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

Nicholas Fawcett* Simon Price†

*Bank of England

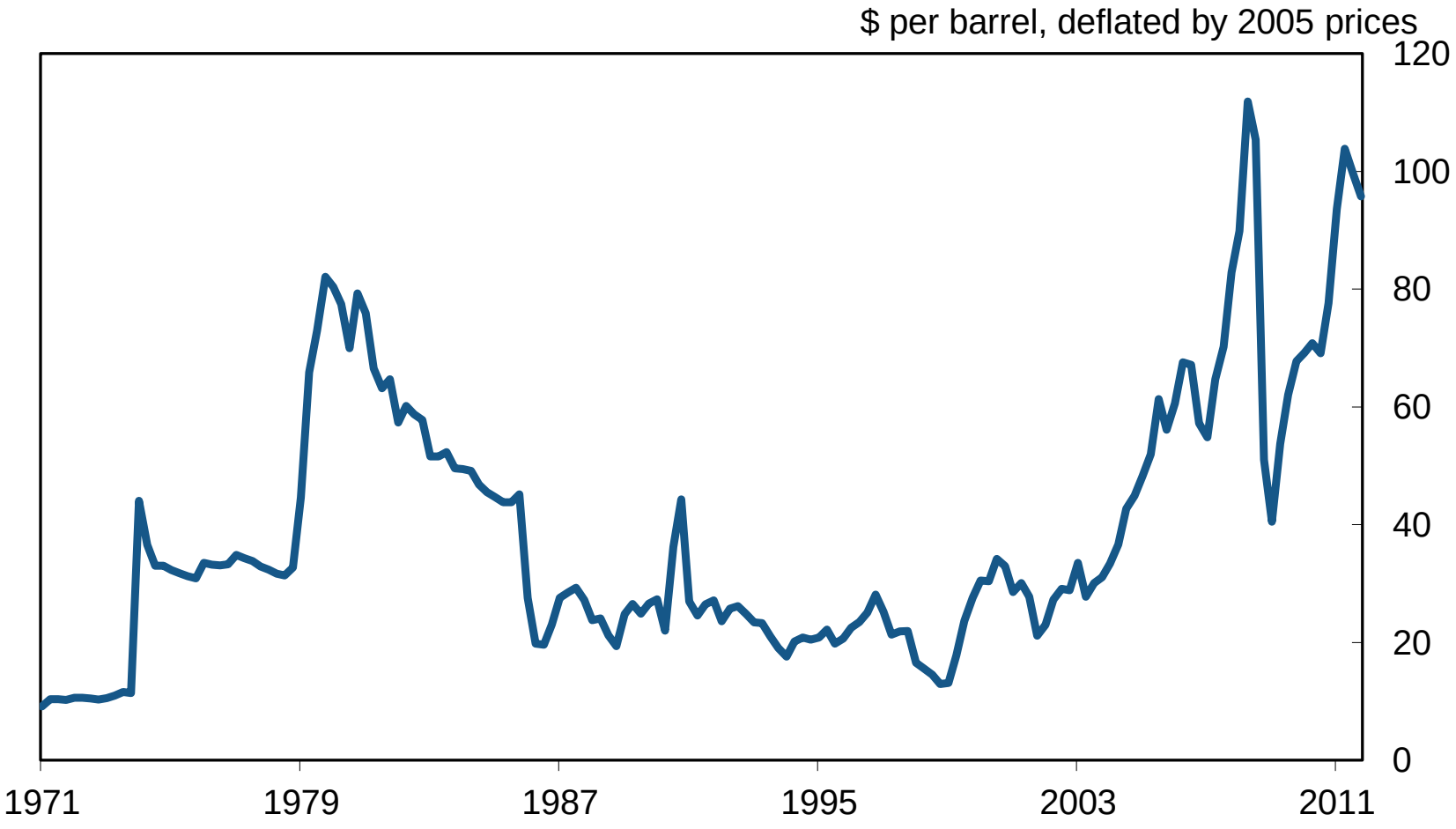
†Bank of England and City University

City University
March 2012

Overview

Overview

Real dollar oil price 1970 - 2011



Why do we care about oil prices?

