%. The greatest reductions in oil demand were achieved by France and Sweden; their residential and commercial consumption of energy shifted dramatically away from oil toward electricity, and their electricity generation almost eliminated oil use by substituting hydro and especially nuclear. These OECD demand reductions provide useful comparisons for OPEC and the Middle East, within which there are similarities but also important differences. Within Middle East OPEC, there is still substantial use of Residual Oil (20% of Total Oil consumption), for which natural gas or other fuels could be easily substituted. In Non-Middle-East OPEC, however, Residual Oil constitutes only 11% of Total Oil consumption, so the fuel-switching reductions there would be more limited. Transport Oil constitutes 45% of Total Oil consumption for Middle East OPEC and 69% for Non-Middle-East OPEC.

Table 2 also shows oil product prices, at retail for diesel and gasoline as of November 2008, in US cents per liter. For comparison, the world crude oil price that month was 30 US cents per liter (Metschies, 2009). Product prices in OPEC and the Middle East vary substantially across countries. In general they are highly subsidized, are below world export product prices, and in many countries they are even lower than the world crude oil price. In OECD countries, product prices are five to ten times higher than in OPEC countries due to substantial taxes, especially in Europe and Japan. Increasing domestic product prices would be difficult politically, and may have limited effect on reducing demand if transport oil price elasticities are small. These and other policies are discussed in great detail in Bahgat (2012), Metschies (2009), Mitchell and Stevens (2008), and Krane (2013).

Table 2 also shows vehicle ownership data: total cars and trucks per 1000 population. Most OPEC countries have relatively low levels of vehicle ownership; almost all are substantially below levels in Europe and North America. As shown in Dargay et al. (2007), vehicle ownership can grow at least as fast as per-capita income in developing countries. Thus OPEC countries can expect substantial growth in vehicle ownership for an extended period, which will increase Transport Oil demand, even if product price subsidies are reduced.

3. Review of the literature

There is a significant literature on the demand for oil and energy, for many countries and regions. See Dargay and Gately (2010) for a

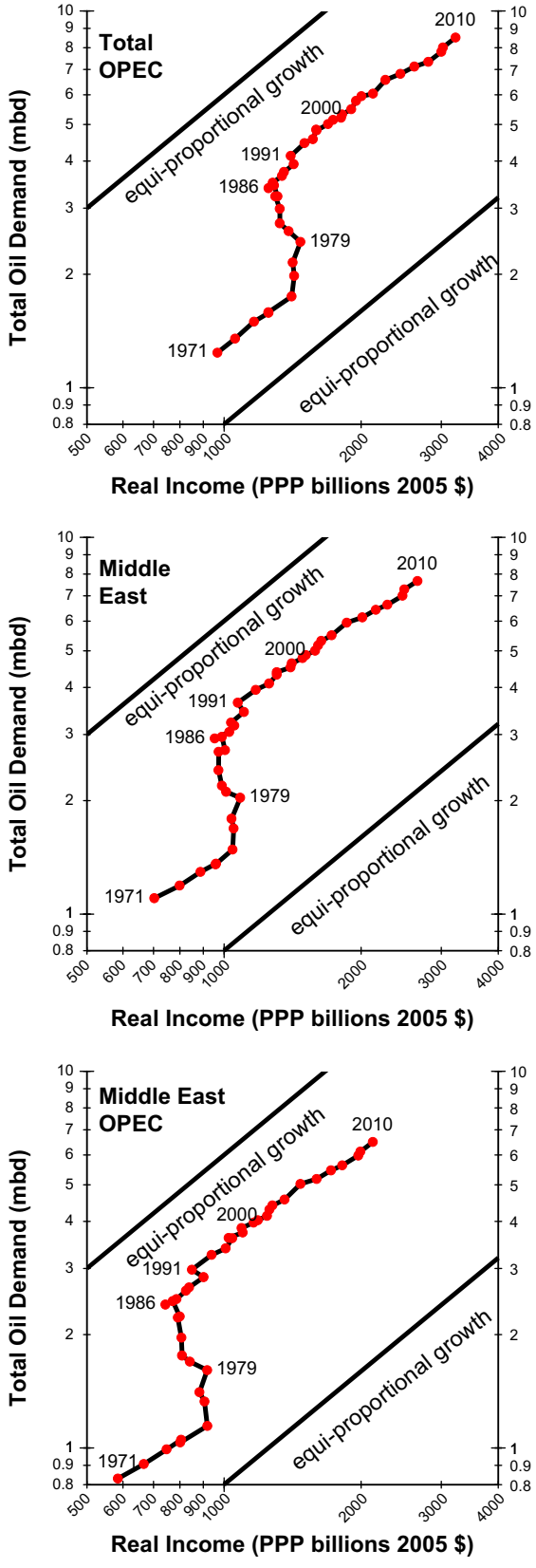

Fig. 3. Total Oil Demand and Real Income, 1971–2010: Total OPEC, Middle East, and Middle East OPEC.
Data Sources: See Appendix A.

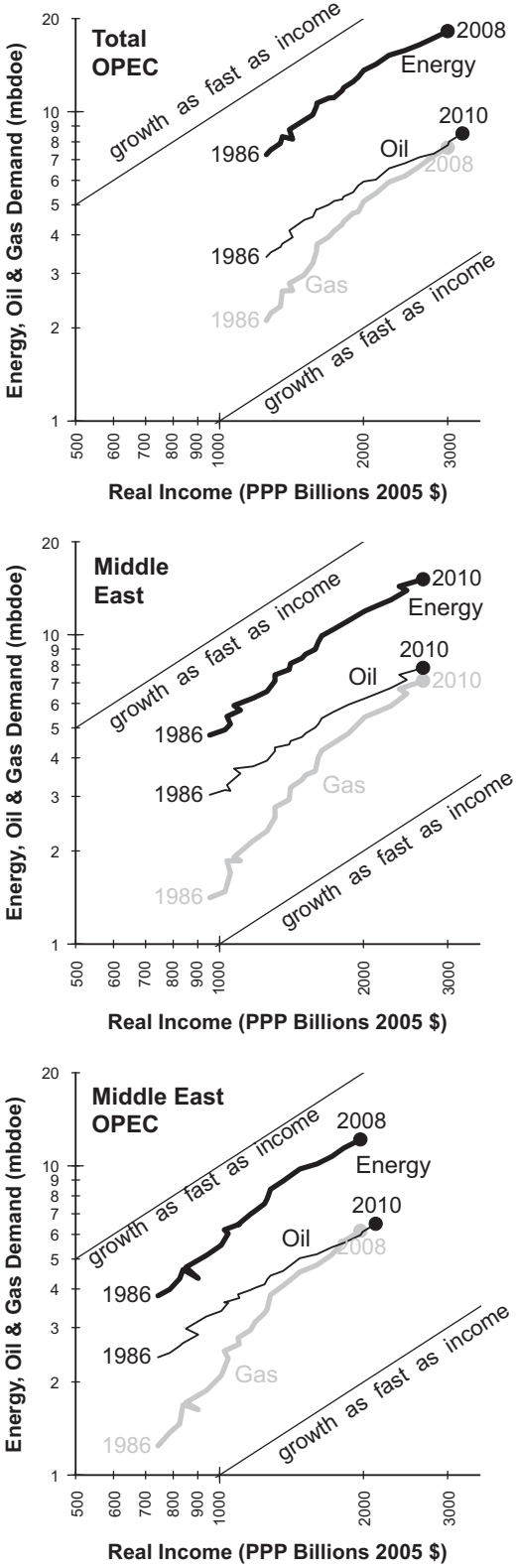

Fig. 4. Energy, Oil, Natural Gas and Real Income, 1986–2010: OPEC, Middle East, and Middle East OPEC.
Data Sources: See Appendix A.

recent example of this work, and see the surveys and extensive bibliographies by Dahl (1993, 1994, 2007). An early analysis of energy demand within the OPEC countries was published by Al-Janabi (1979). Important studies on gasoline demand were published for Saudi Arabia by Al-Sahlawi (1988a), for Kuwait by Eltony and Al-Mutari (1995), and for Iran by Ahmadian et al.

Table 2
Countries' oil consumption levels, oil shares of energy consumption, product prices and vehicle ownership, for selected years: OPEC, Middle East, and OECD.
Sources: Oil Consumption from IEA; Oil % Share of Energy Consumption from BP; Product Prices from Metschies (2009), Vehicle Ownership from Dargay et al. (2007).

