

# World Oil Demand in the short and long run: a cross-country panel analysis

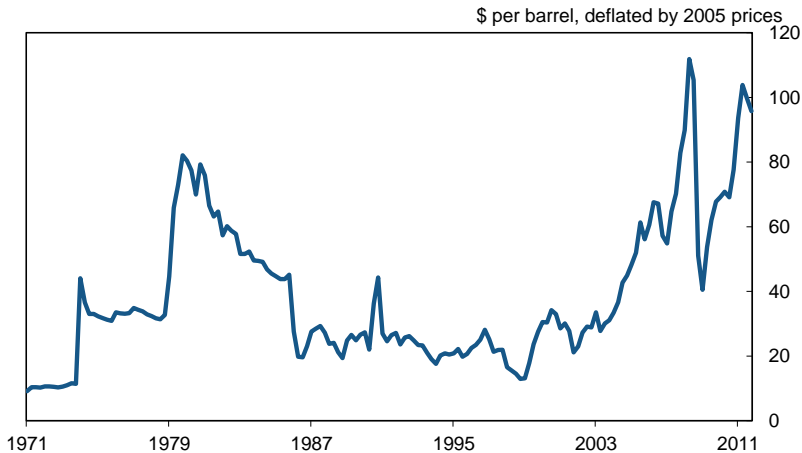
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# Why do we care about oil prices?



## Jim Hamilton's 2008 view

*Unquestionably the three key features in any account are the low price elasticity of demand, the strong growth in demand from China, the Middle East, and other newly industrialized economies, and the failure of global production to increase.*

## Kilian and Murphy beg to differ about the elasticity

*Hamilton observed that existing estimates of this elasticity in the literature are close to zero[.] These estimates, however, are based on dynamic reduced-form regressions that ignore the endogeneity of the real price of oil. They have no structural interpretation and suffer from downward bias.*

*Our median estimate of the short-run price elasticity of oil demand of -0.44 is seven times higher than standard estimates in the literature, but more similar in magnitude to recent estimates from alternative structural models.*

## How do we add to this debate?

- Quite different estimates of price and income elasticities extant: Hamilton (2008) *vs* Kilian and Murphy (2011)
- Problem highlighted by Kilian and Murphy is the endogeneity of price responses, which they argue biases price elasticities down
- Our solution - use cross-country panel techniques - resolves the endogeneity problem as for most countries it is plausible that the world price of oil is exogenous to the country
- We also concentrate on long-run elasticities
- Cointegration may aid identification
- Still work in progress

# Existing evidence on price elasticity from panel data sets

## Mixed:

- Typical estimates for long-run price elasticities  $-0.2$  to  $-0.3$
- IMF 2011 WEO notable for finding far smaller price elasticities:
  - **OECD**: short run  $-0.025$  and long run  $-0.093$
  - **Non-OECD**: short run  $-0.007$  and long run  $-0.035$

So a 50% increase in the oil price curbs non-OECD oil consumption by under 2%

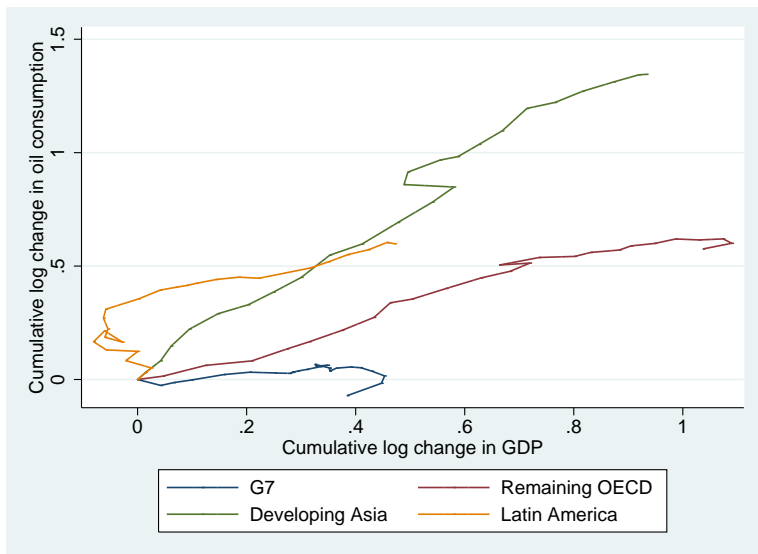
- But these studies are methodologically challenged: ignoring the combined effects of **non-stationarity**, **cross-section dependence** and **heterogeneity**

