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The Energy-Income Relationship in Asian-Pacific Countries

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Abstract: During the last decades energy consumption has increased relatively much in Asian countries as some of these countries have been fast growing economies. Measuring energy intensity as the relationship between primary energy consumption and GDP at purchasing power parities reveals that there does not seem to be significant differences between less developed Asian countries and the industrialized countries in the region. Alternatively, a comparison of per capita energy consumption shows big differences between the Asian countries. When testing for convergence in energy consumption - measured either in relation to GDP or as per capita consumption - the traditional tests (β-convergence and σ-convergence) reveal some positive evidence whereas a more 'restrictive' time series test of convergence (*stochastic convergence*) exhibits evidence in favour of predominantly country-specific trajectories concerning energy intensities.

Keywords: Energy intensity; Convergence; Asian Countries

Introduction

Energy consumption has been rapidly growing in many developing countries during the last decades due to factors like population growth and increased industrialization. By contrast many OECD countries have experienced stagnating energy consumption levels and in some cases, e.g. the per capita oil consumption, there have even been declining trends in the consumption levels. In many developing countries there does not seem to be a similar declining trend in oil consumption - the oil intensity (the oil/GDP-ratio) seems in this case to be much more stable over time. Energy resources might be used in a less efficient manner compared with the industrialized countries and the development process (in countries with low GDP levels) probably requires some expansion in energy consumption. The question of especially oil demand in developing countries has been extensively analysed in a number of studies, Dahl (1993), Choe & Moosa (1997), Moosa (1998), and on the subject of energy consumption in Asian countries some recent empirical studies are Nag and Parikh (2000), Asafu-Adjaye (2000), and Dahl and Kurtubi (2001).
Using time series data covering the period 1971-1999 for primary energy consumption in thirteen Asian-Pacific countries the following analysis examines the question of convergence in energy intensities. The countries appearing in the analysis are: Australia, Bangla Desh, China, Hong Kong, India, Indonesia, Japan, Malaysia, New Zealand, Pakistan, Philippines, South Korea and Thailand. When measuring primary energy consumption relative to purchasing power parity GDP-levels there does not seem to be significant differences between the developing countries and the OECD countries of the region and therefore the latter are also included in the analysis. Hence, as the OECD countries of the region are also part of the sample - and the remaining countries also differ relatively much with respect to for example level of income - the analysis primarily addresses questions related to energy intensity convergence in the Asia-Pacific region. The applied methodologies are the tests for *β-convergence* and *σ-convergence* - often used in the economic growth literature - and also a more recent time series test for so-called stochastic convergence is included in the analysis.

The following Part 2 of the paper deals with the data set and gives a short graphical description of the development in energy intensities in the respective thirteen countries. The next part presents the concept of *β-convergence* and *σ-convergence* followed by the empirical testings. In Part 4 the statistical properties of the data are investigated - most of the variables turn out to be non-stationary - and in this context the methodologies from the recent time series literature concerning convergence and non-stationarity are discussed and the *stochastic convergence* test applied to the data. Finally, Part 5 concludes.

The development in energy intensities: All data used in the analysis are from the World Energy Database (2000 Edition) produced by ENERDATA (France). From the data source the following variables are used (with notation as appearing in the following parts):

EIR: Energy-Income Ratio, calculated from: Primary energy consumption (conventional and non-conventional), measured in tonnes of oil equivalents (toe), divided by GDP, measured in constant '95 US $, purchasing power parity converted (PPP).

EPR: Energy-Population Ratio, calculated from: Primary energy consumption (conventional and non-conventional), measured in tonnes of oil equivalents (toe), divided by the total population.
The EIR is the most often used measure of energy intensity, but has also been criticized as the concept involves some sensitivity with respect to e.g. changing economic structure, fuel substitution, measurement problems related to GDP, etc. A series of papers in Opec Review deals with the problems related to the measurement of energy intensity and also presents a comprehensible empirical data set, Paga and Gürer (1996), Gürer and Ban (1997, 1998).
The data set consists of annual data covering the time period 1971-1999 for the beforementioned thirteen Asia-Pacific countries. The sample is divided into the following two groups used in the subsequent analyses:

Group I: Australia, Hong Kong, Japan, New Zealand and South Korea.

