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The world per capita electricity consumption distribution: Signs of convergence?

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ABSTRACT

Considering residential per capita electricity consumption as one of the most suitable economic welfare indicators, the aim of this paper is to explore worldwide differences on this variable over the period 1980–2007. The paper adds to the standard practice of σ and β convergence analysis by tracking the external shape and time evolution of the entire distribution, applying nonparametric techniques (density functions and stochastic kernels) to a sample of 98 countries. The main finding is that a weak process of electricity consumption convergence has taken place. This reduction of disparities is clearly related to at least three issues: firstly, the rapid economic changes experienced by some developing countries; secondly, the energy conservation policies implemented by most developed countries following the first oil shock; and, thirdly, the growing awareness on energy issues in rich countries. Notwithstanding this, the ergodic distribution on per capita electricity consumption indicates that large cross-country disparities will persist in the long-run.

1. Introduction

Do poor economies and rich economies tend to converge over time, or do they diverge? This question has drawn the attention of policy-makers and academics alike for about two decades. According to the *Oxford English Dictionary*, convergence is a tendency to become similar or identical. Although this definition is somewhat illuminating, it is convenient to note that when economists speak of convergence they tend to refer to either nominal or real convergence. Generally speaking, it is this second meaning—the approximation in the levels of economic welfare or standard of living across economies—the one considered in the studies on spatial/territorial convergence.

The variables that best represent economic welfare or development are a matter of heated discussion, although by and large per capita income (or per capita GDP) seems to be the more suitable. In some cases, however, other indicators may better reflect the level of development. Among these, per capita electricity consumption is considered to be one of the most relevant alternatives (Joyeux and Ripple, 2007).[1] Both theoretical nresearch[2] and most empirical studies (following the pioneering work of Kraft and Kraft, 1978) have demonstrated a causal relationship between per capita electricity consumption and per capita GDP. The *direction* of this relationship, however, may differ from country to country, on the methodology employed and even on the time span being considered. The literature distinguishes four categories: no causality at all, causality from electricity consumption to GDP growth, causality from GDP growth to electricity consumption, and bi-directional causality between the two. The empirical results on this issue are varied and sometimes conflicting, as shown in Table 1. For instance, Yoo (2006) and Wolde-Rufael (2006), using similar methodologies, find mixed results for Asian and African countries, respectively. Chen et al. (2007), applying traditional methods and more effective techniques in panel-based tests also, conclude in mixed results for a sample of 10 Asian countries. Finally, using a somewhat novel methodology, a recent paper by Chontanawat et al. (2008) studying over 100 countries concludes that the causal relationship more often goes from energy to GDP. Contrary to conventional thinking, however, they find that this type of causality is more prevalent in developed countries. This issue is very relevant as each category has clear but different implications "for government in the design and implementation of its electricity policy" (Chen et al., 2007, p. 2611).

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[1] As Joyeux and Ripple (2007) put it, "given that electricity consumption at the residential level is perceived to provide valuable insights into the standards of living of a country's residents, any index that aims to measure standard of living but does not capture this information should be questioned" (p. 50).

[2] From a theoretical perspective, energy is considered a key input (along with labour and various types of capital) for economic growth.

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Table 1
A summary of empirical studies on the relationship between electricity consumption and economic growth

Authors	Countries	Time period	Methodology	Relationship category
Aqeel and Butt (2001)	Pakistan	1955–1996	Hsiao's version of Granger causality test	(2)
Chen et al. (2007)	10 Asian countries	1971–2001	Panel causality test	Mixed
Chontanawat et al. (2008)	100 countries	1960–2000	Stationarity and cointegration tests, Hsiao and error-correction model	Mixed
Ghosh (2002)	India	1950–1997	Standard Granger causality test	(3)
Jumbe (2004)	Malawi	1970–1999	Standard Granger causality, cointegration and error-correction model	(2)
Morimoto and Hope (2004)	Sri Lanka	1960–1998	Standard Granger causality test	(2)
Shiu and Lam (2004)	China	1971–2000	Error-correction model	(2)
Wolde-Rufael (2004)	Shanghai	1952–1999	Modified Granger causality test	(2)
Wolde-Rufael (2006)	17 African countries	1971–2001	Modified Granger causality and cointegration test	Mixed
Yang (2000)	Taiwan	1954–1997	Standard Granger causality test	(2)
Yoo (2005)	Korea	1970–2002	Error-correction model	(2)
Yoo (2006)	4 Asian countries	1971–2002	Standard and Hsiao's version of Granger causality and cointegration tests	Mixed

Notes: (1): no causality at all; (2): causality from electricity consumption to GDP growth; (3): causality from GDP growth to electricity consumption; (4): bi-directional causality between the two.