	Total oil consumption (mbd)		Transport oil consumption (mbd)		Residual oil consumption (mbd)		Oil as % of energy		Oil+gas as % of energy		Oil product prices (2008 US ¢/liter)		Vehicles per 1000
Year	1971	2010	1971	2010	1971	2010	1971	2010	1971	2010	Diesel 2008	Gasoline 2008	2010
Total OPEC	**1.24**	**8.51**	**0.41**	**4.32**	**0.56**	**1.55**							
Non-Middle-East OPEC:	*0.41*	*2.01*	*0.19*	*1.39*	*0.10*	*0.23*							
Venezuela	0.27	0.75	0.11	0.46	0.07	0.09	57%	43%	93%	77%	1	2	
Ecuador	0.03	0.27	0.02	0.15	0.01	0.05	86%	81%	90%	84%	27	51	59
Algeria	0.05	0.30	0.03	0.21	0.01	0.01	67%	38%	97%	100%	20	34	
Nigeria	0.04	0.30	0.02	0.25	0.01	0.01					113	59	
Angola	0.02	0.15	0.01	0.18	0.01	0.00					39	53	
Libya	0.01	0.24	0.01	0.14	0.00	0.07					12	14	
Middle East OPEC:	*0.83*	*6.49*	*0.22*	*2.93*	*0.46*	*1.32*							
Saudi Arabia	0.31	2.71	0.04	1.10	0.25	0.26	94%	61%	100%	100%	9	16	219
Iran	0.32	1.79	0.13	0.91	0.09	0.32	66%	40%	97%	99%	3	10	98
UAE	0.00	0.70	0.00	0.35	0.00	0.31	10%	35%	100%	100%	62	45	
Qatar	0.00	0.17	0.00	0.08	0.00	0.00	9%	29%	100%	100%	16	22	
Iraq	0.07	0.81	0.02	0.35	0.03	0.31					1	3	41
Kuwait	0.12	0.32	0.02	0.13	0.09	0.13	69%	59%	100%	100%	20	24	405
Middle East Non-OPEC	*0.27*	*1.03*	*0.09*	*0.57*	*0.13*	*0.29*							
Total Middle East	**1.10**	**7.52**	**0.31**	**3.50**	**0.59**	**1.61**	**79%**	**51%**	**99%**	**98%**			
OECD Countries, Total	**36.64**	**46.52**	**12.96**	**26.56**	**9.79**	**3.56**	**50%**	**38%**	**70%**	**63%**			
Japan	4.40	4.41	0.67	1.56	2.02	0.50	74%	40%	75%	57%	130	142	685
France	2.08	1.76	0.47	0.94	0.56	0.09	64%	34%	71%	50%	145	152	658
Germany	2.90	2.44	0.73	1.29	0.68	0.17	46%	36%	52%	59%	156	156	474
Great Britain	2.08	1.59	0.58	1.06	0.84	0.07	49%	35%	57%	76%	165	144	618
Italy	1.80	1.53	0.36	0.84	0.86	0.21	74%	42%	84%	82%	163	157	719
Sweden	0.55	0.32	0.10	0.18	0.23	0.05	67%	30%	67%	33%	152	138	605
USA	15.80	19.18	7.78	13.43	2.30	0.68	44%	37%	78%	64%	78	56	829

(2007)[2]. Multi-fuel studies (gasoline, diesel, jet fuel, total oil) were done for Saudi Arabia by Al-Sahlawi (1997), and by Al-Faris (1997) for six oil products – gasoline, jet fuel, gasoil/diesel, LPG, kerosene, and residual fuel oil – for all the countries of the Gulf Cooperation Council (GCC): Saudi Arabia, Kuwait, UAE, Qatar, Bahrain, and Oman. In addition, Al-Sahlawi (1988b) analyzed energy demand in the GCC countries. Most of these analyses were partial adjustment models: demand being a linear function of income, price, and lagged demand.

Subsequent work has utilized the newly developed statistical methods of panel co-integration[3]. Eltony (1996) analyzed gasoline demand for the countries of the GCC. Narayan and Smyth (2007) analyzed oil demand for all the countries of the Middle East. Our paper, also using panel co-integration methods[4], extends previous work in several directions:

- we use the longest data period: 1971–2010; none of the articles cited above, for the Middle East and OPEC, utilize data beyond 2002;
- we analyze more countries: all 12 current OPEC members and 7 other countries in the Middle East that are not members of OPEC; this facilitates comparison of our projections with those of IEA and others who make projections for Middle East but not for OPEC;
- we analyze the demand for multiple fuels: total oil and three oil product groups (transport oil, residual fuel oil, and other oil); natural gas; and total energy;
- We analyze *total* demand and income rather than *per-capita* values; this minimzes problems due to asymmetric response of demand to increases and decreases in income.[5]

We compare many of these studies' long-run income elasticities of demand, in the summary of our own elasticity estimates below.

4. Econometric analysis

We want to estimate the long-run responsiveness of the demand for oil (as well as energy and natural gas) to changes in current and past levels of income: the long-run "income elasticity" of demand. Demand is influenced by current and past values of income, capital stock, end-user prices of oil and competing fuels,

[2] Several previous studies on gasoline demand in Iran are cited and discussed in Ahmadian et al. (2007).

[3] Gately et al. (2012) employ both approaches – partial adjustment models and co-integration methods – in analyzing demand for oil and oil products in Saudi Arabia. The two methods yield similar income-elasticity estimates.

[4] Several of these co-integration studies have addressed the issue of causality – whether income "Granger causes" energy demand, or whether energy demand "Granger causes" income, or both. Al-Iriani (2006) and Mehrara (2007) concluded that income "Granger causes" energy demand and not the reverse, for the GCC and OPEC countries respectively. Our analysis of this question is consistent with theirs for energy; we also reach this conclusion for oil and natural gas. Reaching the opposite conclusion, however, was Lee (2005), who analyzed oil demand for a panel of 18 developing countries; however, only two of these countries were oil producers (Venezuela and Indonesia) and none of the countries were in the Middle East. Finally, Damette and Seghir (2013), using a panel of a dozen oil exporters over 1990–2010, found "a short-run unidirectional causality from energy consumption to income growth, whereas in the long-run, it is the economic process that determines the energy consumption trend" (p. 193).

[5] As shown in Gately and Huntington (2002) and Dargay and Gately (2010), per-capita oil demand in the Oil Exporting Countries responds asymmetrically to increases and decreases in per-capita income: big increases when income rises but little declines when income falls.

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Table 3
Long-run income elasticities of demand, using panel dynamic OLS. Annual data 1971–2010 for oil, and 1971–2008 for energy and natural gas.

	Oil, total	Oil, transport	Oil, residual	Oil, other	Energy, total	Natural gas[g]
Total OPEC		0.94	0.02	1.04	0.98	1.44
Non-Middle East OPEC						
Venezuela	1.09	1.33	−0.24?	1.21	1.38	1.36
Ecuador	1.49	1.53	0.98	1.94	1.24	2.22
Nigeria	0.76	1.05	0.38?	−0.31?	0.82	2.25
Algeria	1.14	1.17	−0.73	1.32	1.63	2.09
Angola	1.1	1.35	−1.03	1.39	0.83	2.52
Libya	−0.82	−0.30?	−1.14?	−1.85	−1.25	−1.45
Middle East OPEC						
Iran	1.04	1.23[a]	0.51	1.14	1.61	3.25?
Iraq	0.32?	0.59?	0.15?	0.11?	0.02?	−1.01
GCC: Gulf cooperation council[c, e, f]						
Saudi Arabia (GCC)	1.71[b]	1.90[b]	0.36?	3.29	2.36	2.59
Kuwait (GCC)	0.67	−0.01?[d]	1.35	0.62?	0.5	0.79?
UAE (GCC)	1.76	1.48	1.23	2.7	1.67	1.79
Qatar (GCC)	0.95	1.08	−1.63?	0.96?	0.93	0.92
Non-OPEC Middle East						
Bahrain (GCC)	0.25	0.87	−3.88	0.13	1.08	1.21
Oman (GCC)	0.88	1.14	0.78	1.38	1.94	2.12
Yemen	0.84	0.84	0.56	1.36	0.94	
Syria	0.89	0.78	1.25	0.65	1.18	4.39
Lebanon	−0.76	−0.96	−0.42?	−0.66?	−0.82	
Israel	0.57	1.06	−0.08?	0.82	0.99	0.13?
Jordan	1.27	1.22	1.56	1.05	1.49	
Total Middle East		0.8	0.14	1.04	1.07	1.63

Note: ? Indicates statistically insignificant coefficient ($p > 0.05$); all other coefficients are statistically significant.

[a] Long-run income elasticity of gasoline demand, Iran = 1.25; Ahmadian et al. (2007) using 1968-2002 data.

[b] Long-run income elasticities of demand, Saudi Arabia: 2.0 for total oil, 1.5 for gasoline, 0.83 for diesel, 0.88 for jet fuel; Al-Sahlawi (1997) using 1971–1995 data.

[c] Long-run income elasticity of demand for gasoline in GCC group: 0.28–0.43; Eltony (1996) using 1975–1993 data. Al-Sahlawi (1997) using 1970–1991 data, gasoline: Saudi Arabia 0.1, Kuwait 1.2, UAE 1.0, Qatar 0.1, Bahrain 1.2, Oman 1.1.

[d] Long-run income elasticity of gasoline demand, Kuwait = 0.48; Eltony and Al-Mutari (1995) using 1970–1989 data.

[e] Long-run income elasticity of residual oil demand: Saudi Arabia 0.24, UAE 3.83, Bahrain 1.91; Al-Sahlawi (1997) using 1970–1991 data.