Group II: Bangla Desh, China, India, Indonesia, Malaysia, Pakistan, Philippines and Thailand.

The per capita GDP (in US $, PPP-converted) is used for the split of the data into these two groups. South Korea is included in group I as the per capita income level in this country (especially in the last part of the sample period) is closer to the average of these countries than to the average income levels of group II.
The long-run development in the energy intensities is depicted in Fig. 1 and 2.

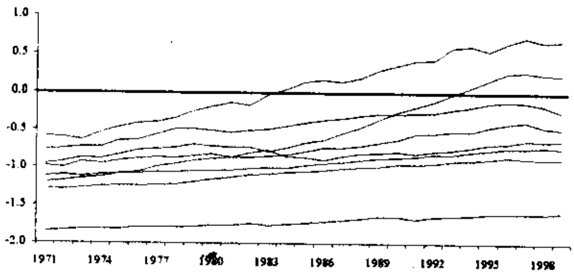

Fig. 1: The energy intensity (EIR) in Group I countries, log values, 1971-1999
Note: Primary energy measured in ktoe (1000 tonnes of oil equivalents), and GDP measured in constant US $ (1000 '95 US $, PPP-converted); the intensity is exhibited in natural log values. The included countries are: Australia, Hong Kong, Japan, New Zealand and South Korea.
Source: Calculated with data from the World Energy Database (2000 Edition, ENERDATA, France).

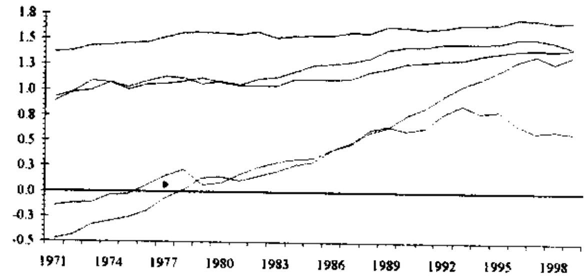

Fig. 3: The energy-population ratio (EPR) in Group I countries, log values, 1971-1999
Note: Primary energy measured in ktoe (1000 tonnes of oil equivalents), and population measured in 1000 persons; the ratio is exhibited in natural log values. The included countries are: Australia, Hong Kong, Japan, New Zealand and South Korea.
Source: Calculated with data from the World Energy Database (2000 Edition, ENERDATA, France).

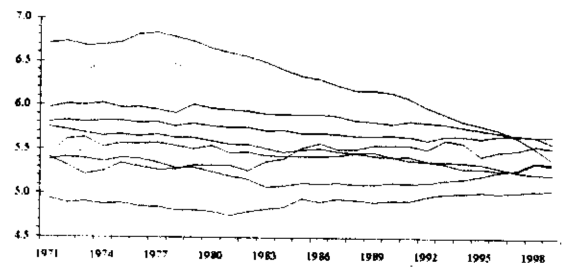

Fig. 2: The energy intensity (EIR) in Group II countries, log values, 1971-1999
Note: Primary energy measured in ktoe (1000 tonnes of oil equivalents), and GDP measured in constant US $ (1000 '95 US $, PPP-converted); the intensity is exhibited in natural log values. The included countries are: Bangla Desh, China, India, Indonesia, Malaysia, Pakistan, Philippines and Thailand.
Source: Calculated with data from the World Energy Database (2000 Edition, ENERDATA, France).

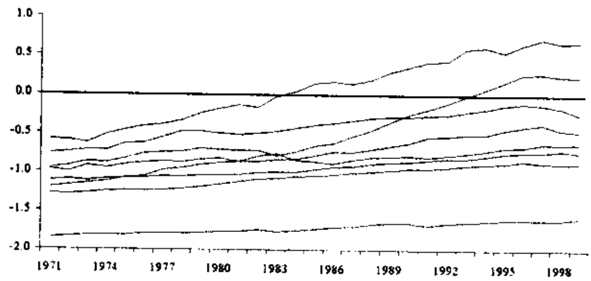

Fig. 4: The energy-population ratio (EPR) in Group II countries, log values, 1971-1999.
Note: Primary energy measured in ktoe (1000 tonnes of oil equivalents), and population measured in 1000 persons; the ratio is exhibited in natural log values. The included countries are: Bangla Desh, China, India, Indonesia, Malaysia, Pakistan, Philippines and Thailand.
Source: Calculated with data from the World Energy Database (2000 Edition, ENERDATA, France).