# Trends in energy intensity

## Looking at the longer trends in energy consumption

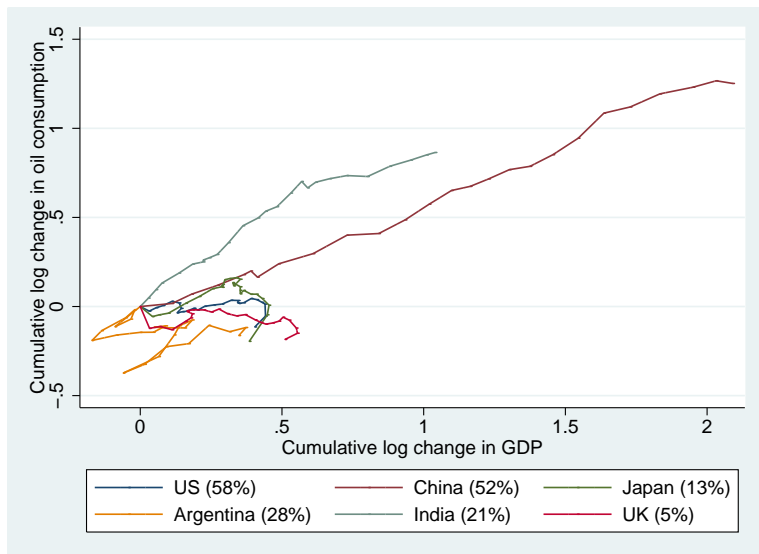
- Rühl et al (2011, BP) point to trend of falling energy use per unit of GDP independently of income level
- They argue that efficiency gains from technological progress more than offset the rise in energy intensity we would usually expect with growing manufacturing sectors in developing countries
- May be an argument for looking at countries or groups of countries separately
- So are there different trends in oil intensity over the course of the dataset?

# Trends in energy intensity, 1984–2009





# Trends in energy intensity: specific countries



## Panel dataset

- 53 countries
- 4 groups: G7 countries; selected other OECD members; developing Asian economies; and Latin American economies
- Data span 1984 – 2009 (arguably when oil-use regime stable)
- Account for over 75% of global oil consumption in 2009
- Largest-consuming countries – United States, China, Japan, India and Germany – account for 47%

For each country, three series are constructed:

1. Oil consumption per capita ( $O_t$ )
2. Real oil price in national currency (deflated with national consumption deflators) ( $P_t$ )
3. Real GDP per capita in national currency ( $Y_t$ )

## Groups

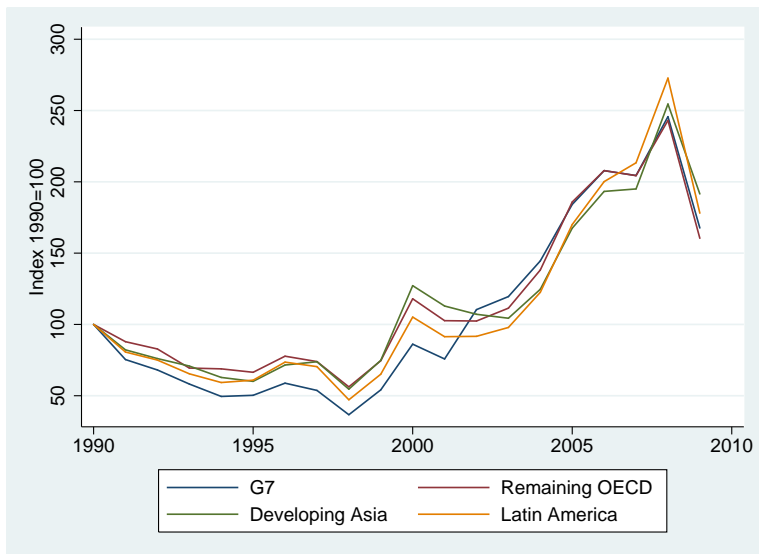
G7	Remaining OECD	Developing Asia	Latin America
Canada	Australia	Bangladesh	Argentina
France	Austria	China	Bolivia
Germany	Belgium	India	Chile
Italy	Cyprus	Indonesia	Colombia
Japan	Denmark	Malaysia	Costa Rica
UK	Finland	Myanmar	DominicanRep
US	Greece	Nepal	El Salvador
	Hong Kong	Pakistan	Guatemala
	Iceland	Philippines	Haiti
	Ireland	Sri Lanka	Honduras
	Korea	Thailand	Jamaica
	Luxembourg	Vietnam	Nicaragua
	Netherlands		Panama
	New Zealand		Paraguay
	Portugal		Peru
	Spain		Uruguay
	Sweden		
	Switzerland		

