Check proposal type: ***Typical Concurrent Paper_X__*** **Extended Presentation Paper___**

STUDY ON THE INEQUALITY OF GLOBAL ENERGY CONSUMPTION BASED ON THE ZENGA (2007) INDEX

Qiaosheng Wu, China University of Geosciences, School of Economics and Management, Wuhan,430074,China,qshwu@cug.edu.cn
Jinwei Wang , China University of Geosciences, School of Economics and Management, Wuhan,430074,China, wjwcfok@126.com
Svetlana Maslyuk, Monash University, School of Business and Economics, Australia, Svetlana.Maslyuk@monash.edu.au

Keywords

Energy consumption, Gini index, Zenga index

Overview

Inequality in energy consumption world-wide, and hence emissions of the Greenhouse gases into the atmosphere, has received very limited analytical attention. The existence of such inequality (which is due to unequal access to modern energy resources, inadequate energy infrastructure, limited use of energy efficient technologies in developing countties, etc) together with other factors, makes it difficult to develop binding international environmental targets. In order to quantify the extent of inequality in energy consumption for a large panel of counties, we use the Gini (1914) index and the Zenga (2007) index as measures of energy consumption inequality. There are very few studies in the energy literature apart from Jacmart et al. (1979), Jaconson et al. (2005), Banerjee and Yakovenko (2010) and Giannini Pereira et al. (2011) that have studies energy consumption inequality. Such studies reveal that provided appropriate adjustments are made, conventional methods of measuring income inequality, such as the Lorenz curve and the Gini index, can be successfully applied to the issues of inequality measurement of CO_2 emissions (Groot, 2010) as well as energy consumption. The major finding of these studies is that energy consumption inquality does exist amoung the countries, but the extent of inquality somewhat diminishes over time. According to Banerjee and Yakovenko (2010), globalization is one of the reasons for decline in inequality, while Wu et al. (2012) propose that improvement in essential infrastrucuture in developing countries, electricification and other measures that improve access to modern energy services could be additional reasons for a decline in inequality. The main contribution of this research is that while the Gini index is used as a reference point, this is the first application in the energy literature of a modern inequality measure, Zenga (2007) index, to the analysis of global per capita energy consumption inequality. The advantage of the Zenga index over the Gini lies in its applicability to data with a heavy-tailed distribution, such as per capita energy consumption. In addition, inequality based on the Zenga index can be further decomposed depending on 'high' and 'low' per capita energy consuming countries. It should also be noted that Zenga index detects, with the same sensibility, all deviations from equality in any part of the distribution. In this study, we use two nonparametric estimators to estimate the Gini and Zenga indeces based on the per capita energy consumption data from 109 countries over the period 1971 to 2009. The source of energy consumption data is International Energy Agency.

Methods

Let $F(x)=P[X\le x]$ denotes the cumulative distribution function （CDF） of the nonnegative random variable X and $F^{-1}(p)=\inf\{x:F(x)\ge p\}$ denotes the corresponding quintile function. The Lorenz function $L_F(p)$ is given by $L_F(p)=\frac{1}{u_F}\int_0^p F^{-1}(s)ds$ where $u_F=E[X]$ is the unknown true mean of X. The classical Gini index G_F can be calculated based the Lorenz curve: $G_F=\int_0^1(1-\frac{L_F(p)}{p})\varphi(p)dp$ where $\varphi(p)=2p$. Note that $\varphi(p)$ is a density function on [0, 1]. Zenga's (2007) index Z_F of inequality is defined by the formula

$$Z_F=\int_0^1\left(1-\frac{L_F(p)}{p}\bullet\frac{1-p}{1-L_F(p)}\right)dp$$

The Gini and Zenga indices G_F and Z_F respectively are weighted averages of the Gini and Zenga curves $G_F(p)$ and $Z_F(p)$. Since for Zenga index calculation, we use the uniform weight function $\varphi(p)=1$ Zenga index is more impartial than Gini: it is based on all complementary disjoint country subgroups and gives the same weight to each comparison. The two nonparametric estimators for Gini and Zenga indeces G_F and Z_F respectively are given by the following formulas $\widehat{G}_n=1-\frac{1}{n}\left(2\sum_{i=1}^{n-1}\frac{\sum_{k=1}^{i}X_{k:n}}{\sum_{i=1}^{n}X_{i:n}}+1\right)$ and $\widehat{Z}_n=1-\frac{1}{n}\sum_{i=1}^{n-1}\frac{i^{-1}\sum_{k=1}^{i}X_{k:n}}{\sum_{i=1}^{n}X_{i:n}}$

where $X_{1:n} \leq \cdots \leq X_{n:n}$ are the order statistics of $X_1, \cdots, X_n$