As mentioned earlier the data - and especially the GDP data - are sensitive to the quality of the statistical sources, i.e. the national statistical bureaus, and therefore the data and the conclusions from the following analyses should be treated with some care. Historical national account data for developing countries must be relatively inaccurate as demonstrated in the recent issue of World Energy Outlook (OECD/IEA 2000). Using the available data as exhibited in Fig. 1 and 2 reveals that there does not seem to be significant differences in energy intensities of developing countries and industrialized countries. This is also in accordance with the PPP-corrected intensities repeatedly reported in the Opec Review, see e.g. Gürer and Ban (1997). From the graphs some convergence towards a common level of energy intensity in the late 1990s seems to take place - and that convergence is most dominant concerning the less developed countries (Fig. 2).

Correspondingly, Fig. 3 and 4 present the data for the energy-population 'intensity' (EPR) and contrary to the energy-income intensities the EPR-variables all show up with increasing trends over the whole-sample period.

For the energy-population ratios there does not seem to be much empirical evidence in favour of a convergence hypothesis. Additionally, the Figs. reveal that it is important to distinguish between energy consumption measured relative to income and population, respectively, as these two often used measures of energy intensity behave very differently over time.

Testing the β-convergence hypothesis: The energy intensities presented in Part 2 can be analysed using standard methodologies regarding convergence which were originally developed for studying the convergence of real per capita GDP for a cross-section of economies. In relation to growth issues two main concepts of convergence, called *absolute β-convergence* and *σ-convergence*, have been applied - which have also gained popularity in other research areas such as e.g. price convergence, Camarero *et al.* (2000).

Consumption converges in the β-sense if countries with low energy consumption levels face higher growth rates in consumption than high-use countries. Denoting the energy intensity (log values) in country i at time t by y_{it} the measure of convergence is derived from the following regression, with t-n indicating the first period in the sample:

$$y_{i,t} = \alpha + (1-\beta) y_{i,t-n} + \varepsilon_{i,t} \qquad (1)$$

The estimate of β reveals the rate of convergence where a value close to 1 indicates (absolute) convergence and the opposite conclusion of 'no convergence' implies a parameter estimate which does not deviate significantly from zero.
A group of countries is said to exhibit σ-convergence if the standard deviation of the variable $y_{i,t}$, e.g. representing energy intensities, is decreasing over time. If σ_t denotes the standard deviation of $y_{i,t}$ across the countries at time t we have that

$$\sigma_t \langle \sigma_{t-n} \qquad (2)$$

From Table 1 it can be concluded that some β-convergence is taking place for the combinations EIR-Group II countries and EPR-Group I countries as the respective β-parameters are 0.65-0.81 and significantly deviating from zero. These results are also in accordance with the σ-convergence hypothesis with the σ_t -estimates declining over time, as expected.

Table 1: Test values for (β, σ) - convergence

		$\hat{\beta}$	$\hat{\delta}_{t-n}$	$\hat{\delta}_t$
Variable: EIR				
All countries	0,626	-0,178	0,468	0,327
Group I	-0,307	-0,555	0,298	0,483
Group II	0,812	-0,134	0,523	0,199
Variable: EPR				
All countries	0,023	-0,143	0,974	1,057
Group I	0,655	-0,228	0,784	0,411
Group II	-0,37	-0,331	0,379	0,69

Notes: The numbers in parenthesis are standard errors of the β-estimates. Log values of EIR and EPR used in the calculations.

Testing for convergence by using (β,σ)-methodology can be criticized because only initial and final values of the variables are used and therefore the resultant parameter estimates may be sensitive to the specific values of these observations. A *necessary* condition for the existence of σ-convergence is the existence of β-convergence, but β-convergence does not constitute a *sufficient* condition for σ-convergence. If initial low level countries face the far strongest growth rates in energy intensities they may override initial high level countries at the end of the period with the consequence that the dispersion between countries may be unchanged (or may even have increased). This is one of several drawbacks of these measures of convergence, and they have recently been critically commented in a number of studies, Bernard and Durlauf (1991, 1995, 1996), Greasley and Oxley (1997), Harris and Trainor (1999). Therefore, a pure time series test methodology seems appropriate to give full evidence on the convergence hypothesis.