## Panel considerations

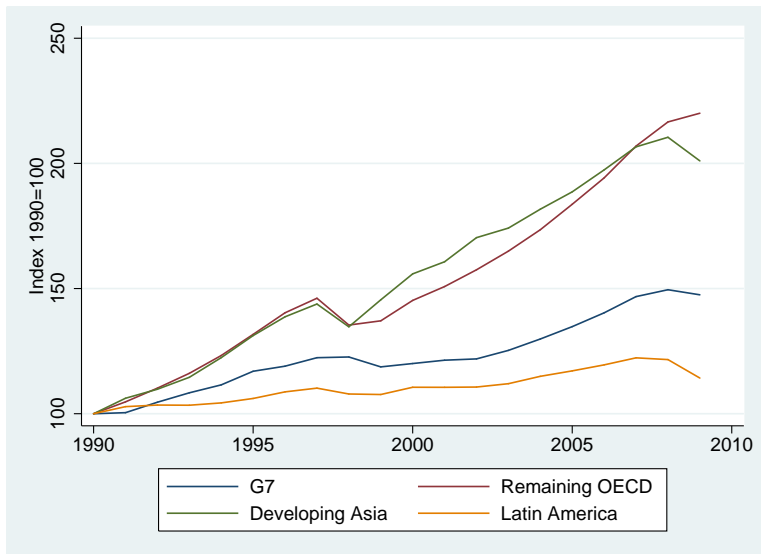
Why put the countries into four groups?

- In traditional short- $T$  panel applications, impose common parameters (pooling)
- Even in longer  $T$  applications, practitioners often pool
- But our model likely to have dynamics, and heterogeneity - well known from Pesaran and Smith (1995) pooled estimates inconsistent even in large samples
- Conceivable that the long-run parameters of the model may be common ...
- ... and even if not, cross-sectional dimension could give more precise estimates of average long-run parameters
- Pooling assumption more plausible for countries in similar stages of economic development or size

# Real oil prices



# Real GDP



# Separating the long run and short run

- Want an estimation strategy that teases out the long-run and short-run relationships between oil consumption and its drivers – real GDP and the real oil price
- Best to model this properly: a cointegrated model
- Two distinct advantages over existing studies:
  1. It allows for cross-section dependence in the data
  2. It allows for some differences in relationships across countries
- If the series cointegrate, we can estimate this relationship and how quickly the economy returns to it, after short-run shocks to oil demand, prices or income

# An econometric model

Simple error-correction models for each country

$$\Delta \log O_{i,t} = \mu_i + \gamma_{ip} \Delta \log P_{i,t} + \gamma_{iy} \Delta \log Y_{i,t} + a_i b_i' \log X_{i,t-1} + \epsilon_{i,t} x$$

Country  $i = 1, \dots, N$       Time  $t = 1, \dots, T$

where  $X_t = (O_t P_t Y_t)'$

- Short-run price and income elasticities given by  $\gamma_{pi}$  and  $\gamma_{yi}$
- Long-run elasticities  $b_i = (1 \ b_{pi} \ b_{yi})'$
- $a_i$  feedback of oil consumption to deviations from the long-run relationship
- Cointegration between the variables implies  $a_i < 0$



## How cointegration aids identification

- Elements of  $X_t = (O_t P_t Y_t)'$  are all I(1)
- For ECM to be valid need cointegration
- In principle number of cointegrating vectors  $r$  may be 0, 1 or 2
- If  $r = 2$ ,  $b_i = (1 b_{pi} b_{yi})'$  is a linear combination of two vectors and relation unidentified
- If  $r = 1$ ,  $b_i = (1 b_{pi} b_{yi})'$  theory tells us we have a demand relation
- If cointegration exists, simultaneity bias 2nd order

## Panel rank cointegration tests

- Simple idea in Davidson (1998): irreducible cointegration - look for minimum set of variables such that  $r = 1$
- Can establish cointegration using residual based methods, either single equation or panel based as in eg Pedroni (1995)
- But to establish uniqueness we require rank tests
- Johansen tests generalised to panels by Larsson, Lyhagen, and Löthgren (2001)
- Crosssectional relationships (either in the error structure or causally) create problems
- More flexible tests (eg Larsson and Lyhagen 2007) have high dimensionality and need large  $N$
- But as LL (2007) observe 'An important aspect in the modeling of panel VARs is the trade-off between simplicity and empirical realism, the latter perhaps demanding that a large system has to be estimated, making the statistical analysis less precise.'