Results

Figure 1：Zenga index and Gini coefficients of 109 countries

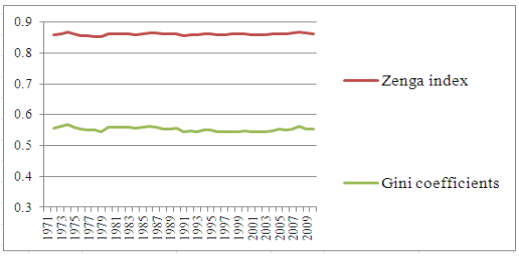

Figure 1 shows the Zenga index and Gini coefficients of 109 countries. The results show that throughout the entire sample period, the Zenga (Gini) index of global per capita energy consumption were greater than 0.80 (0.55).The intuitive interpretation of the Zenga value, for say 2009, of 0.817 is that the mean per capita energy consumption of the lowest 80% of the countries is 81.7% lower than the mean per capita energy consumption of the remaining 'higher' proportion of the countries in the sample. The Mean Gini value of 0.5 indicates that energy consumption inequality was moderate. Note that movements in both Gini and Zenga indices over time are consistent to each other. The fact that the Zenga values were consistently above the Gini values indicates that inequality proxied by the Gini index could have been undervalued.

In line with previous research, our results show that energy consumption inequality does exist between the nations in the sample. Our findings do support decline in inequality in recent years after a long period of slight fluctuations around the mean.

Conclusions

This paper provides some insight on the inequality of energy consumption based on the conventional and recent measures of economic inequality (Gini and Zenga indeces), computed under the assumption that all countries across the globe should have an equal right to use energy for their economic and social development. The recent decline in both the Gini and the Zenga values indicates that per capita energy consumption inequality has been gradually declining around the globe. This means that per capita consumption of energy by the developing nations increases gradually (for example, due to electrification efforts in China, development of alternative energy sources such as sugar cane ethanol in Brazil and Cuba, etc). At the same time, this result reflects the fact that in recent years large energy consuming nations are voluntarily restricting their energy consumption from fossil fuel and increasing from alternative energy sources (for instance due to domestic policy or international treaty participation such as Kyoto protocol), improving energy conservation efforts and improving energy efficiency measures.

References

Banerjee, A., Yakovenko, V. M., 2010. Universal patterns on inequality, New Journal of Physics, 12, 075032.

C. Gini, "Sulla misura della concentrazione e della variabilit`a dei caratteri," in Atti del Reale Istituto Veneto di Scienze, Lettere ed Arti. Anno Accademico, vol. 48, part 2, pp. 1201–1248, Premiate Officine Grafiche Carlo Ferrari, Venezia, Italy, 1914.

Druckman A, Jackson T., 2008. Measuring resource inequalities: the concepts and methodology for an area-based Gini coefficient. Ecological Economics, 65, 242–52.

Duro, J.A., Padilla, E., 2006. International inequalities in per capita CO_2 emissions: a decomposition methodology by Kaya factors. Energy Economics, 28, 170-187.

Groot L., 2010. Carbon Lorenz curves. Resource and Energy Economics, 32, 45-64.

Greselin F, Pasquazzi L, and Zitikis R (2010) Zenga's new index of economic inequality, its estimation, and an analysis of incomes in Italy. Journal of Probability and Statistics, ID 718905:1–26.

Heil, M.T., Wodon ,Q.T., 2000, Future inequality in CO_2 emissions and the impact of abatement proposals. Environmental and Resource Economics, 17, 163-181.

Jacobson, A., Milman, A. D., Kammen, D. M., 2005. Letting the (energy) Gini out of the bottle: Lorenz curves of cumulative electricity consumption and Gini coefficients as metrics of energy distribution and equity. Energy Policy, 33, 1825-1832.

Jacmart,M.C., Arditi, M., Arditi, I., 1979. The world distribution of commercial energy consumption. Energy Policy, 7, 199-207.

Zenga, M, 2007. Inequality curve and inequality index based on the ratios between lower and upper arithmetic means, Statistica & Applicazioni, 5, 3–27.

Padilla, E., Serrano, A., 2006. Inequality in CO_2 emissions across countries and its relationship with income inequality: a distributive approach. Energy Policy, 34, 1762-1772.

Pereira, M. G., Vasconcelos Freitas, M. A., Fidelis da Silva, N., 2011. The challenge of energy poverty: Brazilian case study. Energy Policy, 39, 167-175.

Wu, Q, Maslyuk, S, Clulow, V, 2012. Energy consumption inequality and human development. Energy Efficiency, InTech.