Therefore, given the important role played by per capita electricity consumption as a relevant economic welfare indicator, we choose to address the issue of convergence by studying its evolution in a sample of 98 countries[3]; to the best of our knowledge, no previous paper has dealt with this topic. Regarding the data employed in this analysis, and in order to ensure consistency among countries, the paper uses data provided by Euromonitor International, drawn from its Global Market Information Database (GMID).[4]

The remainder of this paper is organised as follows. A classical analysis of convergence, by applying the concepts of σ and β convergence, is provided in Section 2. This approach (Sala-i-Martin, 1996) only pays attention to the first moments of the distribution, however, and thus presents some drawbacks. For this reason, in Section 3 we investigate spatial disparities more deeply by considering the entire distribution. Following the recommendations of Quah (1996a, b), the external shape of the distribution and the intra-distributional movements of individual countries are examined using a conventional kernel approach. In addition, in this paper we not only apply this approach but, following Hyndman et al. (1996), a novel one (box plots based on highest-density regions), which provides better insights into the dynamics of the electricity consumption distribution. Finally, Section 4 summarises the main results and makes some policy suggestions.

2. Electricity consumption: a classical convergence analysis

Convergence is an interesting but rather imprecise concept, with many interpretations. The most generally accepted measures of real convergence, however, are σ and β convergence (see the seminal papers of Barro and Sala-i-Martin, 1991, 1992). The former holds when the dispersion in economic indicators diminishes; the second when poor economies grow more quickly than rich ones.

As a starting point, we calculate both measures for the per capita electricity consumption distribution in our sample. First, σ convergence is computed by plotting the coefficient of variation (CV) in each year (Fig. 1). As can be seen, Fig. 1 shows—normalising the CV of 1980 to 100—that disparities have declined over the sample period. Two sub-periods can clearly be distinguished: from 1980 to 1986 disparities increased, while afterwards a steady and significant reduction took place. In order to test for the robustness of these results, we have also computed other inequality indicators such as the well-known Atkinson (A(1)), Gini (G) and Theil (T(1)) indexes. The results, also reported in Fig. 1, clearly confirm the existence of a convergence process for the whole period and to a rather similar evolution of national inequalities. However, two minor differences between these inequality indicators and the CV are apparent: firstly, the divergence found for the period 1980–1986 according to the CV is not confirmed for these other inequality measures; secondly, the reduction of disparities is more intense according to the Theil and Atkinson indexes than to the CV.

With respect to the second type of convergence—less restrictive than the first—we estimate a traditional absolute β convergence equation but including country-specific effects in order to reduce the presence of omitted variables.[5] This equation can be written as follows:

$$\Delta \ln Ec_{i,t} = \alpha + \delta_i + \beta \ln Ec_{i,t-1} + \varepsilon_{i,t}, \quad (1)$$

where $\Delta \ln Ec_{i,t}$ is the interannual per capita electricity consumption growth of country i in year t, $\ln Ec_{i,t-1}$ is the per capita electricity consumption in the previous year, δ_i is the fixed effect of country i and ε is the error term. As can be seen, Eq. (1) is estimated by using panel data[6]; the estimation has been carried out by generalised least squares.

It is well known that in order for the hypothesis of convergence to be satisfied, there must be an inverse relation between the growth rate of per capita electricity consumption and its initial level. That is, β must be both negative and significant at standard confidence levels. The results obtained (Table 2) demonstrate significant β convergence over the sample period (1980–2007). Moreover, the value of the β coefficient enables us to state that the convergence took place at an annual rate[7] of 2.73%. Consequently, the time required to cover half the gap separating the countries

[3] For a list of the countries considered in the study, see the Appendix A. Regarding this sample, countries such as Norway and Kuwait have been excluded because of their huge per capita electricity consumption (higher than 1000% of the world average). In total, the sample represents 98.1% of the world electricity consumption in 1980 and 91.3% in 2007. As regards to the sample period, we analyse 1980–2007 simply because it is the wider period for which data for such a large sample of countries are available.

[4] See URL: http://www.portal.euromonitor.com.

[5] We have included a constant term as well as the country-specific effects so that these fixed effects estimates sum to zero. Therefore, these effects must be interpreted as deviations from an overall mean.