# Pooling and heterogeneity

- Allowing the  $ECM_i$  to differ amounts to estimating  $N$  separate regressions, providing distinct parameter estimates
- But doing so ignores that there may be efficiency gains from pooling the data for some countries together
- In any case, we might want to focus more on the behaviour of *groups* of countries than on individual members
- Pooling data together circumvents the low power of estimators in short- $T$  samples

## Pooled mean group estimates

- Impose common *long-run* parameters in a group, ie  $b_i = b$  for all  $i$  in a group - the Pooled Mean Group (PMG) approach of Pesaran, Shin and Smith (1999)
- Group-wide estimates of the other parameters are the cross-section average of country-specific values (Mean Group estimates)
- Avoid mis-specification bias from ignoring cross-section heterogeneity, while still estimating average parameters for each group

## An aside on poolability

Poolability need not imply *homogeneity*.

- Hausman test based on the result that an estimate of the mean long-run parameters in the model can be derived from the average of the unit regressions
- If the parameters are in fact homogeneous, the mean and the individual parameters coincide and the PMG estimates are more efficient
- But even if heterogeneity (which is plausible) PMG may be efficient
- Test interpreted not that parameters are equal, but that the mean (ie, MG) estimate of the parameters is not significantly different from the PMG estimate
- As an empirical issue, it is this average value with which we are concerned, rather than the hypothesis of homogeneity

## How to weight the MG estimates

Simplest mean group estimates are the uniformly-weighted average of individual coefficients. But some countries consume more oil than others. So it makes sense to think of the weighted average:

$$\hat{\gamma}_{pW} = \sum_{i=1}^N w_i \hat{\gamma}_{pi}$$

The set of weights  $w = (w_1 \dots w_N)$  used here are country shares of per-capita oil consumption within each group. The variance of the estimator in this case is:

$$s^2 = \frac{\sum_i w_i^2}{1 - \sum_i w_i^2} \sum_{i=1}^n w_i (\hat{\gamma}_i - \hat{\gamma}_W)^2$$

# Cross-section dependence

- Common shocks – which hit several countries at once, and are correlated with oil prices and/or GDP – are likely, given the nature of the dataset
- But many of the estimators used in existing studies are problematic:
  - Fully Modified OLS (FMOLS) requires cross-section independence: correction mechanisms – *eg* estimating cross dependencies – require significantly larger  $T$
  - Second-generation panel estimators offer more promise – vector error-correction models adjust for cross-section dependence in the panel: but they require large- $T$ , small- $N$  panels

## Common Correlated Effects estimator

Cross-section dependence also affects  $ECM_i$ , but Pesaran (2006, Ecta) proposes a solution: Common Correlated Effects (CCE) estimator models the common shocks as unobserved factors:

- *Cross-section* average of all variables, including the dependent variable, are included as additional regressors
- They act as proxies for the unobserved common factors that vary over time, but are common to all countries in the panel
- Works for multiple common factors, and both  $I(0)$  and  $I(1)$  data
- Since this accounts for cross-section dependence,  $ECM_i$  can still be estimated *via* maximum likelihood



# Overall results

	Long-run elasticities		Short-run elasticities		Feedback
	Price	Income	Price	Income	
G7	-0.068*** (0.028)	0.267** (0.075)	0.008*** (0.001)	0.65*** (0.09)	-0.22*** (0.011)
Remaining OECD	-0.075*** (0.019)	0.93*** (0.049)	-0.047*** (0.006)	0.61*** (0.006)	-0.15*** (0.005)
Developing Asia	-0.106*** (0.046)	0.681*** (0.031)	-0.017*** (0.001)	0.736*** (0.176)	-0.245*** (0.018)
Latin America	-0.154*** (0.019)	1.321*** (0.046)	-0.006 (0.004)	0.905*** (0.033)	-0.110*** (0.009)

- Long-run: pooled for each group
- Hausman test accepts poolability of long-run parameters in all cases
- Short-run & feedback: weighted mean-group estimates