[f] Long-run income elasticity of demand for total energy in GCC group: 2.0; Al-Sahlawi (1997) using 1980–1983 data.

[g] If a country uses no natural gas, no elasticity is shown.

and technology. Unfortunately, we do not have sufficient data over time and across countries for capital stock or technology, nor do we have end-user prices (although we do analyze below the effect of crude oil prices). Hence we focus on the relationship between demand and income; we estimate demand for each fuel separately. For each of the countries of OPEC and the Middle East we use annual data 1971–2010, for country i and year t: demand D_{it} in million barrels per day (mbd) and real income Y_{it} (PPP, constant 2005 international $); see Appendix A for data details. In its simplest log-linear form we have the standard equation used in Narayan and Smyth (2007), which our analysis closely resembles:

$$\log D_{it} = \alpha_{0i} + \alpha_{1i} * \log Y_{it} + \varepsilon_{it} \quad (1)$$

Following the work of Engle and Granger (1987), which focused attention on whether the variables in a regression are stationary, we performed stationarity (unit root) tests[6] on the variables, the results of which are shown in Appendix C, Table C1. The results indicate that, for all variables, the null hypothesis of non-stationarity (of unit root) *in levels* cannot be rejected. This undermines the validity of using ordinary-least-squares (OLS). However, the results of Table C1 also indicate that for all variables most tests *in first differences* allow us to reject the null hypothesis of non-stationarity (of unit root). Hence, the variables are non-stationary in levels but stationary in first-differences, which indicates that the variables are integrated of order one.

In order to test for the existence of a long-run relationship among consumption of oil (or energy or gas) and income, we employ the Pedroni (1999, 2004) panel co-integration tests of the null hypothesis of no co-integration. The tests allow for heterogeneity among cross-sectional units.[7] Table C2 shows the outcomes of these co-integration tests for the consumption of oil (or energy or gas) with income, for each of the three groups of countries.

The results of most of the co-integration tests (except for energy and natural gas) are that the null hypothesis of no co-integration can be rejected at the 5% significant level. Therefore, we conclude that consumption is co-integrated with income for the panels of the country groups, and there exists a long-run relationship between these countries' consumption and income.

Having found that there exists a co-integrating link between these pairs of variables, we then used a panel co-integrating estimator – Dynamic OLS[8] – to measure the income elasticity

[6] We check for non-stationarity by employing several well-known panel unit-root tests: Levin, Lin and Chu (2002) test; Im et al. (2003) *W*-Stat test; ADF-Fisher Chi-square test; and Phillips-Perron (PP)–Fisher Chi-square test. Breitung and Pesaran (2008) is an excellent survey of non-stationary panel data analysis.

[7] Pedroni (1999) introduced seven test statistics, three of which are between-dimension tests and four are within-dimension tests; Pedroni (2004) enhances the latter tests. The between-dimension statistics are group mean panel co-integration statistics, based on estimators that average the individually estimated coefficients for each cross-sectional unit. The within-dimension statistics are panel co-integration statistics and are based on estimators that pool the autoregressive coefficients across different cross-sectional units for the stationarity tests on the estimated residuals; namely, these seven tests are panel v, ρ and non-parametric and parametric t statistics, group ρ and non-parametric and parametric t statistics.

[8] Pedroni (2000) proposed fully modified ordinary least squares (FM-OLS) to estimate the coefficients of co-integrating vectors that are detected by panel co-integration tests. This method permits the existence of heterogeneity between cross section members. Kao (1999) analyzed the properties of the OLS estimator and found that the bias-corrected OLS estimator does not improve on the OLS estimator in general; see also Chen et al. (1999). These results suggest that an alternative such as the fully modified ordinary least squares (FM-OLS) estimator or the Dynamic OLS (DOLS) estimator, are preferable for co-integrated panel regressions. In addition, Kao and Chiang (2000) showed that both the OLS and Fully

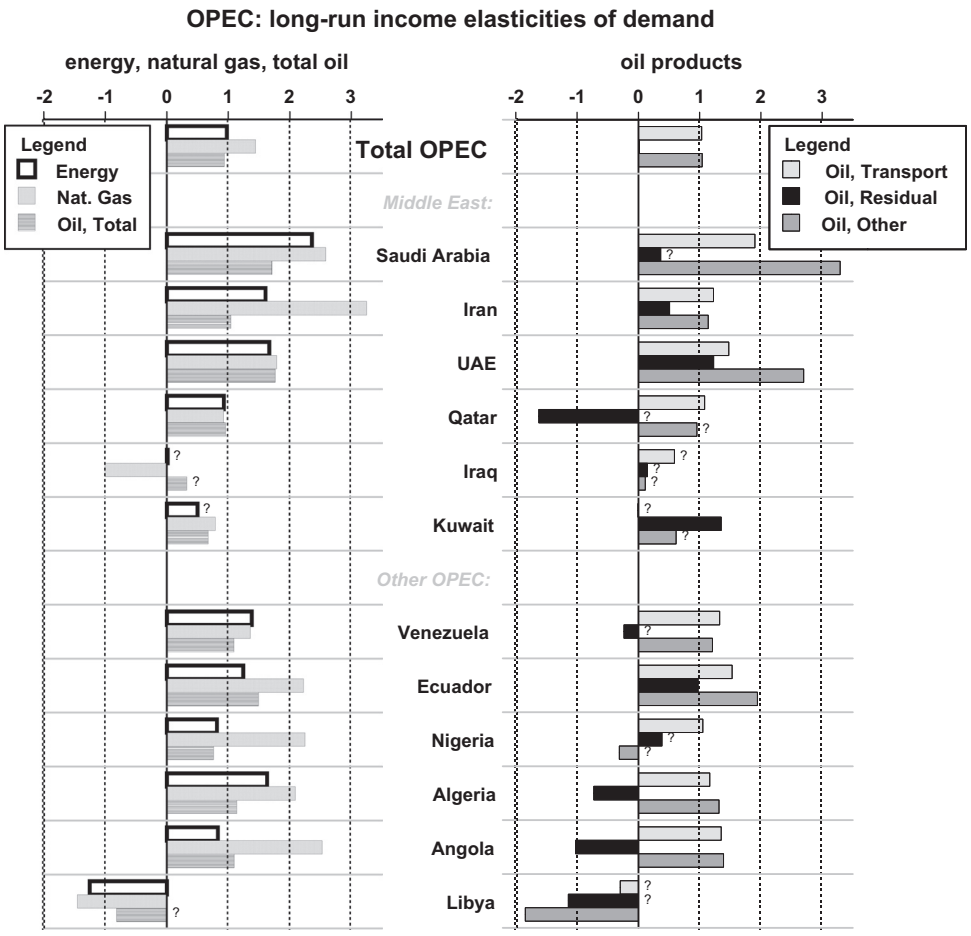

Fig. 5. OPEC Long-run Income Elasticities of Demand (from Table 3):. Energy, Natural Gas, Total Oil, and Oil products.
Note: "?" denotes statistical insignificance: $p > 0.05$; those unmarked are statistically significant.

of demand.[9] Table 3 summarizes our estimated long-run income elasticities of demand: for total oil, for each of the three oil products, and for natural gas and total energy – for all the countries of OPEC (Fig. 5) and the Middle East (Fig. 6).

The income elasticity results for OPEC are that total oil demand increases about as fast as income (elasticity = 0.94 for OPEC), as does transport oil and other oil. This is consistent with what would be expected by Fig. 2, since demand and income move parallel to the equi-proportional growth lines. For Residual Oil the income elasticity is close to zero for Total OPEC; a few members with substantial reserves of natural gas (Algeria, Qatar) have substituted natural gas for residual oil, and their income elasticity is estimated as negative: residual oil declined as income increased.

Similarly, OPEC's income elasticities are 0.98 for energy and 1.44 for natural gas; demand increases as fast as income or faster, respectively. Again, this is what would be expected given Fig. 4: energy and income move parallel to the equi-proportional growth lines, while natural gas increases more steeply.

The countries with the steadiest income growth generally had the highest income elasticities: Saudi Arabia, UAE, Ecuador, and Iran. For a few countries, the income elasticities are not statistically significant, or implausibly low, or even negative in the case of Libya. These are the countries with the greatest disruptions (Iraq, Kuwait) or stagnant income growth (Libya, Nigeria). See the country graphs for the 12 current OPEC members in Appendix B.

We also included price as an explanatory variable in the total oil equation but it was not statistically significant.[10] This does not imply, of course, that increasing domestic end-user product prices would have no effect on restraining demand. It only means that historical prices have been so *consistently* low in the oil producing countries that we cannot detect their effect on oil demand. However, comparisons with OECD countries, in which end-user prices are five to ten times higher (Table 2), suggest that per-capita consumption can be reduced by higher prices.

These estimated income elasticities are consistent with our discussion about the country data in Table 2. For Residual Oil,

(*footnote continued*)
Modified OLS (FMOLS) exhibit small-sample bias and that the DOLS estimator appears to outperform both estimators.

