

Towards a comprehensive framework of the relationships between resource footprints, quality of life and economic development

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Supplementary Information 1

Utilization of residuals to form development clusters

In this supplementary analysis, the residuals from the following regression analyses are used to form development clusters. For all data, see data sheet 3 in [1].

$$\ln (\text{MF})_{i,t} = \text{Intercept} + \text{beta HDI}_{i,t} + u_{i,t} \quad (1)$$

$$\text{HDI}_{i,t} = \text{Intercept} + \text{beta } \ln (\text{MF}_{i,t}) + u_{i,t} \quad (2)$$

$$\ln (\text{CF})_{i,t} = \text{Intercept} + \text{beta HDI}_{i,t} + u_{i,t} \quad (3)$$

$$\text{HDI}_{i,t} = \text{Intercept} + \text{beta } \ln (\text{CF}_{i,t}) + u_{i,t} \quad (4)$$

That means, the regression is carried out for MF and CF, each in both directions (with switched dependent and independent variable), to calculate the residuals of both variables for all countries for all years under review. Table S 1.1 shows the 2015 residuals for a selection of countries, also indicating the trend since 1990. The first column shows the residuals of equation 1, the second column of equation 2, the third column of equation 3 and the fourth column of equation 4. If the residuals of 1 and 3 are positive, the MF/CF is higher than predicted by the model, if they are negative, the footprints are lower (less resource use per capita). If the residuals of 2 and 4 are positive, the HDI is higher than predicted, if they are negative, they are lower. The residuals of 1 and 3 are usually diametrical to those of 2 and 4 – data are to the upper left or the lower right of the curve; exceptions exist at the tails of the curve (compare the USA or Australia).

The data show that most of the countries diverge to higher development, again indicating that the overall regression curve has shifted upwards over time. The tendency that the residuals of the models tested are declining over time does not automatically imply that resource intensity has declined as well, as the residuals are measured from the overall regression line, in which the upward shift over time is not considered. Nevertheless, the residuals can be used for an analysis of the position that a country has in the model, and therefore for setting up clusters.

	ZRE lnMF exby HDI	ZRE HDI exby lnMF	ZRE lnCF exby HDI	ZRE HDI exby lnCF	HDI	Cluster
Germany	-0.63 (--)	1.43 (+)	-0.84 (--)	1.70 (+)	0.93 (+)	A1
Japan	-0.39 (-)	1.13 (+)	-0.47 (--)	1.30 (+)	0.90 (+)	A1
Czech Rep.	-0.06 (-)	0.80 (+)	-0.77 (-)	1.46 (+)	0.88 (++)	B1 to A1
USA	-0.04 (-)	0.90 (+)	0.15 (-)	0.90 (+)	0.92 (0)	A3 to A2
Australia	0.68 (~)	0.36 (~)	-0.06 (-)	1.14 (+)	0.94 (+)	A3 to A2
Barbados	-1.06 (--)	1.38 (++)	-0.30 (-)	0.80 (+)	0.80 (+)	C1 to B1
Cuba	-1.17 (--)	1.40 (++)	-1.18 (--)	1.40 (++)	0.78 (++)	C1 to B1
Gabon	-1.13 (-)	1.11 (+)	-0.98 (--)	0.94 (++)	0.70 (++)	C1 to B1
Côte d'Ivoire	-2.20 (--)	1.27 (++)	-1.33 (--)	0.10 (++)	0.47 (++)	D to C1
Luxembourg	1.48 (0)	-0.43 (~)	1.23 (-)	-0.01 (+)	0.90 (+)	A3
Kuwait	1.70 (-)	-0.94 (+)	1.69 (-)	-0.73 (+)	0.80 (+)	B2 to A3
Kazakhstan	0.66 (~)	-0.10 (+)	0.39 (-)	0.23 (+)	0.79 (+)	C1 to B2
China	0.28 (-)	-0.77 (0)	-0.22 (0)	0.52 (+)	0.74 (+)	C2 to B2
Botswana	2.22 (-)	-1.69 (+)	1.56 (~)	-1.00 (+)	0.70 (+)	C2 to B2
Guinea	0.48 (-)	-1.16 (+)	0.17 (-)	-1.02 (+)	0.41 (+)	D to C2
Niger	1.34 (-)	-2.08 (-)	0.28 (-)	-1.33 (+)	0.35 (+)	D to C2

Table S 1.1: ZRE = standardized residuals, from overall regression analysis; all numerical data in this table from 2015; signs in brackets: trend of this variable since 1990: ++ strong increase; + increase, 0 stable/stagnating, - decrease, ~ unstable); see in detail Supplementary Information 2, Sheet 3.

The countries marked with a red background have a higher footprint than predicted, but a lower HDI.¹ These can be found to the lower right of the regression curve, and are usually resource-based countries, countries with a resource-intensive industrialization path, and unsustainable development. For countries with a green or blue background, the footprints are lower and the HDI is higher than predicted, therefore they can be found at the upper left of the regression line.² These countries have very different characteristics, but apparently a more sustainable development path, which should be an encouraging signal for further research. Interestingly, many countries in this group are islands and/or (former) socialist states. The countries marked in yellow have particularly high HDIs, but very different footprints; Luxembourg (as well as

¹ Further examples for this group are: Congo DR, Rwanda, CAR, Burundi, Zambia, Angola, Lesotho, Swaziland, Mali, Bolivia, Paraguay, Uruguay, Papua New Guinea, Kuwait, UAE, Saudi-Arabia, Oman

² Further examples for this group are: Madagascar, Laos, Myanmar, Haiti, Zimbabwe, Ghana, Sri Lanka, Tajikistan, Georgia, Azerbaijan, Croatia, Dominican Republic, Philippines

other very small states) can be found below the curve, the United States and Australia have recently crossed the curve from below to above, Germany, Japan and many other European countries can be found above the regression line.

Based on this analysis, the development state can be used as the second criterion for a cluster model; as the limits between low, medium and high development are rather arbitrary and shift over time, the author refrains from using specific numbers and explains the clusters in an abstract framework, which has been shown in Section 3.3., Figure 3, in the main text.

References

1. Cibulka, S.; Giljum, S. Data set: Resource footprints, quality of life and economic development. Zenodo. Version 1 **2020**, doi:10.5281/ZENODO.3713211.