- Although energy is a small share of GDP, the enormous recent swings in prices have a substantial impact on the economy
- Despite a fall in oil/GDP oil is still a critical fuel for transport with few substitutes
- If energy prices remain high, it may help reduce carbon emissions (at the time of the Stern Report his proposed carbon tax was already being levied by the oil producers)
- Widely believed that 'oil price shocks' are responsible for many recessions, or at least have an impact on the economy

Shocking stories

- In fact, controversy over meaning of 'oil shocks'
- Clearly, for a small country, changes in oil prices are exogenous
- But important in principle to identify source of the shock
- Views are divided

Supply shocks

Hamilton 1983

All but one of the US recessions since World War II has been preceded ... by a dramatic increase in the price of crude petroleum

Other shocks

Kilian 2009a

[S]hocks to the production of crude oil, while not trivial, are far less important in understanding changes in the real price of oil than shocks to aggregate demand and shocks to the precautionary demand for oil that reflect fears about future oil supplies.

Kilian and Murphy (2012)

A robust finding is that the fluctuations in the real price of oil are mainly driven by oil demand shocks with oil supply shocks playing a minor role.

Aftershocks

Baumeister et al 2009

[T]he consequences of an oil price increase depend crucially on the underlying source of the oil price shift in all countries ... [A]fter an oil demand shock driven by a global economic upswing, output temporarily increases and consumer prices rise strongly.

This is in contrast to an oil-specific demand shock, after which economic activity temporarily declines and inflationary effects are mostly insignificant.

What's special about the oil market?

- Oil market profoundly un-transparent
- Deep uncertainty about size of reserves, inventories, spare capacity
- That means information is very incomplete and asymmetric
- Unconventional backstops viable at maybe \$60-\$70 pb
- But investment lead times can be decades
- Saudi (and therefore OPEC's) ability to undercut means precautionary behaviour in face of massive irreversible investments suggests trigger prices could be very high (witness unprofitability of tar sands in 2009)
- Although recent events may make it politically impossible to lower cut price for fiscal reasons

Intertemporal dimension

- Commodities are a store of wealth
- Both producers and consumers anticipate future demand and supply
- Large quantities of physical stocks for future deliveries either in storage or underground
- That means natural scope for futures markets to exist
- Fulfills an insurance need (hedging)
- That requires 'speculators' to satisfy the demand for hedging
- But unlike financial products there is a physical flow supply and demand to equilibrate

Arbitrage conditions

- Hotelling: producers indifferent between holding oil in the ground and selling tomorrow and selling it now and investing the money
- s spot price, c MC of extraction

$$s_{t+1} - c_{t+1} = (1 + i)(s_t - c_t)$$

- Working: similar issue re holding oil above ground - need to adjust for 'convenience yield' of having it available
- Both conditions hold: perfectly consistent with long-run movements in price of oil as c can vary

Footnote on the oil 'price'

- Price itself far from transparent – prices come from the reporting agencies (Platts, Argus) and information unclear
- Price discovery actually starts from futures, which are less noisy than the 'spots' (themselves all future dated), which are affected by short-term idiosyncratic factors

A major controversy

Financialization

A major controversy

Financialization

Is that the right spelling?

A major controversy

Financialization

Is that the right spelling?

I shall randomize.

Two views on oil price drivers

1. Recent movements in the price of oil (and other commodities) are largely driven by 'speculation', which has increased following the financialisation of commodity markets
2. It's supply and demand, stupid

Speculation

UNCTAD: Price Formation in Financialized Commodity Markets: The Role of Information

[Real] factors alone are not sufficient to explain recent commodity price developments; another major factor is the financialization of commodity markets. Its importance has increased significantly since about 2004, as reflected in rising volumes of financial investments in commodity derivatives markets both at exchanges and over the counter (OTC).