[9] Although Pedroni's methodology allows us to test for the presence of co-integration, EViews software it does not provide an elasticity measure of long-run relationships. For that, we adopted a procedure for estimating the co-integrating vectors using the multivariate group mean panel Dynamic OLS procedure (DOLS), from Pedroni (2001). This procedure is available in the econometric software RATS; the code is available at the RATS Software Forum: http://www.estima.com/forum/viewtopic.php?f=7&t=1056.

[10] We used the world price of crude oil (*BP Statistical Review of World Energy 2011*), in lieu of domestic end-user product prices which were not available for most countries (except for gasoline and gasoil/diesel in a few years: Metschies, 2009). We also used whatever oil product prices were available for a few countries (gasoline, diesel, kerosene, fuel oil), but they were not statistically significant.

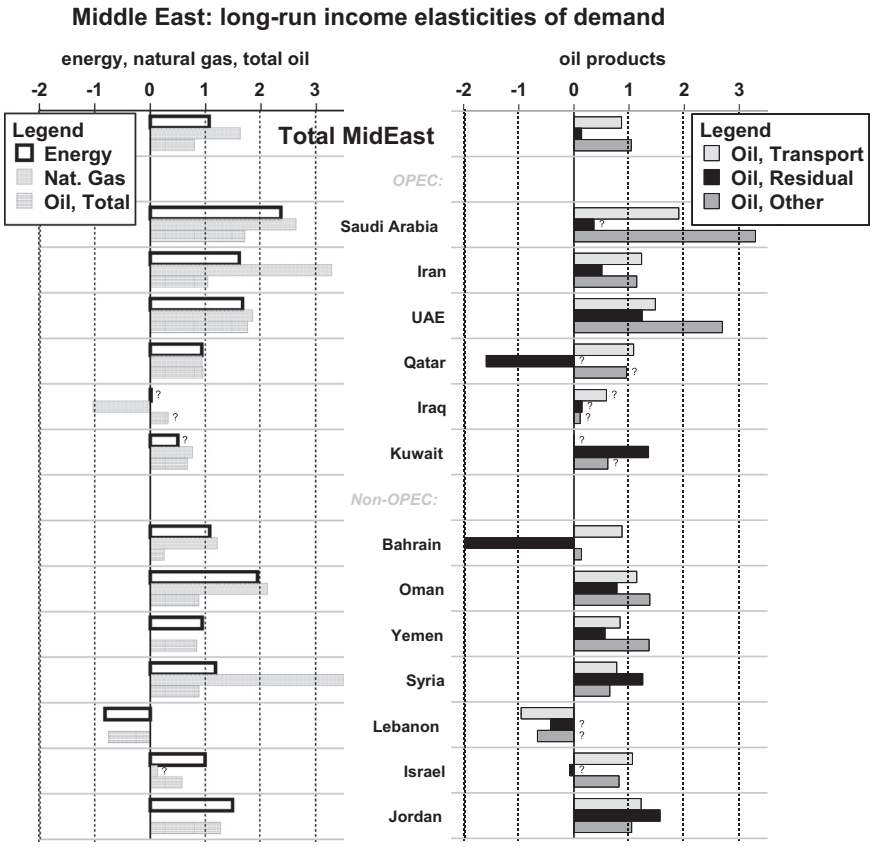

Fig. 6. Middle East Long-run Income Elasticities of Demand (from Table 3):. Energy, Natural Gas, Total Oil, and Oil products.
Note: "?" denotes statistical insignificance: $p > 0.05$; those unmarked are statistically significant.

there could be little or no increase in demand. Indeed it could be greatly reduced, as it was in the OECD, with natural gas and other fuels used as substitutes in electricity generation – especially in Middle East OPEC where it now constitutes 20% of Total Oil Demand. For Other Oil used in residential and commercial sectors, its growth could be slowed by reducing product-price subsidies and especially by policies that would encourage fuel-switching away from oil – to natural gas or electricity – in appliances that are used for cooking and water heating, as was done in Sweden and France especially. It will be more difficult to slow the growth of Transport Oil, which is now more than half of Total Oil in OPEC and the Middle East. Eliminating product-price subsidies will help, although it will be difficult politically, and the impact will be limited if price elasticities are low. However, the growth of vehicle ownership, expected to increase at least as fast as per-capita income, will make it very difficult to keep the growth of Transport Oil much lower than income growth.

Our estimated income elasticities for oil demand can be compared with those in the literature. Gately and Huntington (2002) and Dargay and Gately (2010) estimated *per-capita* demand equations for different groups of countries around the world. For the Oil Exporters they found an asymmetric response to changes in income: oil demand (except for Residual Oil) increased about as fast as income for increases in maximum historical income levels, and nearly as fast for income recoveries. In the most recent summary of demand elasticities, Dahl (2007) reports median estimates for income elasticities for oil products in *all* Non-OECD countries to be about 1 for most oil products; similarly for Dahl (1993, 1994).

Notes at the bottom of Table 3 summarize income elasticities that have been estimated for a few individual countries and fuels: Iran, Saudi Arabia, Kuwait, UAE, Qatar, Bahrain, and Oman. These

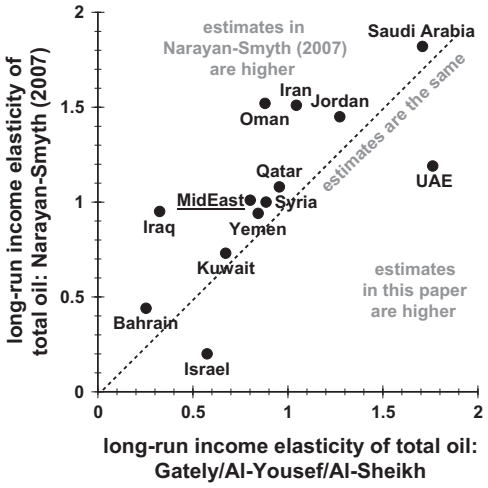

Fig. 7. Long-run income elasticities of total oil demand for all Middle East countries: comparison of our estimates with those of Narayan and Smyth (2007).

show a wide variation; several are similar to our own. Some differences in elasticities may be due to shorter time series, or to differences in specification[11].

[11] It is common to specify *per-capita* demand as a function of *per-capita* income, without testing whether the demand response is symmetric to income increases and decreases. As shown in Gately and Huntington (2002) and Dargay and Gately (2010), symmetric response of *per-capita* demand can be rejected for the Oil Exporters; ignoring this may bias the estimated income elasticity.

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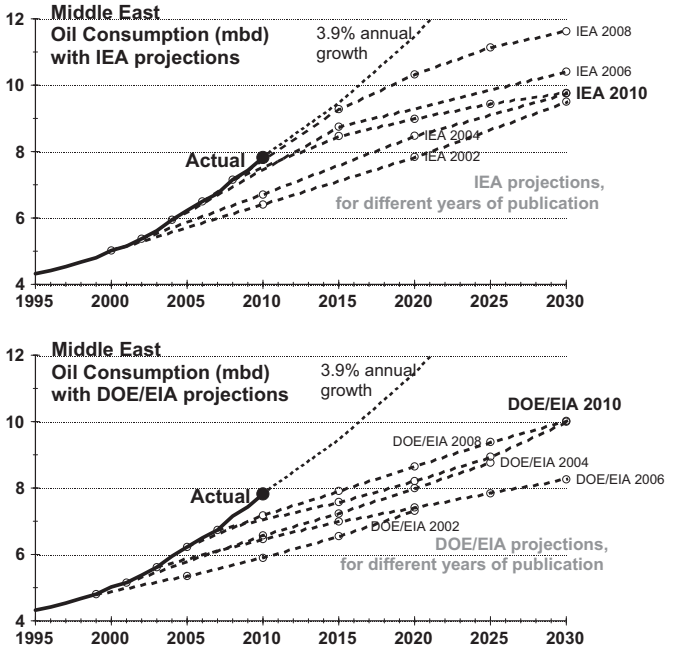

Fig. 8. Comparison of actual Middle East oil consumption 1995–2010 with projections by IEA and DOE/EIA published from 2002 through 2010.
Data Sources: See Appendix A.

Fig. 7 compares our estimates with those of Narayan and Smyth (2007) for the Middle East countries. They used a per-capita demand specification with 1971–2002 data, whereas we use a total demand specification with 1971–2010 data. Their long-run income elasticities for total oil are higher than ours for 10 of the 12 countries in the Middle East, and lower only for UAE and Israel[12]. Their estimated elasticity for Total Middle East was 1.01.

5. Oil consumption projections by IEA, DOE/EIA, BP, and OPEC

5.1. Historical record of under-projection by IEA and DOE/EIA

Our econometric analysis, and that of the literature, indicates that the long-run income elasticity of OPEC and Middle East oil demand is about 1. This means that demand will grow about as fast as income, as it has for the past 40 years.