[6] The study of convergence based on the estimation of cross-sectional regressions (considering only the initial and final years of the study period) ignores the information for the remaining years, thus not providing any insight about the evolution of the entire cross-sectional distribution. Most importantly, as various authors have argued in the context of the economic growth literature (e.g. Durlauf and Quah, 1999; Temple, 1999), cross-sectional regressions are uninformative, since they concentrate exclusively on the behaviour of a representative economy.

[7] The speed of convergence, b, calculated as $b = -\ln(1+T\beta)/T$, is the rate at which per capita electricity consumption approaches its steady state relative to its initial distance from it.

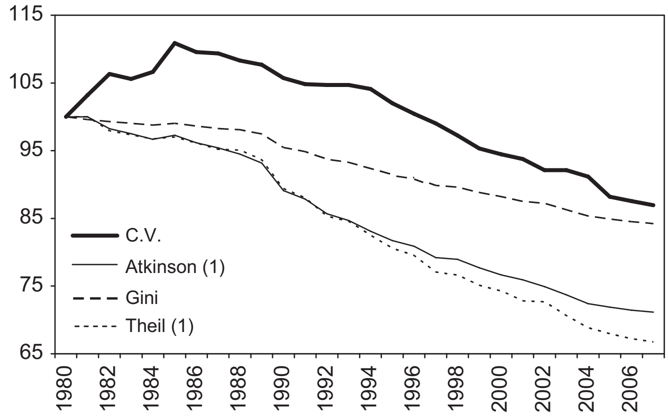

Fig. 1. σ convergence.

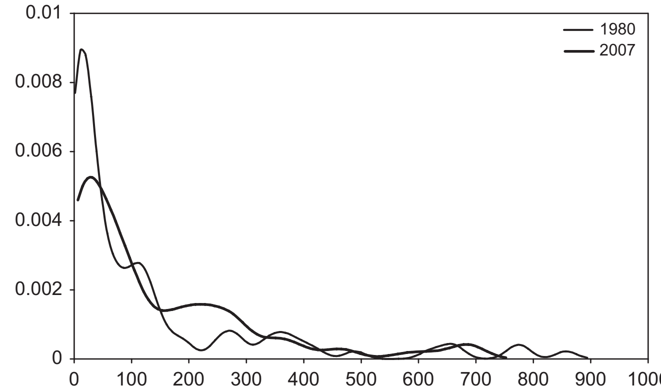

Fig. 2. The initial and final density functions (average = 100).

Table 2
β convergence

Dependent variable: $\Delta \ln Ec_{i,t}$		
	Value	Student's t
Constant	−0.022	−5.44
β	−0.049	−15.95
Adjusted R^2	0.25	
Speed of convergence	2.73	
Half-life	13.7	

from a stationary state (half-life) is 13.7 years.[8] Regarding the country-specific effects,[9] it is worth mentioning that most of them are statistically significant. Specifically, these effects are positive and relatively high in countries such as United Arab Emirates, Canada, United States, Finland and Sweden, while the opposite occurs in African countries such as Cameroon, Congo, Ethiopia, Kenya, Mozambique, Tanzania and Togo.

3. Electricity consumption: distribution dynamics

Although informative, the previous analysis on per capita electricity consumption differences has two important limitations (Quah 1996a, b): it ignores the fact that some countries may shift their relative positions during the study period, and it provides no information on the shape of the distribution. For example, it does not detect multiple modes (Rey and Janikas, 2005). In this section, we complement the previous analysis by considering changes that have taken place in the distribution over time.

To begin with, we scale all national values such that the average per capita electricity consumption is 100. Next, we characterise the external shape of the distribution by estimating univariate density functions with a Gaussian kernel and using the method for bandwidth selection proposed by Sheather and Jones (1991).[10] This analysis is reported only for the initial and final years.[11] The resulting fits, displayed in Fig. 2, allow us to reach the following conclusions:

(1) The shape of the distribution was not stable over the sample period. The probability of finding values at the lower end of the distribution (less that 50% of the average per capita electricity consumption) has significantly decreased, while the probability of finding values in the 150–300 range has greatly increased. The most plausible explanation behind this evolution is that both very poor countries and middle-income countries have experienced rates of growth above the average and, then, their relative per capita electricity consumption has increased.
(2) Accordingly, the fact of convergence seems to be confirmed. The final distribution is slightly more concentrated around the mean, and also shows a reduction in the ratio of extreme values.