This phenomenon is a serious concern, because the activities of financial participants tend to drive commodity prices away from levels justified by market fundamentals, with negative effects both on producers and consumers.

Not speculation?

- Unlike financial assets, commodities are continuously traded for physical delivery - hard to see how financial players can drive us very far away from that physical equilibrium
- Commodity prices have always been volatile and always will be
- Current oil price volatilty below 1970s or 1990s
- Current real oil price high but good reasons why
- Speculators not creating a new demand for the physical product - markets exist to provide insurance for producers and consumers
- The degree of financialization is not generally higher than needed - and liquid markets are useful
- If speculation pushed price above fundamentals, inventories would rise - but inventories in 2006-2008 were declining in many markets

Evidence on bubbles?

- Gilbert UNCTAD (2010) tests for bubbles - cheerleader for existence
- ADF-type test due to Phillips Wu and Yu, 2001 to 2009
- Weak evidence for bubbles using monthly data - possible copper bubble
- Stronger evidence using daily data: *reasonable to conclude that oil and some non-ferrous metals prices have exhibited explosive behaviour over at least some sub-periods*
- But the 'bubbles' very short lived and infrequent
- Could be slow learning fundamentals have changed
- Or close-to-stockout periods (non linearity)
- Recent work by Gilbert (2012) less supportive, especially for oil

Gilbert's current view

Gilbert *et al* (2012)

Our results indicate that [Phillips and Yu]'s claim that the crude oil price was subject to a bubble in 2008 is only weakly supported. Their conclusion is dependent on the data frequency and the test statistic employed as well as the decision to examine prices in levels and not logs.

Fundamentals

- Even if there *is* speculation still possible to look at fundamentals as data non-stationary (variance dominated by fundamentals)
- Object of our work to understand drivers of oil demand
- Controversy in literature about elasticities which we hope to shed light on
- Then given medium term supply, can understand price movements