However, the long-term outlooks published by IEA and DOE/EIA for the last 15 years have persisted in projections of less than 2% annual growth, despite Middle East oil demand growing at 4% annually since 1986 (and 5.1% annually since 1971),. Recent projections to 2030 by British Petroleum (BP) (2011b) of Middle East oil consumption (1.8% growth), and by *OPEC Outlook* (2010) for OPEC consumption (1.7% growth), are similar to those of International Energy Agency (IEA) (2010) and DOE/EIA (2010). None of these institutions – IEA, DOE/EIA, BP, or OPEC – publish any documentation for their projections, econometric or otherwise.[13]

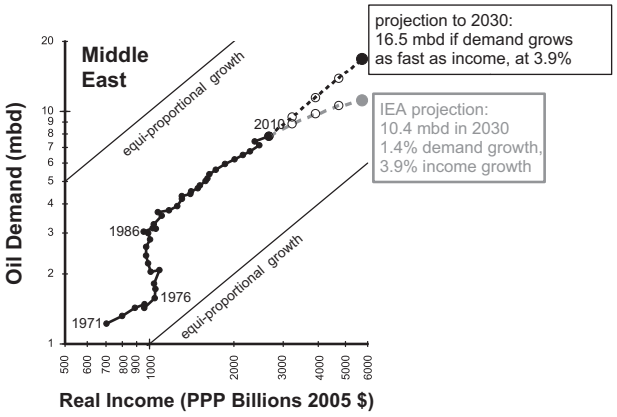

Fig. 9. Total Oil Demand and Real Income, 1971–2010 and IEA projections to 2030.
Data Sources: See Appendix A.

Fig. 8 compares actual Middle East oil consumption for 1995–2010 with projections made by IEA and DOE/EIA, shown as several dashed lines. (Also shown as a dotted line, is a simple projection of oil consumption from 2010 growing at the same rate that is most commonly assumed for income, 3.9% annually). The IEA and DOE/EIA projections have consistently underestimated the growth of actual consumption through 2010. For example, the IEA and DOE/EIA projections published in 2002 were much too low, underestimating the actual 2010 consumption of 7.7 mbd by 20% and 25% respectively. The actual 2010 consumption level of 7.7 mbd was not projected to occur until 2020 or 2025. Subsequent projections persisted with a low projected growth rate of about 2% annually. Each new publication merely increased the starting year's consumption value but did not modify the projected growth rate; for example, the DOE/EIA 2002 publication used 1999 consumption as its starting historical value and projected a growth rate of 1.8% annually. The DOE/EIA, 2010 publication updated the starting historical value to that of 2007 (to a level that, in the 2002 projection, had not been expected to be reached until nearly 2020), but again continued to use the same projected growth rate of 1.8%.

5.2. Middle east region: Projections by IEA and other Institutions

The latest IEA projections (IEA, 2010) of oil consumption and income for the Middle East are plotted in Fig. 9, where they can be compared both to the 1971–2010 historical experience and also to our projections of oil consumption growing as fast as income (3.9% annually). By 2030 the difference between IEA's projection of 1.4% annual growth in oil consumption and our projected growth of 3.9% is more than 6 mbd; our projections are 50% higher than IEA by 2030.

An important reason why IEA oil projections to 2030 are so low is that their *energy* demand projections are also very low. Since 1986, oil demand has grown about as fast as income, energy slightly faster than income, and natural gas *much* faster than income. However, IEA projections to 2030 are that both energy and natural gas will grow more slowly than income, and oil will grow *much* more slowly than income.

Projections by other institutions are similar to those of IEA.[14] DOE/EIA (2010) projects a slowdown in the growth rates of energy, natural gas and oil, to rates that are only half those of the past 40

[12] The only Middle East country excluded is Lebanon, which Narayan-Smith did not report. Our long-run income-elasticity estimates were statistically significant ($p < 0.05$) for every country except Iraq and for Total Middle East. Theirs were not statistically significant ($p < 0.05$) for any Middle East country except Bahrain; for Total Middle East their long-run income elasticity was 1.01 ($p = 0.052$). Not shown are their crude-oil-price elasticity estimates, which they found significant for all countries. We found crude oil prices to not be significant.

[13] The IEA (2010) does not provide any econometric basis for their projections; nor does BP or OPEC. DOE/EIA ((2010), Appendix L) lists the models on which some of their demand projections are based; these are sectoral end-use demand models for various fuels in 16 regions of the world. However, these regional models do not include the Middle East, about whose demand projections DOE/EIA provides no econometric or modeling details.

[14] This institutional consensus on projections is reminiscent of previous experience, critiqued in Gately (2001), "How Plausible is the Consensus Projection of Oil below $25 and Persian Gulf Oil Capacity and Output Doubling by 2020?"

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Table 4
Projections to 2030 of Oil Consumption, Exports and Production by IEA, DOE/EIA, BP and OPEC, with 3 other projections assuming oil consumption grows as fast as income (3.9% annually) and 3 illustrative growth rates of production (1%, 2%, 3% annually).().
Data Sources: See Appendix A

	History			Projections to 2030													
	1971 level	2010 level	% gr.[a]	IEA		DOE/EIA		BP		OPEC Outlook		Consumption grows as fast as income (3.9% annually), with 3 illustrative growth rates of production					
												1% Annual growth in production		2% Annual growth in production		3% Annual growth in production	
				2030 level	% gr.[b]	2030 level	% gr.[b]	2030 level	% gr.[b]	2030 level	% gr.[b]	2030 level	% gr.[b]	2030 level	% gr.[b]	2030 level	% gr.[b]
Total Middle East																	
Oil consumption (mbd)	1.1	7.7	5.1%	10.4	1.5%	11.0	1.8%	11.2	1.9%			16.5	3.9%	16.5	3.9%	16.5	3.9%
Oil exports (mbd)	15.3	17.5	0.4%	21.2	1.0%	21.1	0.9%	24.4	1.7%			14.3	−1.0%	21.0	0.9%	29.0	2.6%
Oil production (mbd)	16.4	25.2	1.1%	31.6	1.1%	32.1	1.2%	35.5	1.7%			30.7	1%	37.4	2%	45.5	3%
Exports as % of Pdn	93%	70%		67%		66%		69%				46%		56%		64%	
Income (B$/year)	703	2660	3.5%		3.9%		3.8%		3.9%				3.9%		3.9%		3.9%
Total OPEC																	
Oil Consumption (mbd)	1.2	8.5	5.1%							11.4	1.5%	18.3	3.9%	18.3	3.9%	18.3	3.9%
Oil exports (mbd)	23.5	25.8	0.2%							36.8	1.8%	23.6	−0.4%	32.7	1.2%	43.7	2.7%
Oil production (mbd)	24.7	34.3	0.8%							48.2	1.7%	41.9	1%	51.0	2%	62.0	3%
Exports as % of Pdn	95%	75%								76%		56%		64%		71%	
Income (B$/year)	967	3223	3.1%								3.5%		3.9%		3.9%		3.9%
Middle East OPEC																	
Oil consumption (mbd)	0.8	6.5	5.4%									14.0	3.9%	14.0	3.9%	14.0	3.9%
Oil exports (mbd)	15.0	17.1	0.3%									14.9	−0.7%	21.2	1.1%	28.7	2.6%
Oil production (mbd)	15.9	23.6	1.0%									28.8	1%	35.1	2%	42.7	3%
Exports as % of Pdn	95%	73%										52%		60%		67%	
Income (B$/year)	585	2122	3.4%										3.9%		3.9%		3.9%

[a] Average annual % growth, 1971–2010.
[b] Average annual % growth, 2010–2030.

years – despite income growth than is projected to be faster than in the past.

BP (2011b) projects an oil growth rate that is only half as fast as income, at one-third the growth rate since 1971. It projects energy growth to be slower than income growth, and much slower than past energy growth. Only natural gas is projected to grow as fast as income, but at only half the growth rate of the past 40 years.

OPEC Outlook (2010) projects that OPEC's own oil consumption growth will be dramatically slower in the future: at half the rate of income growth, and half the rate of growth since 1986. It projects that its growth of natural gas will be slightly faster than income growth, but much slower than its growth in the past.

As noted above, none of these institutions provide any evidence of econometric estimation nor any documentation for the basis of their projections.

5.3. Comparison of oil Projections to 2030

Table 4 compares the projections by IEA, DOE/EIA, BP and OPEC with our projections. We assume, for each of the three groups of countries, that oil consumption grows as rapidly as income (3.9% annually[15]) and we use 3 illustrative growth rates of oil production (1%, 2%, and 3% annually). IEA, DOE/EIA and BP project that Middle East oil consumption will grow much slower than 2% annually, which is less than half the projected rate of income growth – in contrast to the experience of the last 40 years. *OPEC Outlook* makes similar projections for OPEC's own oil consumption. For the Middle East we project oil consumption to be at least 5 mbd higher than the levels projected by IEA, DOE/EIA and BP in 2030, which is 50% higher than what they project. With 2% annual growth in production, our 3.9% consumption growth will allow exports to increase, but only slowly: 0.9% annually, from 17.5 in 2010 to 21 mbd in 2030. In contrast, they project a similar increase in exports but without the need to increase production nearly as much.

