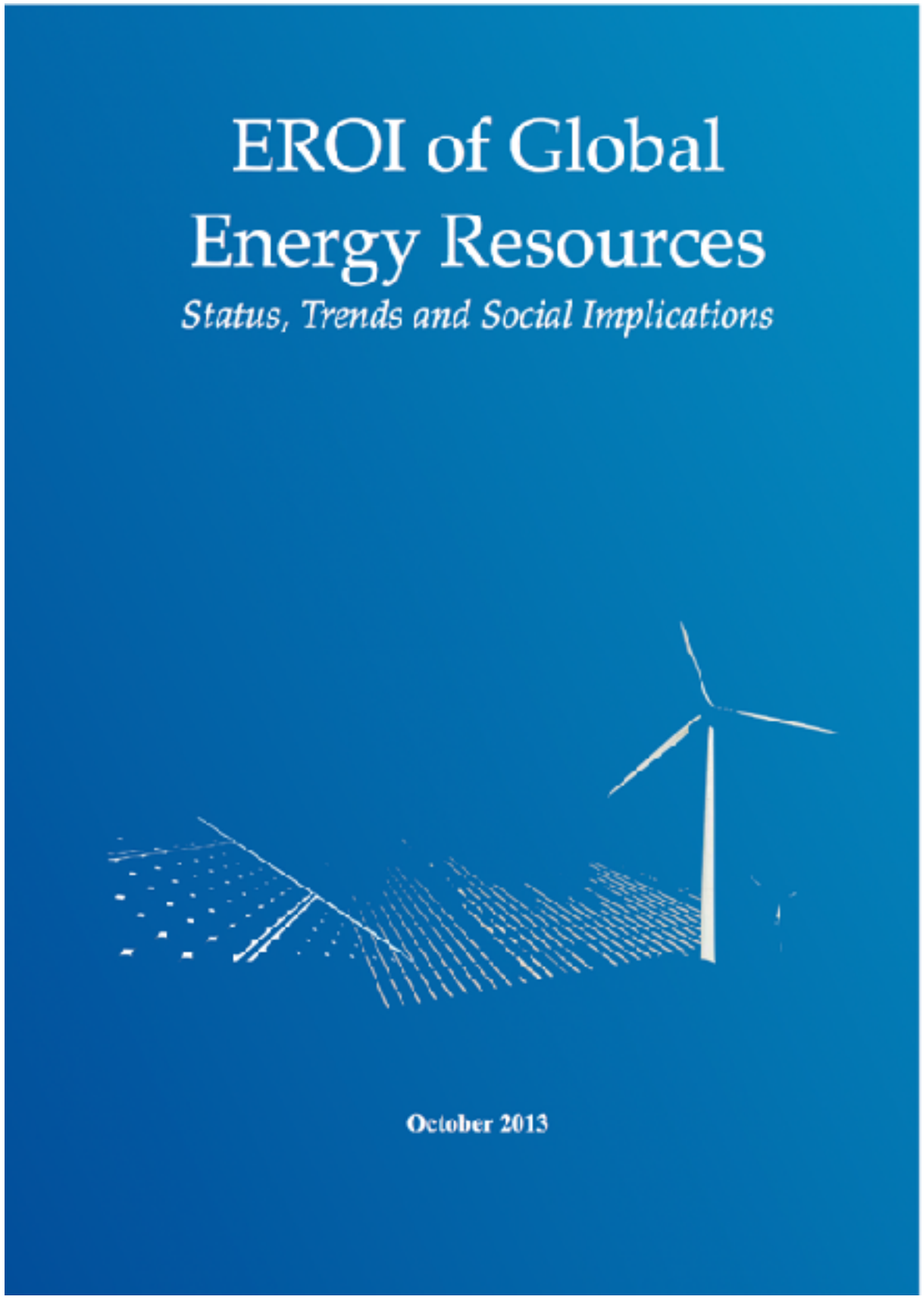
Examining The Relation between Quality of Life and Biophysical vs Economic Conditions