Overview

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

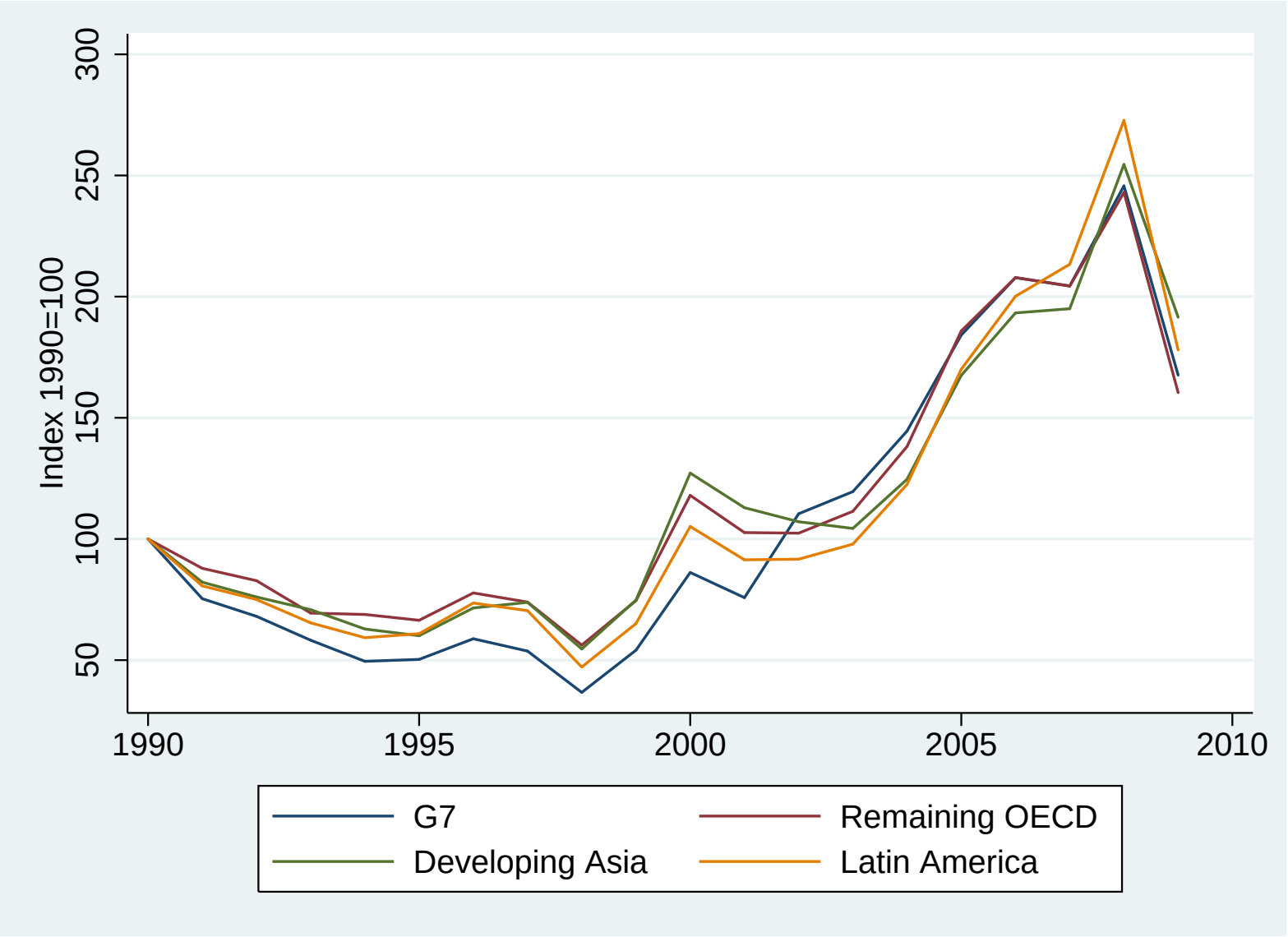
G7	Remaining OECD	Developing Asia	Latin America
Canada	Australia	Bangladesh	Argentina
France	Austria	China	Bolivia
Germany	Belgium	India	Chile
Italy	Cyprus	Indonesia	Colombia
Japan	Denmark	Malaysia	Costa Rica
UK	Finland	Myanmar	DominicanRep
US	Greece	Nepal	El Salvador
	Hong Kong	Pakistan	Guatemala
	Iceland	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