We now turn to intra-distribution dynamics. The stochastic kernel approach (see, for example, the papers by Fingleton and López-Bazo, 2003; López-Bazo, 2003; Ezcurra, 2007) can inform us about the probability of a country moving between any two per capita electricity consumption levels in 1980 and 2007.[12] The results obtained are shown in Fig. 3, where the x-axis represents per capita electricity consumption in 1980 and the y-axis refers to the year 2007. The z-axis measures the conditional probability (density) of each point in the x–y plane. The 2D figure on the right is the contour plot, which is obtained by taking a cut parallel to the x–y plane for a particular density value. Interpreting the results may be easier if we look at the 2D graph. The fact that most contour lines are oriented along the positive diagonal indicates that the level of mobility is low (persistence); it is very rare for a country to change drastically over the sample period. Nonetheless, the breadth of the contours shows that there has been some mobility. Finally, countries in the middle of the distribution are more likely to change than those at the extremes (the conditional probability is lowest about halfway along the positive diagonal). Overall, Fig. 3 seems to indicate that the ranking of countries is quite stable over the sample period.

While it has produced some relevant insights, the traditional stochastic kernel approach also has some drawbacks. First of all, it uses a fixed smoothing parameter (or bandwidth) in the x (1980)

[8] The half-life (h) is the number of years required to eliminate one half of the initial deviation of per capita electricity consumption from its steady-state value. It can easily be calculated using the expression $h = -\ln(2)/\ln(1+\beta)$.

[9] These are not included in Table 2 for reasons of simplicity; however they are available upon request.

[10] Specifically, we have chosen as estimate of scale the minimum between, on the one hand, the standard deviation and, on the other, the inter-quartile range divided by 1.349; besides, we have used two levels of functional estimation in the plug-in rule (Park and Marron, 1992). A good description of this bandwidth selection approach can be seen in Section 3.6 of Wand and Jones (1995).

[11] We computed these density functions for every year. To save space not all graphs are presented, but they are available upon request.

[12] Gaussian kernel and fixed bandwidth are again used in the estimation process. The distributions have also been normalised according to the sample average.

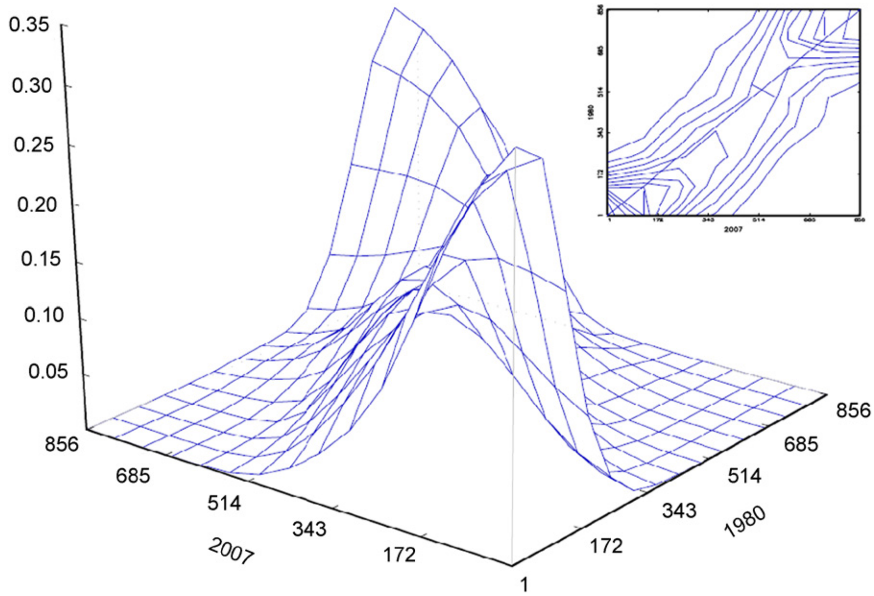

Fig. 3. Intra-distribution dynamics by the traditional stochastic kernel method (average = 100).