Jessica G. Lambert
June 15, 2018
ISBPE 2018 Conference, Aurora, NY
JLambert@NGEI-USA.org

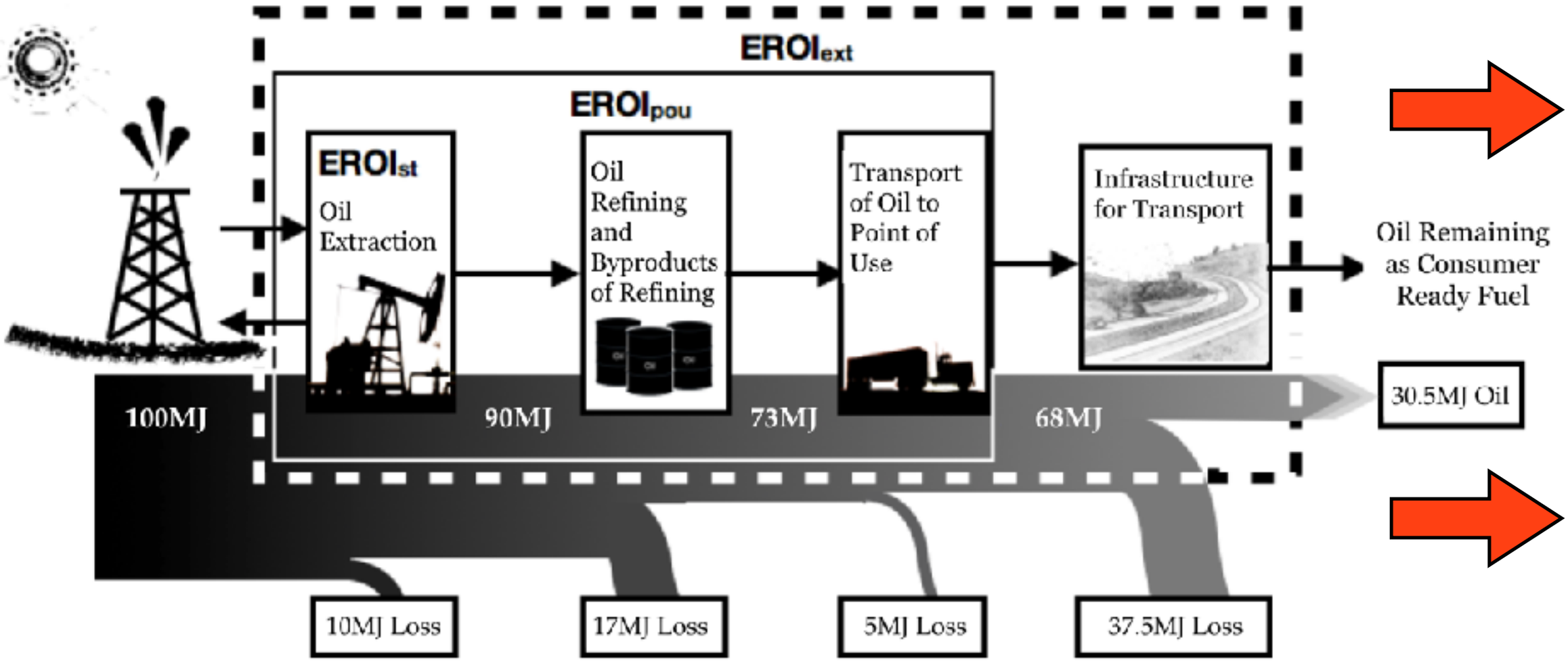
DFID 59717

- review current/historical EROI for fossil fuels and their alternatives
- examine relationship between energy indices and human well-being
- provide insight in formulating development strategies in an uncertain energy future



EROI

EROIsoc



Hall et al. 1986

8

IMPORTED PETROLEUM

The United States relies on two sources for the petroleum that provides about 70% of its energy supplies: domestic resources and imports. Domestic consumption of petroleum has increased more rapidly than production in recent decades, and this difference has been made up by increasing imports. Since 1948, the first year in which the United States was a net importer of oil, the percentage of total oil consumption obtained from foreign sources increased to nearly 50 percent in 1977 (Figure 8.1). Since then it has dropped as the demand for oil has diminished.