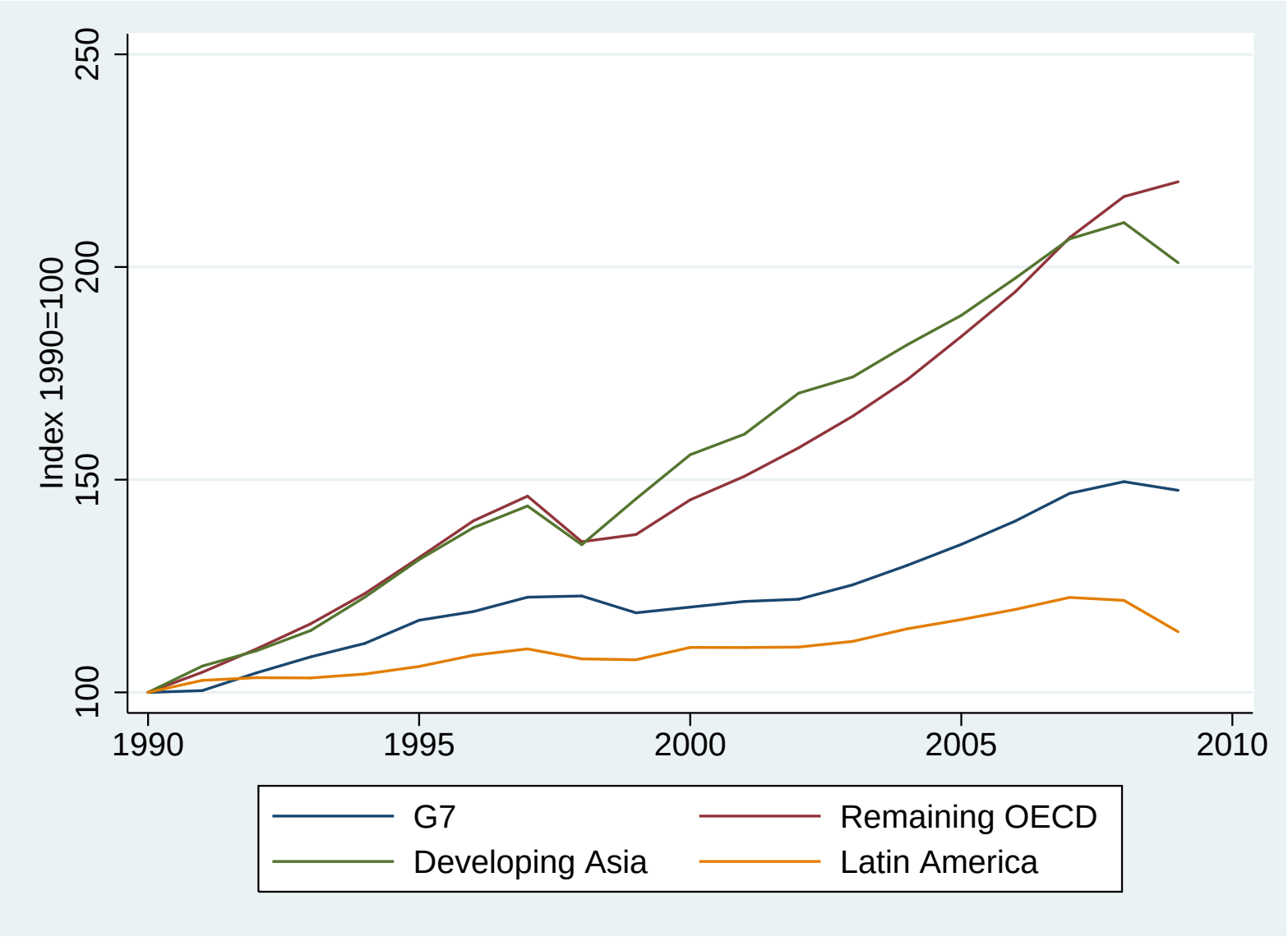
Why put the countries into four groups?

- 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


Index 1990=100
250
200
150
100
1990
1995
2000
2005
2010
G7
Developing Asia
Remaining OECD
Latin America

Overview

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 in 2011

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.

What are the fundamentals?

- 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
- Moreover, as income, oil demand and real oil price are non-stationary, can use (unique) cointegration to identify