Time series test of stochastic convergence: Before the convergence testing framework is extended, the time series properties of the variables EIR and EPR from Part 2 are analysed, i.e. it is tested whether they are non-stationary in levels, i.e. so-called I(1)-variables, as many economic variables, including energy consumption data, are often found to be non-stationary, see e.g. Engsted & Bentzen (1997) for a further description. A variable which can be described by I(1)-behaviour will have no well-defined mean and covariance independent of time and shocks will have permanent effects on future levels of the variable. The unit root tests are performed with a time trend for all variables as some of the series may contain a linear trend. This will give strength to the alternative hypothesis of trend-stationarity, i.e. the variable evolves as a stationary process along a linear trend. The results of the Dickey-Fuller test for unit roots are shown in Table 2.
From all test results in Table 2 it is concluded that none of the variables seems to be stationary as the null hypothesis of non-stationarity cannot be rejected - except the EIR-variable for Bangla Desh. In the latter case the DF-test value exceeds the 5 per cent critical value and hence the 'non-stationarity' hypothesis is rejected in favour of (trend-)stationarity.

Table 2: Unit root tests

	Log (EIP)	Log (EPR)
Australia	-2.18(0)	-2.69(0)
Bangla Desh	-5.94*(0)	-3.11(0)
China	-2.79(2)	-1.62(1)
Hong Kong	-3.00(1)	-1.26(1)
India	-2.24(0)	-2.14(0)
Indonesia	-2.36(1)	-1.99(1)
Japan	-0.32(0)	-2.01(1)
Malaysia	-3.00(0)	-3.56(1)
New Zealand	-1.34(1)	-1.11(1)
Pakistan	-1.65(0)	-0.67(1)
Philippines	-2.43(0)	-2.10(0)
South Korea	-1.78(1)	-1.97(1)
Thailand	-0.06(0)	-1.85(1)

Notes: The number in parenthesis indicates the number of lags included in the Augmented Dickey-Fuller test. Log values of the variables is used and * indicates significant at the 5 per cent level of significance; critical value -3.55 according to MacKinnon (1991).

In order to take into consideration the findings from Table 2, i.e. the non-stationarity of the EIR and EPR variables, an alternative test methodology concerning convergence is added to the analysis. Perron (1989, 1997) demonstrates how to allow for structural breaks when testing for unit roots and more specifically, the methodology for the so-called 'innovational outlier' model includes the possibility of a one-time change in both the intercept term and the slope of the deterministic trend. The time of the break is determined endogenously and following Perron (1997) the test involves estimating a regression as given by equation (3):

$$\Delta\left(Y_{i,t} - \bar{Y}_t\right) = \mu + \Theta DU_t + \beta t + \gamma DT_t + \delta D(T_b)_t + \alpha\left(Y_{i,t-1} - \bar{Y}_{t-1}\right) + \text{lags of } \Delta\left(Y_{i,t} - \bar{Y}_t\right) + \varepsilon_t \qquad (3)$$

T_b: break date
DU_t = 1 if $t>T_b$, otherwise 0 (intercept dummy)
DT_t = $t-T_b$ if $t>T_b$, otherwise 0 (slope dummy)
$D(T_b)_t$ = 1 if $t=T_b+1$, otherwise 0
In this case the difference between the energy intensity of country *i* (Y_i) and the average energy intensity of a group of countries ($\bar{Y}$) is tested for a unit root against an alternative of trend-stationarity. A set of regressions for the trend break (T_b) taking on all values of the time span (except the end points, of course) is done in order to minimize the *t*-statistic on α. When the estimate of α is significantly different from zero the unit root null hypothesis is rejected in favour of a trend stationary alternative. The testing procedure is slightly changed as the test is performed relative to the average value of the energy intensities of a group of countries, see e.g. Li and Papell (1999) for a similar test of income convergence.
This type of convergence test - usually designated as *stochastic convergence* - only requires the log of energy intensities to be trend stationary which is a much weaker form of convergence testing than the testing procedures found in e.g. Bernard and Durlauf (1995, 1996). In the latter a cointegration testing methodology is applied and making distinctions between convergence and catching-up processes.
The data source, cf Part 2, also reports data - concerning calculation of the EIR and EPR variables - for an average of Asian developing countries and for an average representing Asian-Pacific OECD-countries. Hence, the average energy intensity as measured by the EIR-variable for these two categories are used in the testing methodology from equation (3). As the energy-population relation did not seem to exhibit convincing signs of convergence in Part 3 this variable is deleted from the present analysis of stochastic convergence. Table 3 reports the test statistics. The first part of the table refers to the test values where the national energy intensities are tested for convergence relative to the developing countries average (Asia); in the second part the test is performed against the OECD average (Asia-Pacific).
Applying the Perron test for endogenously determined structural breaks the unit root null hypothesis can be rejected in favour of a trend stationary alternative

