Energy Demand and Energy Efficiency in Developing Countries

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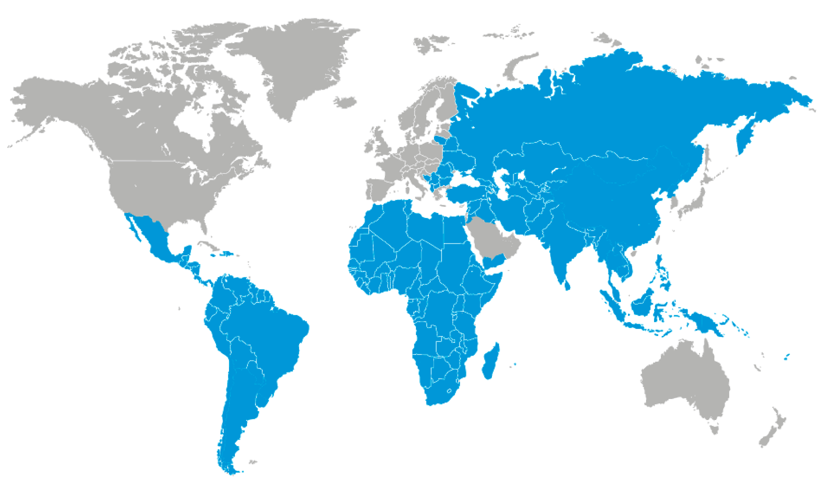
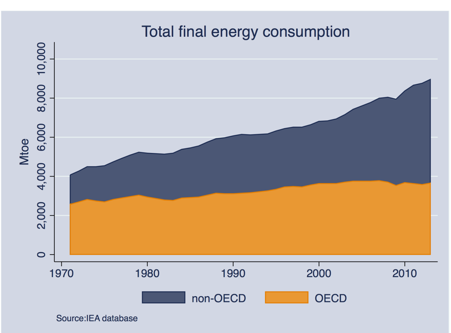
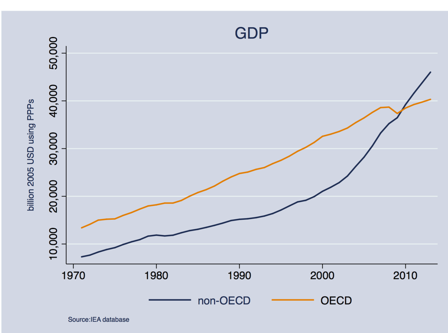
Motivation

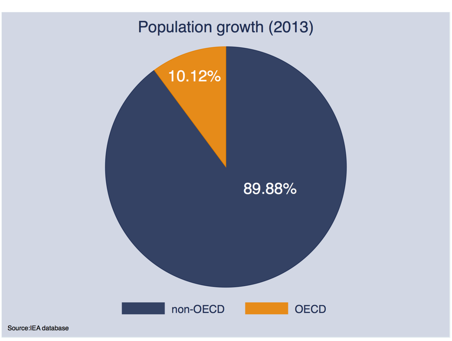
- EA (2012) argues that energy efficiency is an essential part of sustainable energy future and a cost effective way of:
  - reducing energy consumption
  - reducing GHG emissions
  - enhancing security of energy supply
  - mitigating energy price volatility
  - driving economic growth
- Paris agreement, December 2015

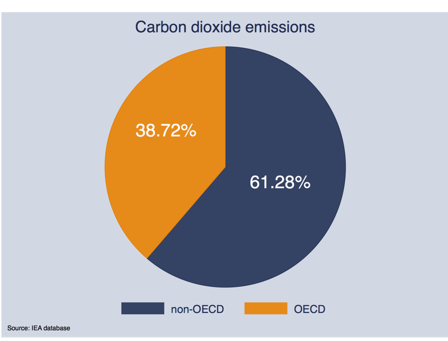
Developing Countries











Problems

$$\textit{Energy Intensity} = \frac{\textit{Energy Consumption}}{\textit{GDP}}$$

- EI is often taken as a proxy for EE, although this is not entirely accurate since trends in energy intensity can be influenced by factors other than energy efficiency (IEA, 2012)

Objectives

Main goal of this study is to estimate the level of 'true' energy efficiency in developing countries by combining:

- Energy demand modelling
- SFA (based on microeconomic theory of production)

Transient/Persistent component

State of the Art

Energy demand frontier function

- Aggregate energy demand function
  - Filippini and Hunt (2011) - *OECD*
  - Filippini and Hunt (2015) - *US*
  - Filippini and Zang (2016) - *China*
- Residential energy demand function
  - Filippini and Hunt (2012) - *US*
  - Filippini *et al.* (2014) - *EU*
  - Alberini and Filippini (2015) - *US*