Existing evidence on price elasticity

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

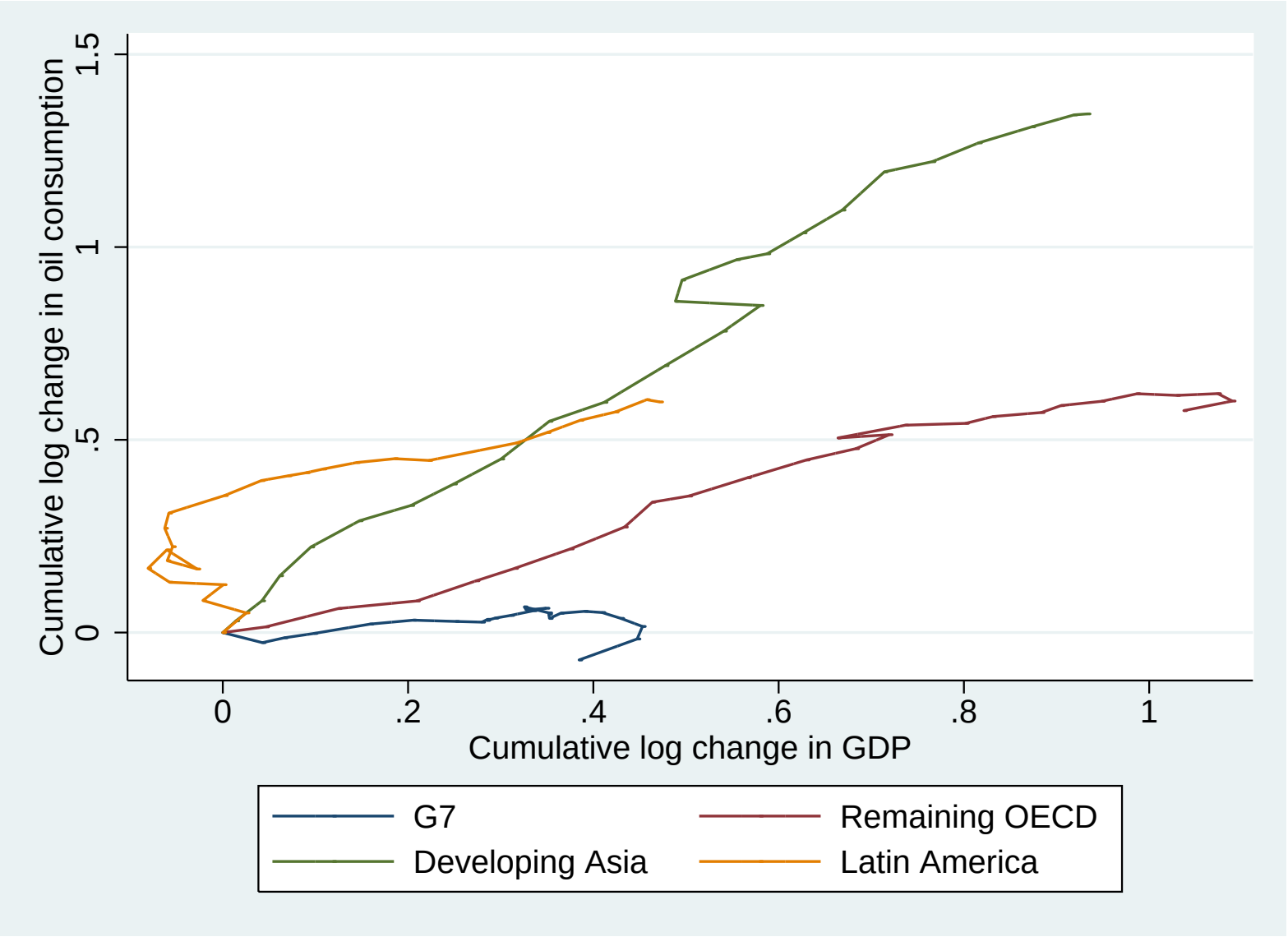
  So a 50% increase in the oil price curbs non-OECD oil consumption by under 2%
- But these studies are methodologically challenged: ignoring the combined effects of non-stationarity, cross-section dependence and heterogeneity