As described in Chapter 7, annual domestic production of both oil and gas generally has diminished since the early 1970s, and very large additions to domestic reserves are unlikely. Furthermore, if trends of the past 30 years continue, the energy discovered by exploratory drilling will approach the energy used to find and extract the petroleum found within the next several decades, so that even if domestic petroleum continues to be found, it may not serve as a net fuel for the nation. Consequently, it appears unlikely that domestic production of oil and gas can be increased to replace imported petroleum, especially if demand for oil again increases.

A number of politicians and economists have advised the federal government to reduce dependence on imports by intensifying efforts to find new domestic petroleum supplies and by developing domestic alternatives, including nuclear power, coal-derived synfuels, oil shale, alcohol fuels, and solar-powered satellites (see Chapters 10–13). Yet, despite the large economic and political costs of relying on foreign oil, federal programs aimed at reducing that dependence, and a decreased demand for petroleum since 1979, imported oil still accounted for about 35% of the liquid petroleum consumed by the United States in 1983.

In addition to limitations imposed by its origins in politically "unstable" regions and its high dollar and energy cost, imported petroleum is a finite nonrenewable resource. Its supply can be analyzed using the same distributional traits used by Hubbert and other petroleum analysts to estimate the size of domestic petroleum resources and the rate at which they are discovered and produced. Since the rigorous and dangerous conditions involved in transporting natural gas severely limit the quantity the United States can import we restrict our analysis to oil alone. Most of the information in the following section was taken from Nehring (1982), and the interested reader should consult that paper for further details.

WORLD OIL SUPPLIES

The most important feature relating to estimating the size of world oil deposits is their concentration in a few, relatively small geographical areas called provinces. As described in Chapter 7, oil forms only under special geological conditions, so oil fields are found only in provinces that contain particular sedimentary formations. Approximately 600 such provinces exist, of which about 420 have been explored. Two hundred and forty of these 420 regions contain oil, and most of the remaining 180 also indicate such possibilities.

But the large number of provinces with oil fields does not automatically indicate significant quantities of oil contained there. Such a conclusion probably is false because most of the world's oil is found in a few provinces with extremely large reserves. Of the 420 provinces that contain oil, only seven contain more than 25 billion bbl, which is about one year's world oil consumption at its peak in 1980 (Table 8.1). Together, these seven provinces contain over two-thirds of known world oil supplies. The largest of these provinces, the Arabian–Iranian, contains nearly half of world oil supplies. Summing the known oil deposits in the 18 major provinces listed in Table 8.1 indicates the special-

189

that fuel. For imported oil or gas Kaufmann and Hall (1981) used the following equation:

$$\text{EROI} = \frac{CE_i}{EE_e}$$

$$= \frac{(\text{kcal imported fuel/\$ imported fuel})}{(\text{kcal embodied in exports/\$ exports})} \quad (8.1)$$

$$= \frac{\text{kcal imported}}{\text{kcal exported}}$$

in which CE_i is the chemical energy in an average dollar's worth of imported fuel and EE_e is the embodied energy in an average dollar's worth of export, assuming that the mix of commodities exchanged for fuel, or for the foreign exchange used to

e.g. USA = EROIsoc 32.06

$$EROI_{SOC} = \frac{\frac{\eta_1 E_{U1} + n_2 E_{U2} + \eta_n E_{Un}}{\eta_1 E_{P1} + \eta_2 E_{P2} + \eta_n E_{Pn}}}{Energy\ intensity\ of\ the\ economy}$$

Variables	Meaning	Unit
E_T	Total Energy Consumed by Society	MJ
GDP	Gross Domestic Product	USD
E_U	Energy per Unit of Fuel	MJ
E_P	Price per Unit of Fuel	USD
	Ratio of net Energy Contribution	n.a.