(stochastic convergence) in only seven of the twenty-six cases from Table 3 when testing relative to overall average values of energy intensities - and using either a 5% or a 10% level of significance. The Perron test is also applied to all combinations or pairs of countries - as an alternative to testing against an average energy intensity variable - but this does not fundamentally influence the results already presented and therefore these test values are not exhibited. In relatively few of the cases the null of a unit root was rejected in favour of a stochastic convergence alternative at the 5% level of significance. Therefore, the conclusion from this part of the analysis seems to be that the development in energy intensities is driven by country-specific factors and that no evidence in favour of convergence in an absolute sense is present - although the national levels of energy intensities (EIR) are more similar today than two-three decades ago.

Table 3: Test statistics for stochastic convergence hypothesis of the energy-income intensity

Average intensity (Y)	Developing Countries (Asia)			OECD countries (Asia/Pac.)		
	T_b	t_α	k	T_b	t_α	k
Australia	83	-8.13*	5	87	-2,95	0
Bangla Desh	79	-6.23*	0	92	-6.05*	5
China	74	-5.61*	1	91	-5,24	3
Hong Kong	77	-5.34**	1	90	-3,84	0
India	75	-6.22*	3	85	-3,22	0
Indonesia	96	-3,33	0	83	-3,46	0
Japan	83	-2,49	0	81	-3,79	0
Malaysia	83	-4,39	0	83	-4,89	0
New Zealand	77	-3,95	3	87	-3,84	0
Pakistan	89	-2,16	0	79	-4,8	0
Philippines	79	-4,06	3	83	-3,3	4
South Korea	89	-5.74*	4	77	-4,5	5
Thailand	81	-0,99	0	81	-3	0

Notes: The critical value is -5.59 at a 5% level of significance (indicated by an * in the table), and -5.29 at the 10% significance level (**), according to Perron (1997). The number of lags included in (3) is indicated by the k-value.

Conclusions

Time series data covering the period 1971-1999 for energy intensities in thirteen Asian-Pacific countries have been used in order to address the question of convergence in energy consumption patterns. When measuring the energy intensity as an energy-income relationship - with income converted to purchasing power parities - there seems to be some signs of convergence for this group of countries. Applying the β-convergence and σ-convergence tests reveal that especially for the developing countries the convergence process is most obvious.

Additionally, time series data for the energy-population ratio are also added to the analysis. Contrary to the energy-income ratio this variable shows up with increasing time trends for most of the countries and there are no signs of convergence as the levels of the per capita energy consumption increasingly diverges.

Finally, the notion of *stochastic convergence* is tested applying a unit root test allowing for structural breaks in the data set, following Perron (1997). The energy-income intensities in levels are tested relative to the averages of both Asian developing countries and Asian-Pacific OECD countries. Hence, stochastic convergence is present when the difference between energy intensities of two countries - or between one country and a group average - is trend-stationary as a unit root behaviour (non-stationarity) is excluded. Therefore, energy intensities may converge in an absolute sense in the long run.

The conclusion from this part of the analysis does not confirm a general hypothesis of stochastic convergence as the empirical evidence only favours this hypothesis in a few cases. Therefore, the development in energy consumption and energy intensities is mostly driven by country-specific factors in this selected sample of Asian-Pacific countries - although there are signs of convergence for the energy-income intensities as found in the β-convergence analysis.

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