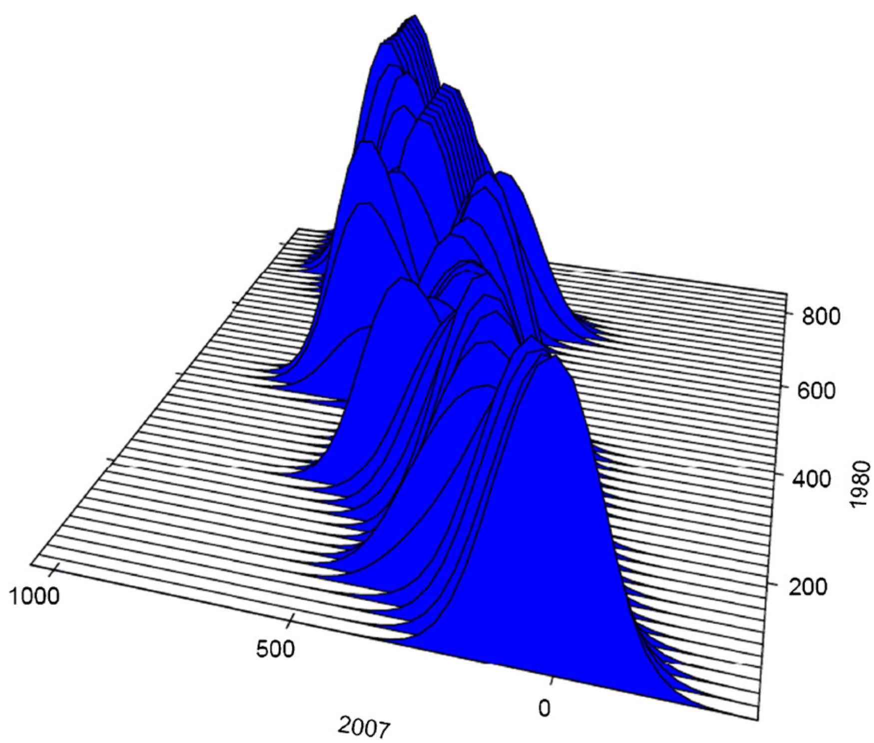

Fig. 4. Intra-distribution dynamics by stacked conditional density plot (average = 100).

and *y* (2007) directions. Second, it treats the conditional probability as a bivariate density function. To solve these problems, we employ a novel stochastic kernel approach that provides more clear-cut results. Specifically, we follow Hyndman et al. (1996) by displaying the *stacked conditional density* and *highest conditional density region* plots. We refer the reader to Hyndman for technical details. The first advantage of this method is that it allows for different bandwidths in the *x* and *y* directions. That is, it includes two parameters "which control the smoothness between conditional densities in the *x* direction and the smoothness of each conditional density in the *y* direction" (Arbia et al., 2006, p. 6). In our case the optimum bandwidths in the *x* and *y* directions have been computed according to rules laid out by Bashtannyk and Hyndman (2001). The second advantage of this approach is that it has better statistical properties than standard stochastic kernel estimators.

The *stacked conditional density* plot is shown in Fig. 4. This figure displays one conditional probability density for each value of the per capita electricity consumption in 1980. According to these results, it seems that the countries under study, especially those with not very high initial levels, have essentially maintained their relative per capita electricity consumption, although some signs of mobility appear in the middle and upper end of the distribution.

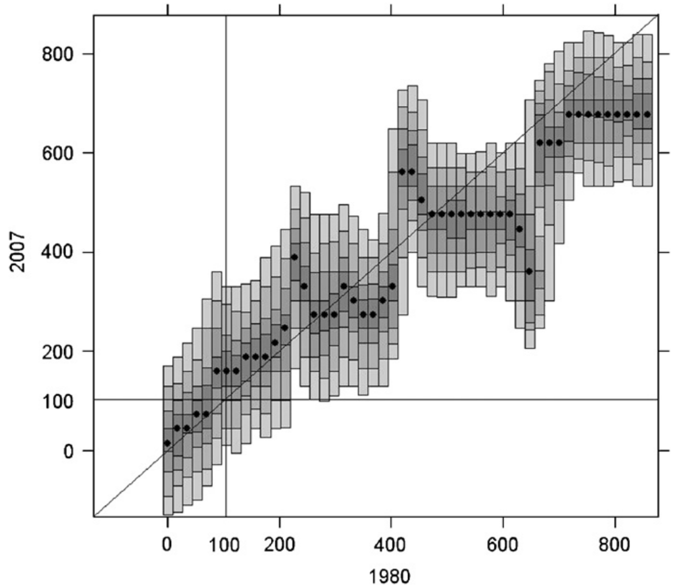

Fig. 5. Intra-distribution dynamics by highest conditional density region plot (average = 100). From dark to light, the shadings represent 25%, 50%, 75% and 90% of the total probability. Bullets indicate the mode.