USA:
Et = 90643 PetaJoules
GDP = 13898.3 Billion USD

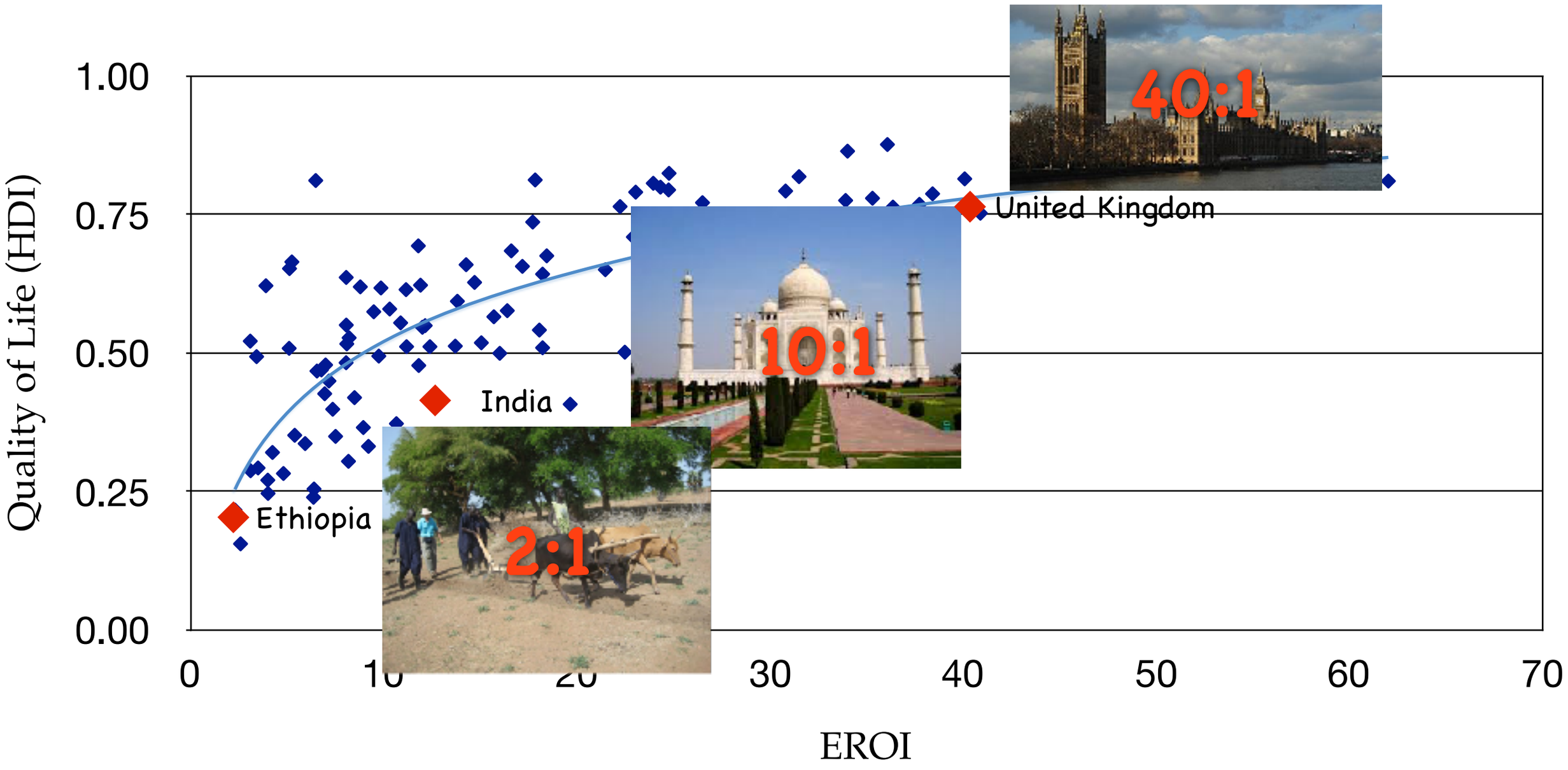
Coal - 21%
Et = 904,896 Thousand mTons
Ep = $46.99 per mTons
Eu = 22,930 MJ per mTons