For the OPEC countries the results are similar. Growth as fast as income will increase oil consumption from 8.5 in 2010 to 18.5 mbd in 2030. With 2% annual growth in production, to 51 mbd in 2030, oil exports can increase, but only slowly: 1.2% annually, from 25.8 in 2010 to 32.7 in 2030. With only 1% annual growth in production, however, oil exports will decline, because domestic consumption increases faster than production.[16]

[15] Faster growth in oil consumption is projected for Saudi Arabia in two recent studies. Annual growth of 5% is projected in Gately et al. (2012). Similarly, Lahn and Stevens (2011) in their Business-As-Usual scenario project 5.36% annual growth. They also consider two alternative scenarios: (1) higher production and consumption of natural gas, which substitutes for oil consumption and slows oil growth to 3.7% annually; (2) nuclear power development combined with increasing energy efficiency, which slows oil growth to 2.6% annually. None of these projections, (*footnote continued*) however, have Saudi oil consumption growing slower than 2% annually, which is what IEA, DOE/EIA, BP, and OPEC *Outlook* are assuming for the Middle East and OPEC.

[16] In contrast to the relatively optimistic projections by IEA, DOE/EIA, BP and OPEC, a more pessimistic outlook for OPEC exports can be found in Mitchell and Stevens (2008).

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Table 5
Effect of an extra 6 mbd increase in OPEC consumption in 2030 on Non-OPEC Demand, Supply and Price.
Data Sources: See Appendix A.

	History		Projections for year 2030	
	1971	2010	DOE Ref. Case projection: 11 mbd OPEC consumption in 2030	Same OPEC production as DOE but 17 mbd OPEC consumption in 2030
Oil liquids consumption (mbd)				
Non-OPEC	46.7	78.9	93	89.4
OPEC	1.2	8.5	11	17
World	47.9	87.4	104	106.4
Oil liquids production (mbd)				
Non-OPEC	26.1	47.8	60	62.4
OPEC	24.7	34.3	44	44
World	50.8	82.1	104	106.4
OPEC oil liquids exports in 2030 (mbd)	23.5	25.8	33	27
Price in 2030 (2010 $/b)	$16	$80	$125	$143
OPEC oil export revenue in 2030 (B$/year)	$139	$749	$1506	$1405
Non-OPEC oil expenditures in 2030 (B$/year)	$276	$2289	$4243	$4651

5.4. World oil market implications of much higher OPEC consumption

Let us assume that OPEC′s domestic consumption grows 6 mbd faster by 2030 than the projections of these institutions. This would imply that price would have to be higher than projected, to stimulate Non-OPEC supply and reduce Non-OPEC demand by enough to offset any net reduction in OPEC exports. The amount of the price increase will depend upon the price elasticities of non-OPEC demand and supply, and upon the amount of any increase in OPEC production in response to the increased OPEC consumption. Table 5 compares the DOE/EIA projections for 2030 of demand, supply and price with an alternative projection that assumes long-run price-elasticities of Non-OPEC demand and supply of −0.3 and +0.3 respectively; these elasticities were used by Smith (2009). The alternative projection assumes no offsetting increase in OPEC production, so that OPEC exports are 6 mbd lower than in the DOE/EIA projection, because of the increase in OPEC consumption. Hence, price will have to increase by enough to lessen Non-OPEC consumption and stimulate Non-OPEC supply to reduce Non-OPEC ′s imports by 6 mbd. In this example, price is $18 higher ($143 vs. $125), which lessens Non-OPEC demand by 3.6 mbd (from 93 to 89.4) and stimulates Non-OPEC supply by 2.4 mbd (from 60 to 62.4). The effect on OPEC export revenue is negative, as the higher price only partially offsets the reduction in OPEC exports; OPEC export revenue would be $101 billion lower in 2030 than in the DOE/EIA projection. Non-OPEC oil expenditures, however, would be $408 billion higher, because the higher price is only partially offset by the reduction in Non-OPEC oil consumption. This example is only illustrative of the magnitudes involved. The price increase would be lessened by offsetting increases in OPEC production or by higher price-elasticities.

6. Conclusions

All the major institutions – IEA, DOE/EIA, BP, and OPEC – project growth rates of oil consumption for the Middle East and OPEC that are less than 2% annually, with income growth about 4%. By contrast, since 1971 the average annual growth rate of OPEC consumption has been 5.1% for oil (5.5% for energy) with income growth of 3.1%; growth rates for the Middle East are similar. These institutions provide no econometric analysis in support of their persistent hopefulness.

Unlike these projections that OPEC oil demand will grow only half as fast as income, we believe that it will increase about as fast as their income. The income elasticity of oil demand, econometrically estimated by us and by much of the literature, is near 1. Given standard income growth projections, by 2030 OPEC will consume about 50% more oil (6 mbd) than is projected by IEA, DOE/EIA, BP, and OPEC itself. This will have important implications for increases in OPEC oil production or decreases in OPEC exports. Oil prices are likely to increase faster than projected, in order to slow the growth of Non-OPEC oil consumption and stimulate Non-OPEC production.

Of course, it is possible that OPEC′s oil consumption could grow only half as fast as their income, as the IEA and DOE/EIA have been projecting for more than a decade, persistently but wrongly. However, this has not happened in four decades, and there is no reason to expect it will start happening soon. Their projections represent what Samuel Johnson called, in another context, “the triumph of hope over experience.”

Appendix A. Data

We used 1971–2008 IEA data for consumption of oil, natural gas, and total energy, with 2009–10 estimates of oil consumption from JodiDATA:

1971–2008: IEA, Energy Balances of Non-OECD Countries, Paris, 2010.
2009–2010: Joint Organizations Data Initiative, www.JodiData.org.

We calculated Transport Oil as the sum of Motor Gasoline, Aviation Fuels, and GasOil (which includes not only diesel oil but also light fuel oil used for heating and other purposes; these are disaggregated by the IEA only for the OECD countries). Other Oil is calculated as Total Oil minus Transport Oil and Residual Oil; it includes LPG, naphtha, non-jet kerosene, and other products. For 2009–2010, we used oil product data from JodiDATA by assuming the following: (1) JodiDATA “kerosene” was disaggregated into jet-fuel kerosene and other kerosene in the same proportion as the 2008 IEA data, and then aggregated gasoline, gasoil, and jet-fuel kerosene into “transport oil”; (2) the IEA total increased from 2008 to 2009 and 2010 by the same percentage as the totals from JodiDATA; (3) Other Oil in 2009 and 2010 was calculated as the difference between the

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total demand calculated in (2) minus transport oil calculated in (1) and the JodiData values for Residual Oil in 2009–2010.

Other data used were the following:

- Population: Penn World Tables 7.0: Alan Heston, Robert Summers and Bettina Aten, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, May 2011. http://pwt.econ.upenn.edu/php_site/pwt_index.php.
- "Real Income" calculated from Penn World Tables data, as Population times PPP Converted GDP Per Capita (Chain Series), at 2005 constant prices.
- World crude oil prices (2010 $ per barrel), 1971–2010: BP Statistical Review (2011a).
- Middle East consumption of natural gas and energy, 2009–10: BP Statistical Review (2011a).

Appendix B. Individual OPEC countries' Oil Demand and Income

Also see Figs. B1 and B2.