Trends in energy intensity

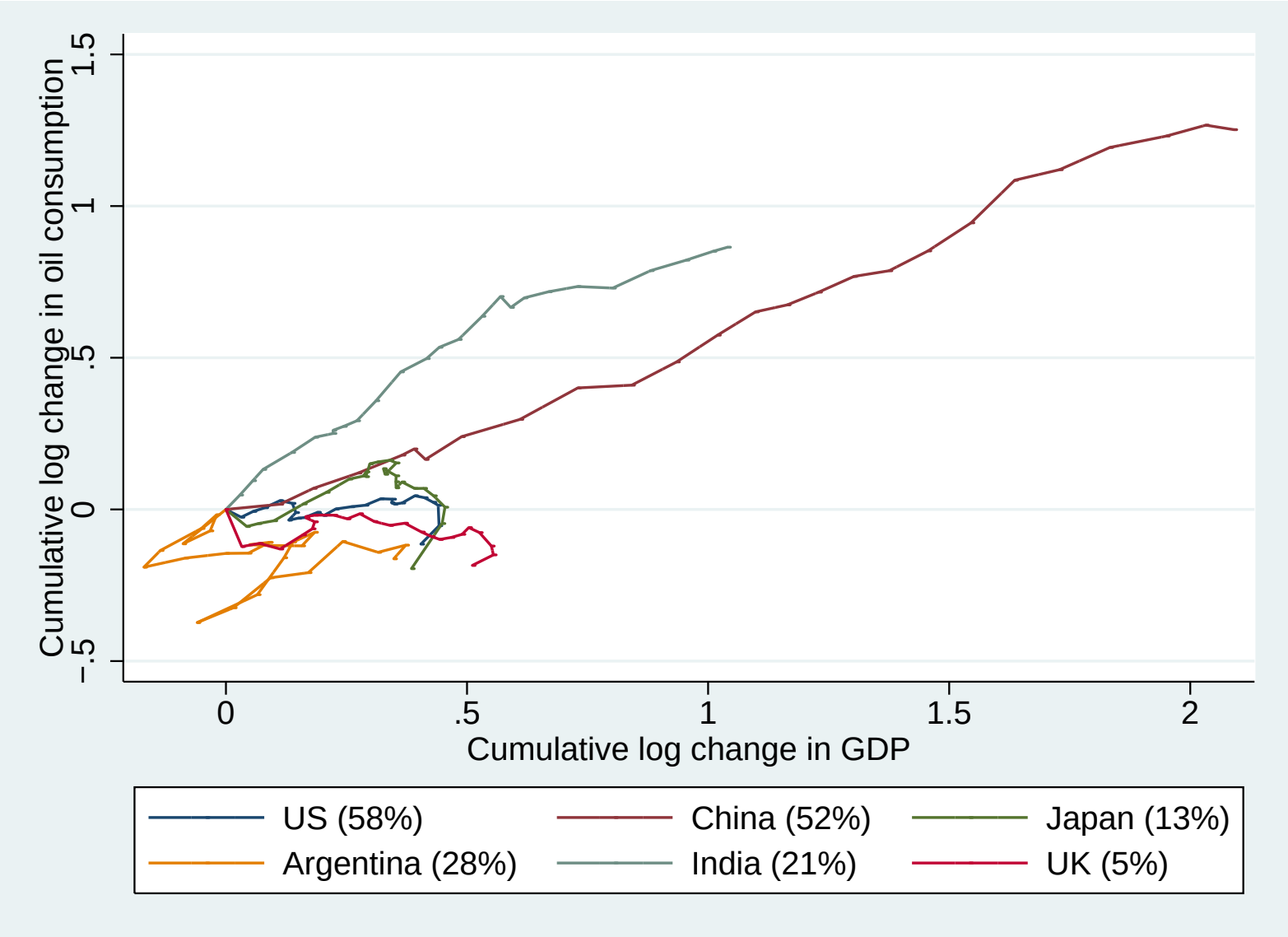
But looking at the longer trends in energy consumption

- 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
- Central question to our panel: 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



Overview

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

An error-correction model spells this out:

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

$$\text{Country } i = 1, \ldots, N \qquad \text{Time } t = 1, \ldots, T$$

where $X_t = (O_t \; P_t \; Y_t)'$

- Short-run price and income elasticities given by γ_{pi} and γ_{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 (1) 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

Pooling and heterogeneity

- Allowing the relationship specified in (1) to differ from country to country 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:

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

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

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

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 (1), 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, (1) can still be estimated *via* maximum likelihood