Oil - 38%
Et = 18,771 Thousand BBL per day
Ep = $59.04 per BBL
Eu = 5,455 MJ per BBL

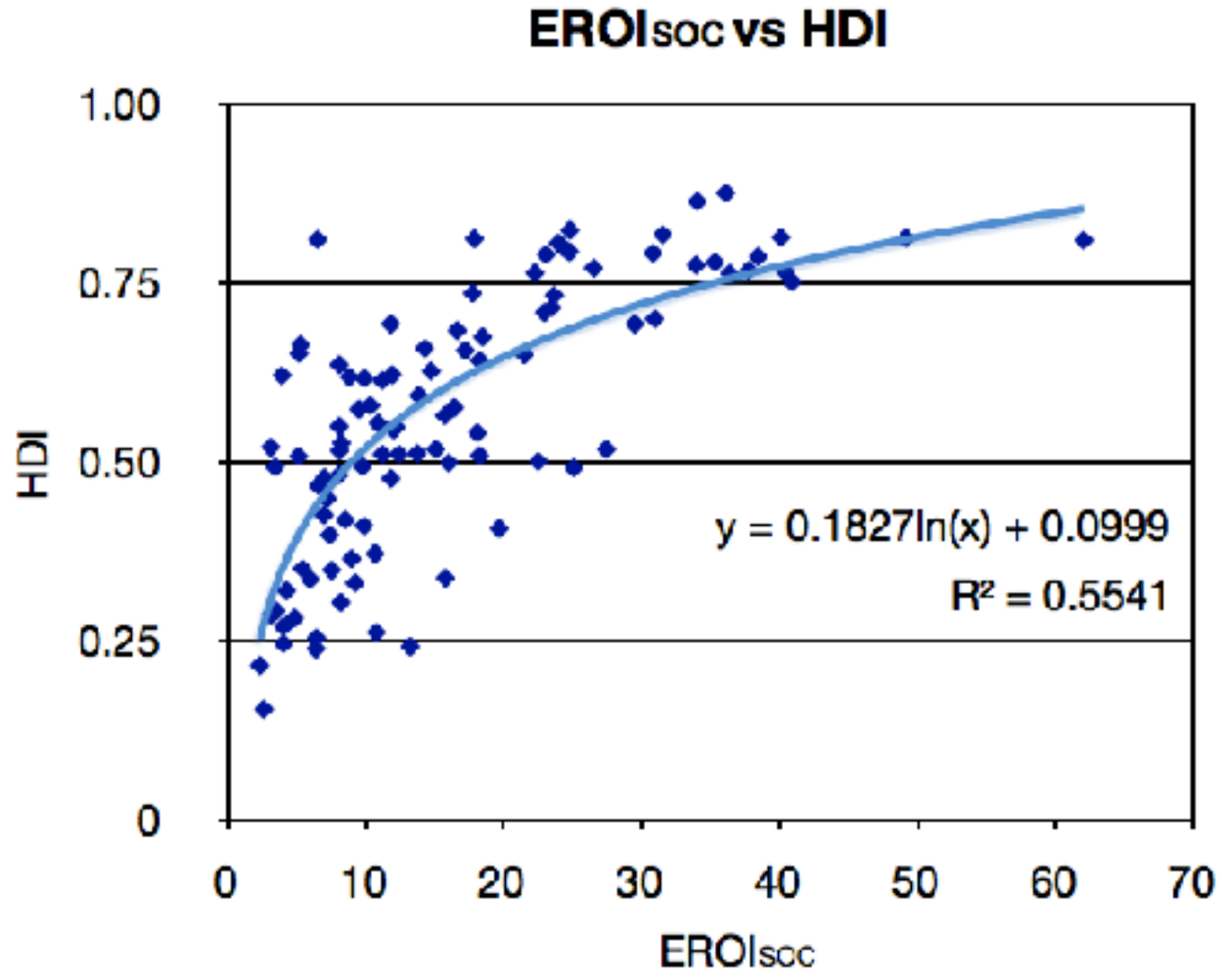
N.Gas - 25%
Et = 22,910 Billion Cubic Feet
Ep = $4.19 per Thousand Cubic Feet
Eu = 1079 MJ per Thousand Cubic Feet