Fig. 4 provides a bit more detail than Fig. 3, but not much in the way of new insights. A more informative way to represent (and detect) the distribution changes is by looking at the *highest conditional density region* plot (Fig. 5). The highest-density region is defined as "the smallest region of the sample space containing a given probability" (Hyndman et al., 1996, p. 327). Thus, each vertical strip in Fig. 5 represents the highest-density portion of the probability distribution for a given per capita electricity consumption level in 1980. These four shadings in each bar represent total probabilities of 25%, 50%, 75% and 90% (from darker to lighter shades). In addition, a bullet (•) indicates the mode (maximum value) of each conditional probability distribution.

Although Fig. 5 shows that mobility within the distribution is generally small for countries with a per capita electricity consumption level below 400, the modes indicate that those countries with the greatest initial electricity consumption have approached the average. This is obvious, as all the bullets on the right-hand side of the distribution lie below the main diagonal.[13] Conversely, the relative electricity consumption of countries below the average has slightly increased (their modes lie above the diagonal). We can also observe the "mass" of probability, noting that most of the dark areas on the right-hand side (countries with high consumption) do not cross the diagonal. This shows that while these countries enjoy a certain mobility, their direction of motion strongly favours convergence.

To conclude this analysis, we plot the ergodic or long-term equilibrium distribution (Fig. 6). This is computed by iterating the stochastic kernel. Unlike the initial and final distributions (Fig. 2), the ergodic distribution has only one mode. This suggests that in a hypothetical long-term equilibrium, we are unlikely to find poles or clusters among countries. Finally, it is worth mentioning that, according to the significant mass of probability concentrated at the lower and upper ends of the distribution, the convergence process mentioned in this paper will not continue indefinitely. In other words, the per capita electricity consumption across countries seems to have a minimum bound. Additionally, the shape of the ergodic distribution suggests that disparities in per capita electricity consumption will remain very high in the foreseeable future.

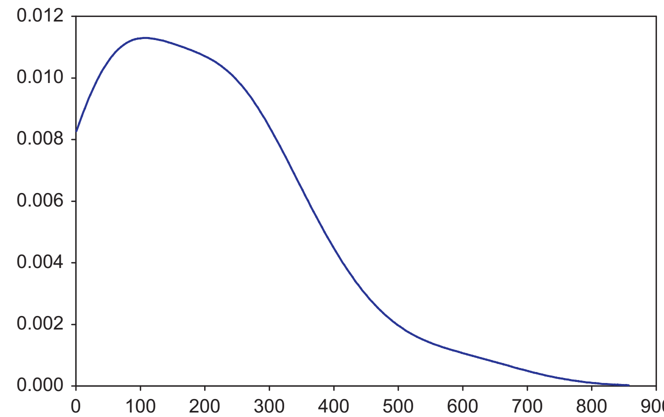

Fig. 6. Ergodic distribution (average = 100).

4. Conclusions

This paper has measured disparities in per capita residential electricity consumption in a sample of 98 countries over the period 1980–2007. In particular, we were interested in finding evidence of convergence in the distribution of this indicator. To this end, we employed both traditional (parametric) indicators of convergence and more recent (nonparametric) developments. Our most relevant conclusions are as follows.

On the one hand, our analysis reveals that a traditional σ and β convergence process on per capita electricity consumption across countries has taken place for the sample period. As long as this variable is considered to be a good indicator of the standard of living, this result is consistent with previous works on per capita income convergence.

This reduction of disparities in the per capita electricity consumption is clearly related to at least three issues. Firstly, the rapid economic changes that were experienced by some developing countries. Secondly, the energy conservation policies implemented by most developed countries following the first oil shock, intended to increase efficiency and reduce the intensity of electricity use[14] (Narayan et al., 2007). And thirdly, the growing awareness on energy issues in rich countries and increasing social pressure to mitigate carbon dioxide emissions. However, both in the developing and, especially, in the developed countries, there is still a large cost-effective saving potential, mainly through the adoption of new demand and supply side policies. As for the demand side, it should be obvious that the most suitable policies that can be mentioned are those devoted to: (a) the consumers having to pay the real price of the electricity services being offered; (b) the subsidising of using energy-efficient technologies by consumers; and (c) the launching of promotion campaigns to change electricity consumption habits, while preserving the same level of comfort. In relation to the supply side, the implementation and penetration of new technologies using more efficiency standards,[15] building codes, and so on could also be crucial for

[13] These countries are the ones that contribute most to the convergence.