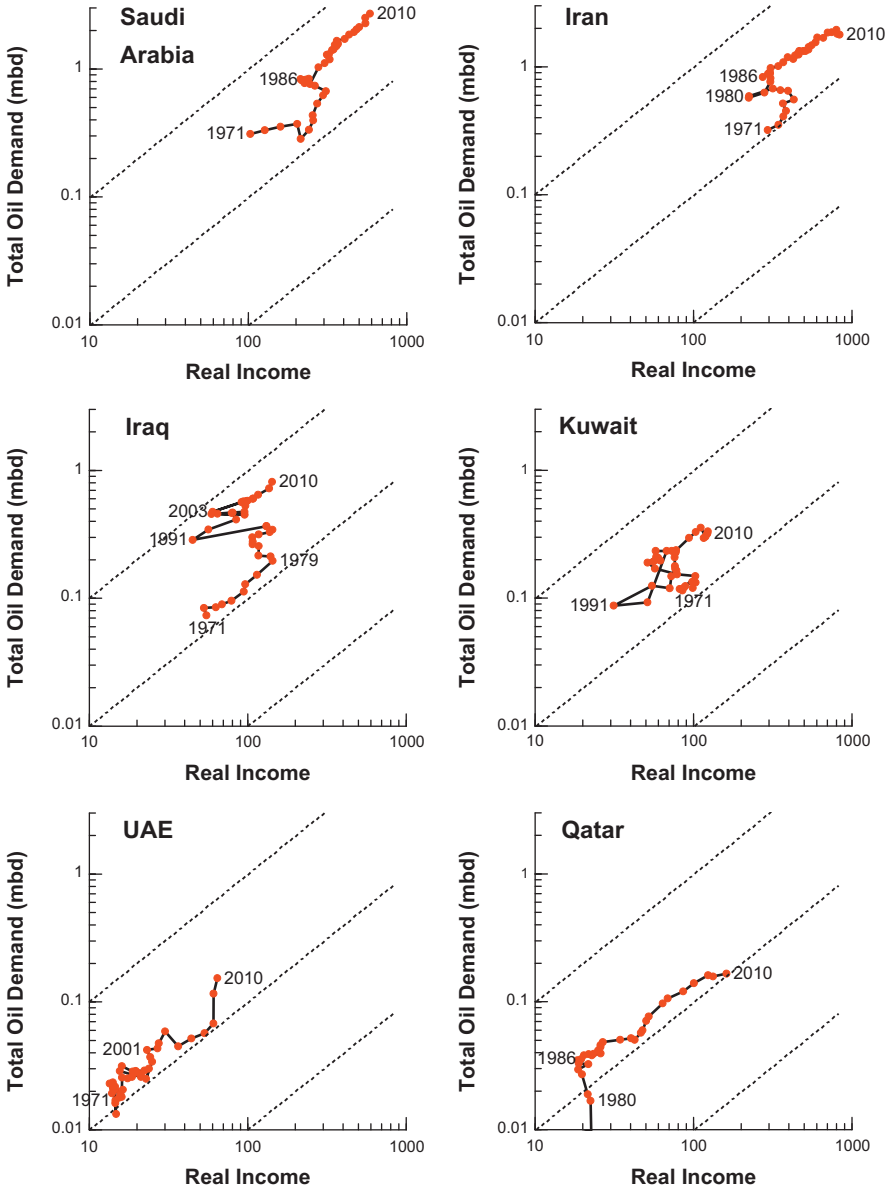

Fig. B1. Total Oil Demand and Real Income, 1971–2010: individual countries in Middle East OPEC.

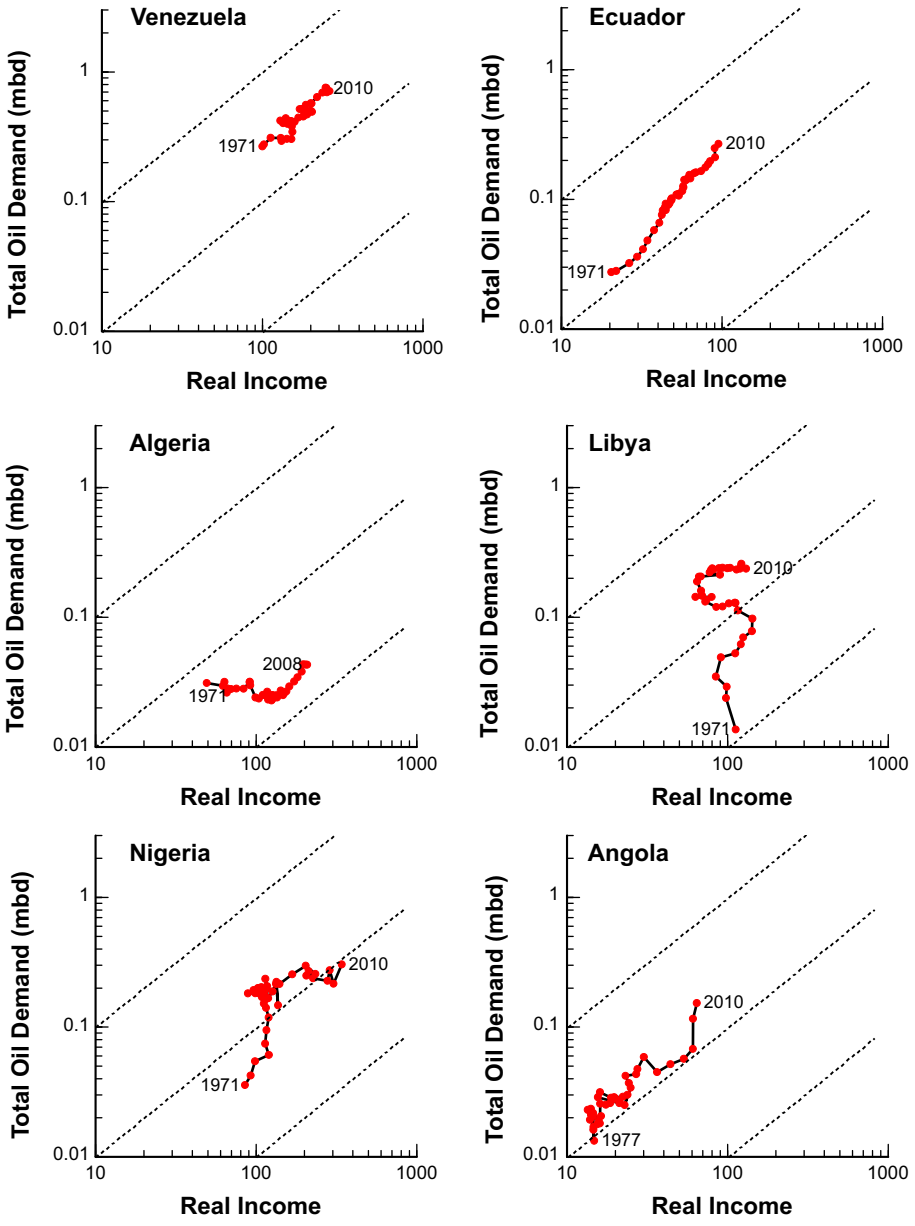

Fig. B2. Total Oil Demand and Real Income, 1971–2010, for other OPEC countries.

Appendix C. Statistical results

The results indicate that, for all variables, the null hypothesis of non-stationarity (of unit root) *in levels* cannot be rejected. This undermines the validity of using ordinary-least-squares (OLS). However, the results of Table C1 also indicate that for all variables most tests *in first differences* allow us to reject the null hypothesis of non-stationarity (of unit root). Hence, the variables are non-stationary in levels but stationary in first-differences, which indicates that the variables are integrated of order one.

The results of most of the co-integration tests (except for energy and natural gas) are that the null hypothesis of no co-integration can be rejected at the 5% significant level. Therefore, we conclude that consumption is co-integrated with income for the panels of the country groups, and there exists a long-run relationship between these countries' consumption and income (Table C2).

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Table C1
Panel Unit Root Test Results for oil products, energy, natural gas and income for the three groups: Middle East, OPEC, and Middle East OPEC.

	Levels				First Differences			
	Levin, Lin and Chu	Im, Pesaran and Shin W-stat	ADF – Fisher Chi-square	PP – Fisher Chi-square	Levin, Lin and Chu	Im, Pesaran and Shin W-stat	ADF – Fisher Chi-square	PP – Fisher Chi-square
Middle East								
Total oil	5.6	5.1	13.9	11.9	1.5*	−4.1*	70.1*	248.5*
Transport oil	5	5.2	12.8	13.2	2.4	−3.8*	69.1*	246.1*
Residual oil	−0.1	0.2	27.8	58.1*	−5.6*	−9.7*	148.4*	296.3*
Other oil	3.9	4.1	13.9	10.6	−0.3	−4.2*	98.4*	277.5*
Energy	0.9	−1.4	29.1	27.8	6.4*	−3.1*	66.3*	311.9*
Natural gas	0.2	−1.9*	30.6	29.6	−0.1	−5.1*	79.5*	265.2*
Income	−0.6	2.1	23.3	36.3	−12.5*	−12.4*	191.7*	280.2*
OPEC								
Total oil	4.2	7	11.7	10.8	−1.5	−7.2*	119.4*	250.0*
Transport oil	4.5	7.8	7.8	6.6	−2.6*	123.8*	123.8*	231.8*
Residual oil	0	0.2	25.3	28.6	−11.0*	−12.1*	187.1*	332.1*
Other oil	2.2	3.7	12.1	13.5	−7.7*	−9.3*	152.2*	350.0*
Energy	1.3	−1.6	28.6	25.4	5.8	−3.0*	70.8*	277.8*
Natural gas	0.4	−1.6	29.6	25.4	−3.7*	−5.9*	98.1*	262.7*
Income	0.8	2.7	20.5	27.2	−11.0*	−11.0*	167.4*	243.1*
Middle East OPEC								
Total oil	4.8	6.5	1	0.9	−1.6	−4.7*	49.0*	111.6*
Transport oil	3.8	6.5	1.1	1	−1.3	−4.4*	45.1*	105.0*
Residual oil	0.1	0.9	9.5	10.8	−6.5*	−7.7*	80.3*	153.8*
Other oil	−3.8	−1.4	17.9	19.2	−5.8*	−6.8*	72.4*	149.7*
Energy	0.6	−1.3	15.7	15.3	3.6	0.1	24.0*	146.7*
Natural Gas	0.2	−1.5	17	15.3	2.9*	−6.3*	67.9*	140.1*
Income	7.6	7.3	5.2	4.9	−5.7*	−6.5*	79.1*	79.3*

* Indicates that the null hypothesis of a unit root can be rejected because *P*-value is less than 0.05.

Table C2
Results of Pedroni's panel co-integration tests for models of consumption of oil products, energy, and gas on income, for Middle East, OPEC, and Middle East OPEC, with no intercept, no deterministic trend, and lag length selection based on SIC.