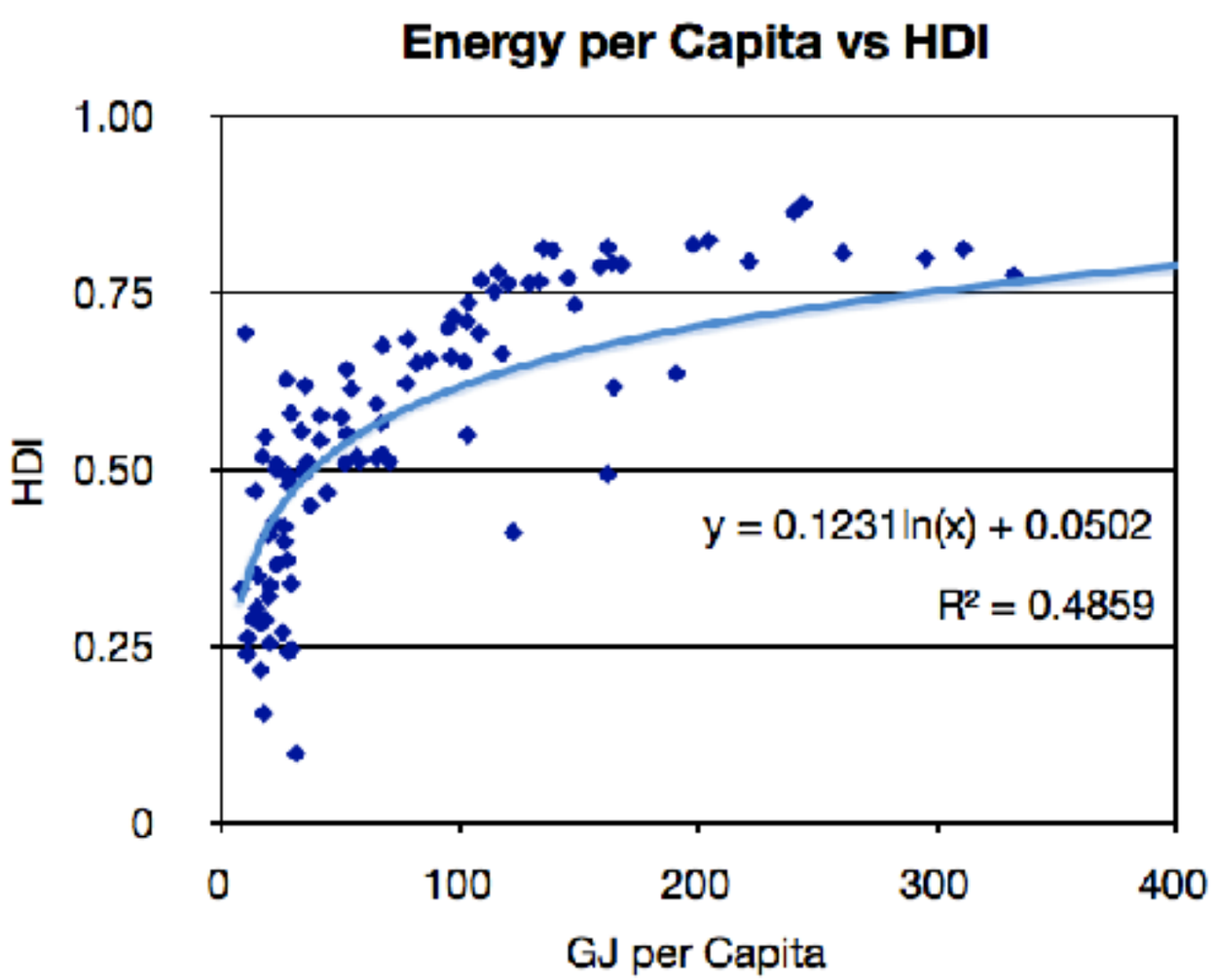
Alternate and Nuclear - 12%
Et = 1.07E+17
Ep = $0.10 per kWh
Eu = 3.6 MJ per kWh

