# A Multivariate STIRPAT and Convergence Approach to the Water-Energy-Food Nexus

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**Overview**

This is provides new evidence on the convergence process of energy, water and food per capita consumption levels for 108 countries from 1971 to 2018, using a common data set, with VAR and panel data approach. We establish a new notion of multivariate sigma and beta-convergence. In addition we analyze a multivariate model of STIRPAT or Stochastic Impacts by Regression on Population, Affluence, and. Technology for the Water enrfgy food nexus. The results reveal that there is evidence of sigma- absolute beta- and conditional beta-convergence process for the countries. Moreover, the multivariate approach reveals that there are spillover effects with complex positive impact of each variable on the others in the analyzed countries.

Methods

According to the well-known IPAT identity, an environmental impact (I) is the result of the combined pressure of population (P), affluence (A), and Technology (T). That is:

(1) $$I = P \text{ x } A \text{ x } T$$

While effective, to make (1) operational several problems arise:

- It is not an identity strictly speaking, and there is no reason why the right hand side variables should be multiplicative – there could be interactive effects and there could be additional variables affecting the environmental impact
- It is difficult to find satisfactory or appropriate proxies for environmental impact, for affluence and for technology – per capita GDP is typically used for affluence while environmental impact can be proxied by emissions or concentrations of various air, water, soil pollutants
- As it stands it is not amenable to econometric estimation

The last problem has been solved in the literature by adding exponential parameters to each argument, appending and error term and log-linearizing (1). The resulting model is known as STIRPAT or Stochastic Impacts by Regression on Population, Affluence, and. Technology. Thus:

(2) $$I_t = e^{\alpha} P_t^{\beta} A_t^{\gamma} T_t^{\delta} e^{u_t}$$

So that:

(3) $$lnI_t = \alpha + \beta lnP_t + \gamma lnA_t + \delta lnT_t + e^{u_t}$$

Often (3) is estimated on a cross country basis using panel datasets.

We now adapt this framework to the analysis of the Water-Energy-Food (WEF) nexus. Let $I_t$ be given by the vector $[W_t, E_t, F_t]$. Then the STIRPAT version of the WEF nexus is:

(4) $$\begin{bmatrix} lnW_t \\ lnE_t \\ lnF_t \end{bmatrix} = \begin{bmatrix} c_W \\ c_E \\ c_F \end{bmatrix} + \begin{bmatrix} a_{WP} & a_{WA} & a_{WT} \\ a_{EP} & a_{EA} & a_{ET} \\ a_{FP} & a_{FA} & a_{FT} \end{bmatrix} \begin{bmatrix} lnP_t \\ lnA_t \\ lnT_t \end{bmatrix} + \begin{bmatrix} u_W \\ u_E \\ u_F \end{bmatrix}$$

The estimation of (4) requires a SUR method, as the system is simultaneous with the same explanatory variables in each equation.

The estimation enables us to quantify the population, affluence and technology elasticities for water consumption, energy consumption, and food consumption.

**Results**

We have taken data from the World Bank Indicators and the data tc360 World Bank. The data for water energy and food are as follows.

Food data is the daily caloric supply as computed by FAO, United Nations Food and Agriculture Organization. The unit of measurement is kcal/person/day. The period is 1961 – 2018. The source for 1961 2013 is:http://www.fao.org/faostat/en/#search/Food%20supply%20kcal%2Fcapita%2Fday The source for 2014 2018 is:

http://www.fao.org/faostat/en/#search/Food%20supply%20kcal%2Fcapita%2Fday

Water data is the renewable internal freshwater resources per capita. The unit of measurement is cubic meters/per capita/year. The period is 1962-2017 and the data are available at quinquennium frequency. Annual data are obtained by interpolation. The year 2018 data is obtained with preliminary estimation. The source is: World Bank indicators, Food and Agriculture Organization, AQUASTAT Main Database. Website accessed on [19/02/2020 9:11]: https://data.worldbank.org/indicator/ER.H2O.INTR.PC

Energy data is the energy use per capita. The unit of measurement is kg of oil equivalent per capita. The data are annual and the period is 1971-2018. The source for 1971 2013 is: IEA Statistics https://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE The source for 2014 2018 is: https://databank.worldbank.org/home.aspx and www.iea.org

The population is from World Development Indicators (WDI), Millions. The GDP per capita is from from World Development Indicators (WDI), Constant 2015 USD. The Technology index (Xindex) is a composite index originally developed, taking a composite average of 9 indicators: percentage of alternative sources; percentage of chemical exports; number of fixed telephone lines per 100 habitants; number of cell phones per 100 habitants; number of scientific journals and articles per capita; percentage of ICT service exports; percentage of R&D expenditure of GDP; percentage of enrollment in tertiary education.

We have estimated eq (4). We have introduced a legged dependent variable, so the system is a SVAR with lag=1 and we have introduced N-1 country dummies. We obtain interesting preliminary results, noting that the sum of the coefficients is >1 for all three impact factors.

**Conclusions**

The results reveal that there is evidence of a significant STIRPAT explanation of the water energy foed nexus and we find sigma- absolute beta- and conditional beta-convergence process for the countries. Moreover, the multivariate approach reveals that there are spillover effects with complex positive impact of each variable on the others in the analyzed countries. The speed of convergence is simulated to assess when the desired levels according to the prescription of the SDG of per water, energy and food capita consumption is reached by each country. Results have important policy implications for interventions on macro variables. Investment has a positive accelerating effect on water convergence. In addition, investment, openness to foreign trade and inflow of foreign direct investment have a positive accelerating effect on food convergence as well as on energy convergence.

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