[14] By "energy intensity" we refer to the amount of energy required to generate each unit of output.

[15] Although the impact of these technologies replacing old ones tends to be relatively modest at the beginning, it increases a lot over time, thus considerably reducing energy consumption. As it happens at the European Union level, these new technologies could be implemented through "Codes of Conduct", that is, voluntary agreements with manufacturers establishing minimum energy efficiency levels and power management guidelines.

Table A1

Algeria	Ghana	Peru
Angola	Greece	Philippines
Argentina	Guatemala	Poland
Australia	Haiti	Portugal
Austria	Honduras	Romania
Bangladesh	Hong Kong, China	Senegal
Belgium	Hungary	Singapore
Bolivia	Iceland	Slovakia
Brazil	India	South Africa
Brunei	Indonesia	South Korea
Bulgaria	Iran	Spain
Cameroon	Ireland	Sri Lanka
Canada	Israel	Sudan
Chile	Italy	Sweden
China	Jamaica	Switzerland
Colombia	Japan	Syria
Congo	Jordan	Taiwan
Congo-Brazzaville	Kenya	Tanzania
Costa Rica	Libya	Thailand
Côte d'Ivoire	Luxembourg	Togo
Cuba	Mexico	Trinidad and Tobago
Cyprus	Morocco	Tunisia
Czech Republic	Mozambique	Turkey
Denmark	Myanmar	United Arab Emirates
Dominican Republic	Nepal	United Kingdom
Ecuador	Netherlands	Uruguay
Egypt	New Zealand	USA
El Salvador	Nicaragua	Venezuela
Ethiopia	Nigeria	Vietnam
Finland	Oman	Yemen
France	Pakistan	Zambia
Gabon	Panama	Zimbabwe
Germany	Paraguay	

residential electricity saving (Bertoldi and Atanasiu, 2008). In summary, the new electricity-saving policies should consider that such savings hinge both on accurate technological equipment and rational behaviour (Bonneville and Rialhe, 2006).

On the other hand, the shape of the per capita electricity consumption distribution has varied significantly over time. More countries are positioned near the mean in 2007 than in 1980. Our analysis of intra-distributional mobility—based on traditional stochastic kernel estimation and an examination of the highest-density regions of conditional probability distributions—has demonstrated that most countries with above-average 1980 consumption levels moved towards the average by the end of the sample period. Specifically, we note that those countries experiencing the largest changes were initially located at the upper end of the distribution. This result suggests that energy policies have committed the developed countries to more efficient practices, and worldwide that this rule is more strictly enforced by the most developed countries.[16]

Finally, the ergodic distribution leads us to expect that large disparities in per capita electricity consumption will persist even in the long-run. This being so, it should be kept in mind by governments and international agencies when considering the definition, implementation and enforcing of additional energy-saving policies, especially in the most developed countries, where energy efficiency has to be increasingly considered as the ''fifth fuel''.[17]

[16] A good example of electricity reforms intending to bring more effective competition in energy markets is the European Union (Glachant and Lévêque, 2008).

[17] Notwithstanding this, it is necessary to point out that, due to the so-called ''rebound effect'', energy efficiency policies may produce lower results than expected; economists considered that this effect can cancel out between 25% and 40% of the initially expected energy savings.

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Appendix A

List of countries considered in the analysis are shown in Table A1.