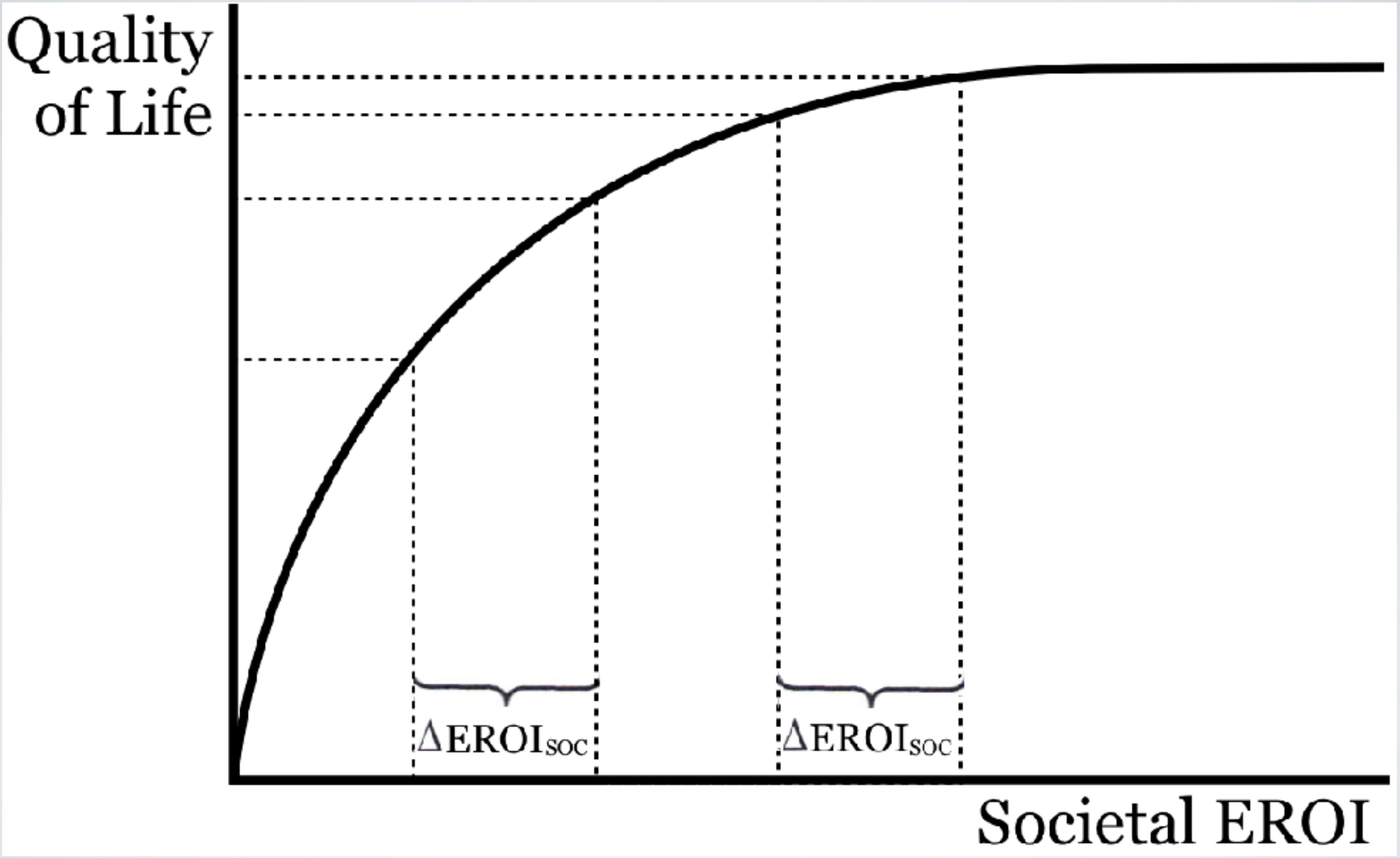
EROIsoc vs. HDI