Overview

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

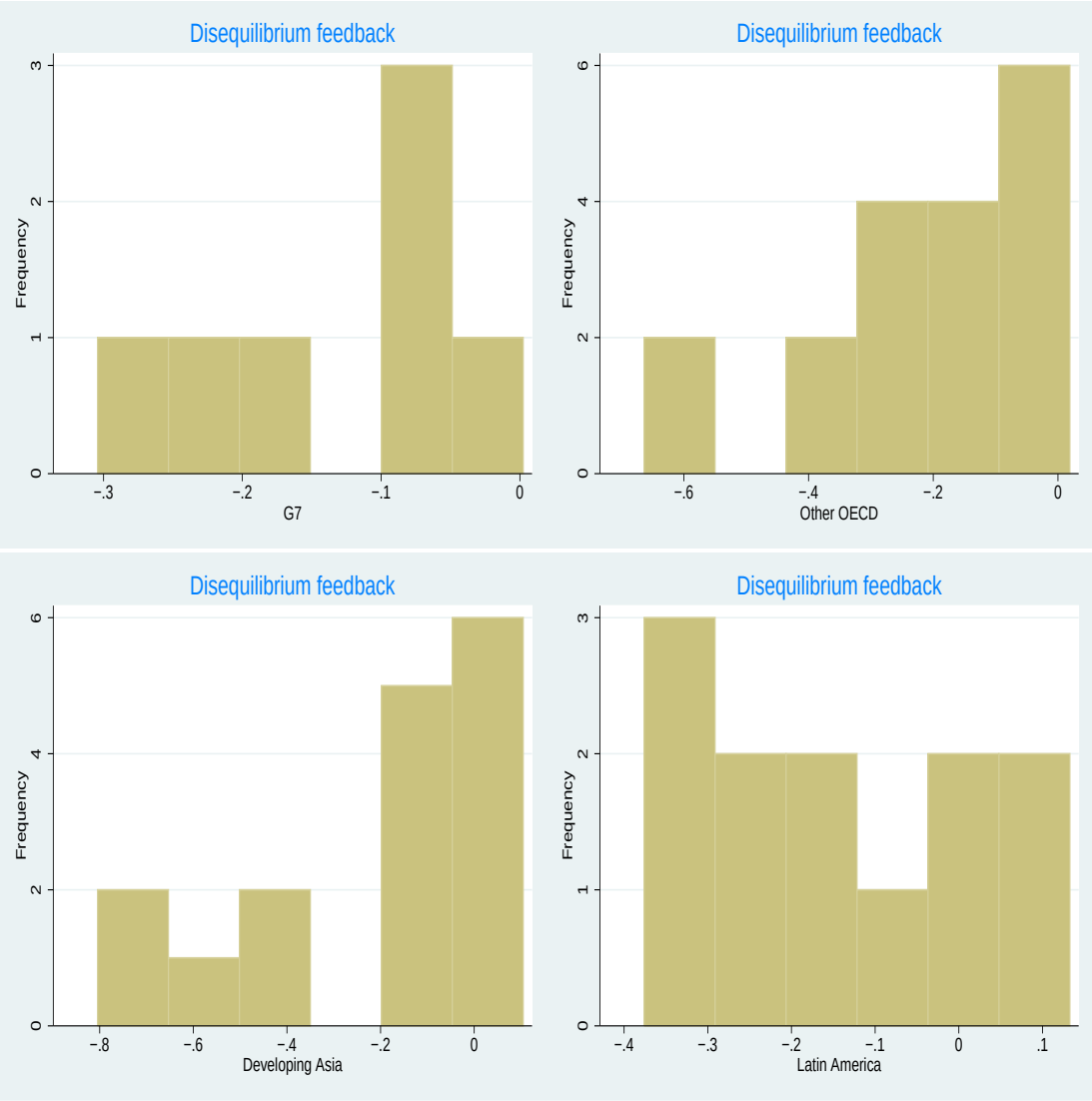
The long-run elasticities differ markedly between groups:

- 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. Ongoing research into how to estimate cointegrating relationship

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

Overview

Concluding thoughts

- Oil matters
- 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

Overview

Oil - demand, supply and shocks

- Baumeister, Peersman and Van Robays (2009) *The economic consequences of oil shocks: differences across countries and time*
- 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*

Bubbles

- Figurola-Ferretti, Gilbert andMcCrorie (2012) *Recursive tests for explosive behaviour and bubbles: some extensions with application to crude oil and copper*

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*