References

Aqeel, A., Butt, M.S., 2001. The relationship between energy consumption and economic growth in Pakistan. Asia-Pacific Development Journal 8 (2), 3342–3350.
Arbia, G., Basile, R., Piras, G., 2006. Analyzing intra-distribution dynamics: a reappraisal. ERSA Conference Papers.
Barro, R., Sala-i-Martin, X., 1991. Convergence across states and regions. Brookings Papers on Economic Activity 1, 107–182.
Barro, R., Sala-i-Martin, X., 1992. Convergence. Journal of Political Economy 100 (21), 223–251.
Bashtannyk, D.M., Hyndman, R.J., 2001. Bandwidth selection for kernel conditional density estimation. Computational Statistics and Data Analysis 36, 279–298.
Bertoldi, P., Atanasiu, B., 2008. Characterization of residential lighting consumption in the enlarged European Union and policies to save energy. International Journal of Green Energy 5 (1–2), 15–34.
Bonneville, E., Rialhe, A., 2006. Demand Side Management for Residential and Commercial End Users 〈www.leonardo-energy.org〉.
Chen, S., Kuo, H., Chen, C., 2007. The relationships between GDP and electricity consumption in ten Asian countries. Energy Policy 35 (4), 2611–2621.
Chontanawat, J., Hunt, L., Pierse, R., 2008. Does energy consumption cause economic growth?: evidence from a systematic study of over 100 countries. Journal of Policy Modeling 30, 209–220.
Durlauf, S.N., Quah, D., 1999. The new empirics of economic growth. In: Taylor, J.B., Woodford, M. (Eds.), Handbook of Macroeconomics, vol. 1A. North-Holland, Amsterdam, pp. 231–304.
Ezcurra, R., 2007. Distribution dynamics of energy intensities: a cross-country analysis. Energy Policy 35 (10), 5254–5259.
Fingleton, B., López-Bazo, E., 2003. Explaining the distribution of manufacturing productivity in the EU regions. In: Fingleton, B. (Ed.), European Regional Growth. Springer, Berlin, pp. 375–410.
Ghosh, S., 2002. Electricity consumption and economic growth in India. Energy Policy 30 (2), 125–129.
Glachant, J.M., Lévêque, F. (Eds.), 2008. Electricity Reform in Europe: Towards a Single Energy Market. Edward Elgar Publishing, Cheltenham, UK.
Hyndman, R.J., Bashtannyk, D.M., Grunwald, G.K., 1996. Estimating and visualizing conditional densities. Journal of Computational and Graphical Statistics 5 (4), 315–336.
Joyeux, R., Ripple, R., 2007. Household energy consumption versus income and relative standard of living: a panel approach. Energy Policy 35 (1), 50–60.
Jumbe, C.B.L., 2004. Electricity consumption and GDP empirical evidence from Malawi. Energy Economics 26, 61–68.
Kraft, J., Kraft, A., 1978. On the relationship between energy and GNP. Journal of Energy Development 3, 401–403.
López-Bazo, E., 2003. Growth and convergence across economies: the experience of the European Regions. In: Fingleton, B., Eraydin, A., Paci, R. (Eds.), Regional Economic Growth, SMEs and the Wider Europe. Ashgate, London, pp. 49–72.
Morimoto, K., Hope, C., 2004. Impact of electricity supply on economic growth in Sri Lanka. Energy Economics 30, 1287–1298.
Narayan, P., Smyth, R., Prasad, A., 2007. Electricity consumption in G7 countries: a panel cointegration analysis of residential demand elasticities. Energy Policy 35 (9), 4485–4494.
Park, B.U., Marron, J.S., 1992. On the use of pilot estimators in bandwidth selection. Journal of Nonparametric Statistics 1, 231–240.
Quah, D., 1996a. Regional convergence clusters in Europe. European Economic Review 40 (3–5), 951–958.
Quah, D., 1996b. Twin peaks: growth and convergence in models of distribution dynamics. Economic Journal 106, 1045–1055.
Rey, S., Janikas, M.V., 2005. Regional convergence, inequality, and space. Journal of Economic Geography 5 (2), 155–176.
Sala-i-Martin, X., 1996. The classical approach to convergence analysis. Economic Journal 106, 1019–1036.
Sheather, S.J., Jones, M.C., 1991. A reliable data-based bandwidth selection method for kernel density estimation. Journal of the Royal Statistical Society, Series B 53, 683–690.
Shiu, A., Lam, P.L., 2004. Electricity consumption and economic growth in China. Energy Policy 32 (1), 47–54.
Temple, J., 1999. The new growth evidence. Journal of Economic Literature 37, 112–156.
Wand, M.P., Jones, M.C., 1995. Kernel Smoothing. Chapman & Hall, London.

Wolde-Rufael, Y., 2004. Disaggregated energy consumption and GDP, the experience of Shangai, 1952–1999. Energy Economics 26, 69–75.
Wolde-Rufael, Y., 2006. Electricity consumption and economic growth: a time series experience for 17 African countries. Energy Policy 34 (10), 1106–1114.
Yang, H.Y., 2000. A note of the casual relationship between energy and GDP in Taiwan. Energy Economics 22, 309–317.
Yoo, S., 2005. Electricity consumption and economic growth: evidence from Korea. Energy Policy 33 (12), 1627–1632.
Yoo, S., 2006. The causal relationship between electricity consumption and economic growth in the ASEAN countries. Energy Policy 34 (18), 3573–3582.