	Panel statistics				Group statistics		
	Panel $v-$ statistic	Panel $\rho-$ statistic	Panel PP statistic	Panel ADF Statistic	Group $\rho-$ statistic	Group PP statistic	Group ADF statistic
Middle East							
Total oil	−0.17	−1.08	−3.07*	−2.45*	−1.84*	−1.65*	−1.84*
Transport oil	0.66	−1.21	−3.23*	−3.05*	0.97	−3.42*	−3.91*
Residual oil	4.36*	−2.53*	−1.5	−0.72	−0.55	−3.29*	−2.36*
Other oil	0.03	−0.35	−1.96*	−1.91*	1.39	−1.70*	−1.4
Energy	−1.53	−1.1	−1.77*	−1.37	1.21	−1.29	−1
Natural Gas	1.43	−0.8	−0.92	−0.7	0.8	−1.11	−1.57
OPEC							
Total oil	0.66	−1.59	−4.18*	−3.96*	0.38	−3.89*	4.97*
Transport oil	1.46	−2.02*	−4.45*	−4.33*	0.65	−4.49*	−5.50*
Residual Oil	2.01*	−3.14*	−3.91*	−3.09*	−1.35	−4.75*	−4.00*
Other oil	−0.04	−0.66	−2.63*	−2.70*	0.86	−3.33*	−2.99*
Energy	−1.05	−0.63	−0.82	−1.03	1.93	0.27	−0.05
Natural gas	0.25	−0.91	−1.55	−1.66*	1.26	−1.27	−1.82*
Middle East OPEC							
Total oil	0.95	−2.30*	−5.27*	−1.60*	−0.3	−3.94*	−1.62
Transport oil	0.36	−0.83	−2.62*	−2.52*	1.09	−3.13*	−3.42*
Residual oil	1.70*	−2.63*	−3.02*	−2.16*	−2.07*	−4.57*	−3.38*
Other oil	−0.21	−0.23	−1.62	−1.74*	1.53	−1.44	−1.64*
Energy	−0.38	−1.58	−2.43*	−2.30*	0.32	−3.16*	−3.48*
Natural gas	0.12	−0.5	−0.69	−1.86*	0.99	−0.4	−2.05*

* Indicates that the null hypothesis of no co-integration can be rejected because *P*-value is less than 0.05.

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References

Ahmadian, Majid, Chitnis, Mona, Hunt, Lester C., 2007. Gasoline demand, pricing policy and social welfare in the islamic republic of Iran. OPEC Review 31 (2), 105–124.

Al-Iriani, Mahmoud, 2006. Energy-GDP relationship revisited: an example from GCC countries using panel causality. Energy Policy 34, 3342–3350.

Al-Janabi, Adnan, 1979. Estimating energy demand in OPEC countries. Energy Economics 1, 87–92.

Al-Sahlawi, Mohammed A., 1988a. Gasoline demand: the case of Saudi Arabia. Energy Economics 10 (4), 271–275.

Al-Sahlawi, Mohammed A., 1988b. GCC energy demand: outlook to 2000. Energy Economics 10 (1), 42–46.

Al-Sahlawi, Mohammed A., 1997. The demand for oil products in Saudi Arabia. OPEC Review 21 (1), 33–38.

Al-Faris, Abdul-Razak F., 1997. Demand for oil products in the GCC countries. Energy Policy 25 (1), 55–61.

Bahgat, Gawdat, 2012. Will Saudi Arabia face an energy crisis? Journal of Social and Economic Studies 37 (2), 181–198.

Breitung, J., Pesaran, M.H., 2008. Unit roots and co-integration in panels. In: Matyas, L., Sevestre, P. (Eds.), The Econometrics of Panel Data, third edition Springer-Verlag, New York, pp. 279–322. (Chapter 9).

British Petroleum (BP), 2011a. BP Statistical Review of World Energy. Available from: ⟨http://www.bp.com/statisticalreview⟩.

British Petroleum (BP), 2011b. BP Energy Outlook 2030.

Chen, B., McCoskey, S., Kao, C., 1999. Estimation and inference of a co-integrated regression in panel data: a Monte Carlo study. American Journal of Mathematical and Management Sciences 19, 75–114.

Dahl, Carol, 1993. A survey of oil demand elasticities for developing countries. OPEC Review XVII (4), 399–419.

Dahl, Carol, 1994. A survey of oil product demand elasticities for developing countries. OPEC Review XVIII (1), 47–87.

Dahl, Carol, 2007. Oil and oil product demand. ENI Encyclopedia of Hydrocarbons, 42–45.

Damette, Olivier, Seghir, Majda, 2013. Energy as a driver of growth in oil exporting countries. Energy Economics 37, 193–199, http://dx.doi.org/10.1016/j.eneco.2012.12.011.

Dargay, Joyce M., Gately, Dermot, 2010. World oil demand's shift toward faster growing and less price-responsive products and regions. Energy Policy 38, 6261–6277.

Dargay, Joyce M., Gately, Dermot, Sommer, Martin, 2007. Vehicle ownership and income growth, worldwide: 1960–2030. Energy Journal 28 (4), 163–190.

Eltony, M.Nagy, 1996. Demand for gasoline in the GCC: an application of pooling and testing procedures. Energy Economics 18, 203–209.

Eltony, M.Nagy, Al-Mutari, N.H., 1995. Demand for gasoline in Kuwait, an empirical analysis using co-integration techniques. Energy Economics 17 (3), 249–253.

Engle, F., Granger, C.W.J., 1987. Co-integration and error correction representation, estimation, and testing. Econometrica 55, 251–276.

Exxon-Mobil, 2010. The outlook for energy: a view to 2030. Available from: ⟨www.exxonmobil.com/corporate/files/news_pub_eo_2010.pdf⟩.

Gately, Dermot, 2001. How plausible is the consensus projection of oil below $25 and Persian Gulf oil capacity and output doubling by 2020? Energy Journal 22 (4), 1–27.

Gately, Dermot, Al-Yousef, Nourah, Al-Sheikh, Hamad M.H., 2012. The rapid growth of domestic oil consumption in Saudi Arabia and the opportunity cost of oil exports foregone. Energy Policy 47, 57–68, http://dx.doi.org/10.1016/j.enpol.2012.04.011.

Gately, Dermot, Huntington, Hillard G., 2002. The Asymmetric effects of changes in price and income on energy and oil demand. Energy Journal 23 (1), 19–55.

International Energy Agency (IEA), 2010. World Energy Outlook 2010. Paris. Joint Organizations Data Initiative. Available from: ⟨www.JodiDATA.org⟩.

Im, K.S., Pesaran, M.H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. Journal of Econometrics 115, 53–74.

Kao, C., 1999. Spurious regression and residual-based tests for co-integration in panel data. Journal of Econometrics 90, 1–44.

Kao, C., Chiang, M.-H., 2000. On the estimation and inference of a co-integrated regression in panel data. Advances in Econometrics 15, 179–222.

Krane, Jim, 2013. Stability versus sustainability: energy policy in the Gulf Monarchies, Cambridge Working Paper in Economics, pp. 1304. ⟨www.eprg.group.cam.ac.uk⟩.

Lee, Chien-Chiang, 2005. Energy consumption and GDP in developing countries: a co-integrated panel analysis. Energy Economics 27, 415–427.

Lahn, Glada, Stevens, Paul, 2011. Burning Oil to Keep Cool: The Hidden Energy Crisis in Saudi Arabia. Chatham House, London.

Levin, A., Lin, C.-F., Chu, C.-S.J., 2002. Unit root tests in panel data: asymptotic and finite-sample properties. Journal of Econometrics 108, 1–24.

Mehrara, Mohsen, 2007. Energy consumption and economic growth: the case of oil exporting countries. Energy Policy 35, 2939–2945.

Metschies, Gerhard P., 2009. International Fuel Prices 2009. German Technical Cooperation GTZ. Available from: ⟨www.Metschies.com⟩.

Mitchell, John, Stevens, Paul, 2008. Ending Dependence: Hard Choices for Oil-Exporting States. Chatham House, London.

Narayan, Paresh Kumar, Smyth, Russell, 2007. A panel co-integration analysis of demand for oil in the Middle East. Energy Policy 35, 6258–6265.

OPEC, 2010. World Oil Outlook. OPEC Secretariat, Vienna.

Pedroni, P., 1999. Critical values for co-integration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and Statistics 61 (4), 653–670.

Pedroni, P., 2000. Fully modified OLS for heterogeneous co-integrated panels. Advances in Econometrics 15, 93–130.

Pedroni, P., 2001. Purchasing power parity tests in co-integrated panels. Review of Economics and Statistics 83, 727–731.

Pedroni, P., 2004. Panel co-integration; asymptotic and finite sample properties of pooled time series tests, with an application to the PPP hypothesis. Econometric Theory 20, 597–625.

Smith, James L., 2009. World oil: market or Mayhem. Journal of Economic Perspectives 23 (3), 145–164.

US Department of Energy, Energy Intelligence Administration (DOE/EIA), 2010. International Energy Outlook 2010. Washington.

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