## Economic interpretation

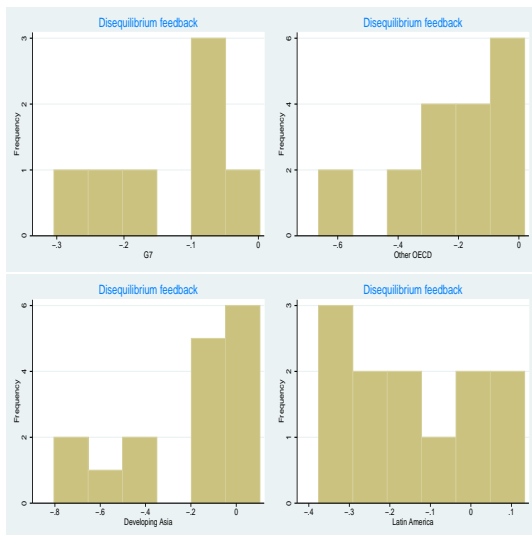
The long-run elasticities differ markedly between groups:

- The developed G7 have a much lower long-run income elasticity than the other groups. Latin America has a high income elasticity, exceeding unity. Developing Asia has an elasticity below that of the remaining OECD countries.
- This contrasts with the widely held view that the developing Asian countries, and in particular China, have higher income elasticities than developed countries. But consistent with some views - eg Rühl et al (2011, BP).
- The price elasticities are small, in line with Hamilton's (2008) views. G7 SR price elasticity positive - but numerically small.
- All the developed price elasticities are below the developing countries', consistent with energy constituting a smaller share in developed countries. While numerically small, the developing elasticity is markedly higher than that reported by the IMF 2011 WEO.

# Cross-country variation inside Mean Group estimates

- How much cross-country variation does the summary results disguise? We can examine this through the distribution of short-run parameters.
- Most of the individual short-run parameters conform to our expectations but not all are well determined. We would not be well advised to use individual country estimates.
- That is of course the value of our panel methods, which gives us confidence that the **intra-group mean effects** are well determined.

# Cross-country variation inside Mean Group estimates



# Reality check

How do we know that this method is valid? Need to check:

1. Long-run pooling assumption
2. Order of integration of data
3. Uniqueness of cointegrating relationship

Summary of answers:

1. **Hausman test** of pooling comfortably passes for all four groups
2. Second-gen **Panel unit root tests** indicate data are  $I(1)$  – these are robust to cross-section dependence
3. Haven't yet done the panel rank tests - strong evidence of cointegration but rank unclear

# Integration and Cointegration

Running Johansen tests on individual countries: % of those within each group that find one, or at least one cointegrating vector

Country Group	Trace (95%)	Trace (99%)	SBIC	HQIC
$r = 1$				
G7	57	43	43	0
Other OECD	44	39	28	17
Developing Asia	42	25	42	42
Latin America	44	50	44	31
$r \geq 1$				
G7	100	57	100	100
Other OECD	94	61	89	100
Developing Asia	58	33	67	100
Latin America	69	63	88	100

# Concluding thoughts

- Results most robust for long-run parameters
- Panel techniques improve efficiency - remarkably, all previous literature has used inappropriate techniques
- Important to understand oil elasticities, on which views divided
  - Short-run price elasticities small, long-run at low end of previous estimates
  - Short-run output elasticities not far from long-run values
  - Some important differences between groups – Asian elasticities lower than is commonly argued
- As data  $I(1)$  cointegration potentially aids identification - yet to be done

# Oil - demand, supply and shocks

- Hamilton, J D (1983) *Oil and the macroeconomy since World War II*
- Hamilton (2008) *Understanding crude oil prices*
- Kilian (2009a) *Not all oil price shocks are alike: disentangling demand and supply shocks in the crude oil market*
- Kilian (2009b) *Oil price shocks, monetary policy and stagflation*
- Kilian and Murphy (2012) *Why agnostic sign restrictions are not enough: understanding the dynamics of oil market VAR models*
- Ruhl, Appleby, Fennema, Naumov and Schaffer (2011) *Economic development and the demand for energy: a historical perspective on the next 20 years*



# Econometrics

- Pesaran (2006) *Estimation and inference in large heterogeneous panels with a multifactor error structure*
- Pesaran, Shin and Smith (1999) *Pooled mean group estimation of dynamic heterogeneous panels*
- Pesaran and Smith (1995) *Estimating long-run relationships from dynamic heterogeneous panels*
- Breitung and Pesaran (2008) *Unit Roots and Cointegration in Panels*

# Panel cointegration

- Davidson (1998) *Structural relations, cointegration and identification: some simple results and their application*
- Larsson and Lyhagen (2007) Inference in Panel Cointegration Models With Long Panels
- Larsson, Lyhagen and L othgren (2001) Likelihood-Based Cointegration Tests in Heterogeneous Panels