Data & Methodology

Based on Filippini and Hunt (2011) the following aggregate energy demand function is specified:

$$e_{it} = \alpha + \alpha^y y_{it} + \alpha^p p_{it} + \alpha^{pop} pop_{it} + \alpha^a a_i + \alpha^{ISD} ISH_{it} + \alpha^{ASH} ASH_{it}$$
$$+ \alpha^{hdd} hdd_{it} + \alpha^{cdd} cdd_{it} + \underbrace{\alpha^t t + \alpha^{t^2} t^2}_{\text{time trend}} + u_{it} + v_{it}$$

Error term consisting of 2 parts $\varepsilon_{it} = u_{it} + v_{it}$.
$v_{it} \sim N(0, \sigma_v^2)$ a symmetric disturbance capturing the effect of noise
$u_{it} \sim N^+(0, \sigma_u^2)$ energy efficiency indicator

where for $i = (1, ..., 39)$ and $t = (1989, ..., 2008)$
$e_{it} = ln$ of total final energy consumption (mtoe)
$y_{it} = ln$ of GDP (2005 USD in PPPs)
$p_{it} = ln$ of real energy price index
$pop_{it} = ln$ of population (millions)
$a_i = ln$ of area size (Km^2)
$ISH_{it} =$ Industry share (% GDP)
$ASH_{it} =$ Agriculture share (% GDP)
$hdd_{it} = ln$ of heating degree days ($70\,^\circ$F)
$cdd_{it} = ln$ of cooling degree days ($70\,^\circ$F)

	Model I MREM	*Model II* TREM	*Model III* GTREM
Country's effect α_i	$\alpha_i = \gamma \bar{X}_1 + \delta_i$ $\bar{X}_i = \frac{1}{T}\sum_{t=1}^{T} X_{it}$	$N(\alpha, \sigma_w^2)$	$N(\alpha, \sigma_w^2)$
Full random error	$\varepsilon_{it} = \delta_i + v_{it}$	$\varepsilon_{it} = w_i + u_{it} + v_{it}$	$\varepsilon_{it} = w_i + h_i + u_{it} + v_{it}$
	$\delta_i \sim N^+(0, \sigma_\delta^2)$ $v_i \sim N(0, \sigma_v^2)$	$u_{it} \sim N^+(0, \sigma_u^2)$ $v_{it} \sim N(0, \sigma_v^2)$ $w_i \sim N(0, \sigma_w^2)$	$u_{it} \sim N^+(0, \sigma_u^2)$ $v_{it} \sim N(0, \sigma_v^2)$ $w_i \sim N(0, \sigma_w^2)$ $h_i \sim N(0, \sigma_h^2)$
Persistent efficiency estimator	$\mathbf{E}(\delta_i \mid \varepsilon_{it})$	$\varnothing$	$\mathbf{E}(h_i \mid \varepsilon_{it})$
Transient efficiency estimator	$\varnothing$	$\mathbf{E}(u_i \mid \varepsilon_{it})$	$\mathbf{E}(u_i \mid \varepsilon_{it})$

Table 1: Econometric specification of stochastic energy demand frontier: Effects, Error Term and inefficiency

Empirical Results

	MREM	TREM	GTREM
income	$.586^{***}$	$.490^{***}$	$.534^{***}$
own price	$-.172^{***}$	$-.208^{***}$	$-.212^{***}$

Table 2: Estimated elasticities

	mean	st. dev.	min	max
MREM	.705	.203	334	.969
TREM	881	.077	.389	.986
PGTREM	.816	.002	.806	.820
TGTREM	.891	.046	.650	975

Table 3: Energy efficiency scores

		(1)	(2)	(3)	(4)	(5)
MREM	(1)	1				
TREM	(2)	.01	1			
PGTREM	(3)	.04	.04	1		
TGTREM	(4)	.02	.96	-.03	1	
EI	(5)	-.21	-.24	-.16	-.28	1

Table 4: Correlation coefficients

	TGTREM	EI	cor
Brazil	.910(1)	.088(10)	.737
Croatia	.909(2)	.106(19)	.486
Pakistan	.909(3)	.122(23)	-.908
...	...	...	...
Armenia	.871(37)	.130(24)	.068
Bolivia	.869(38)	.105(18)	-.989
China	.865(39)	.245(35)	-.824

Table 5: 'True' energy efficiency Vs EI

Conclusions

- There is considerable potential for energy savings and thus reducing the associated CO_2 emissions in developing counties.
- Persistent efficiency is lower than the transient component.
- Strong correlation between TREM and TGTREM
- EI is not generally an accurate proxy of energy efficiency

References

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