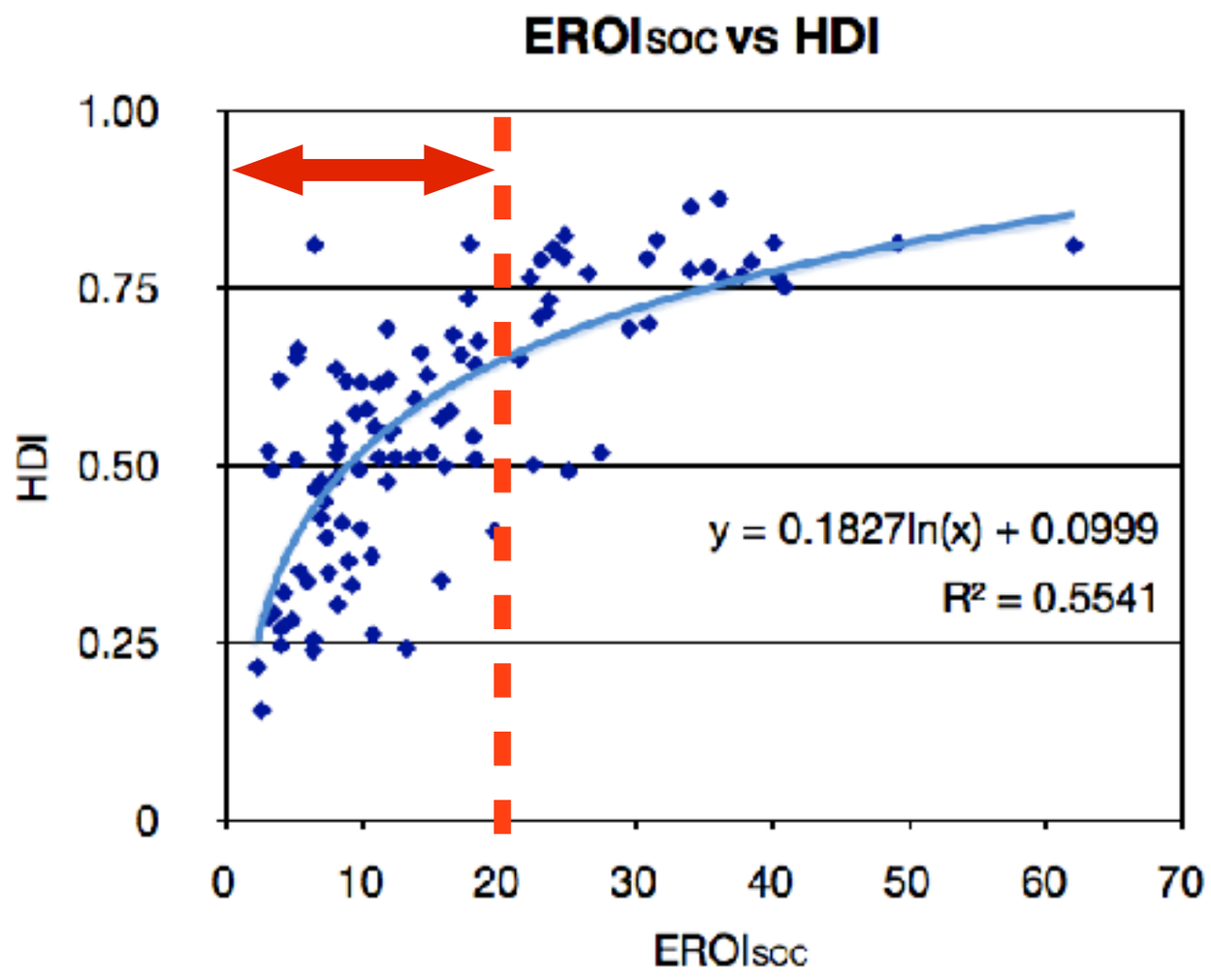
Multiple unrelated energy variables ...

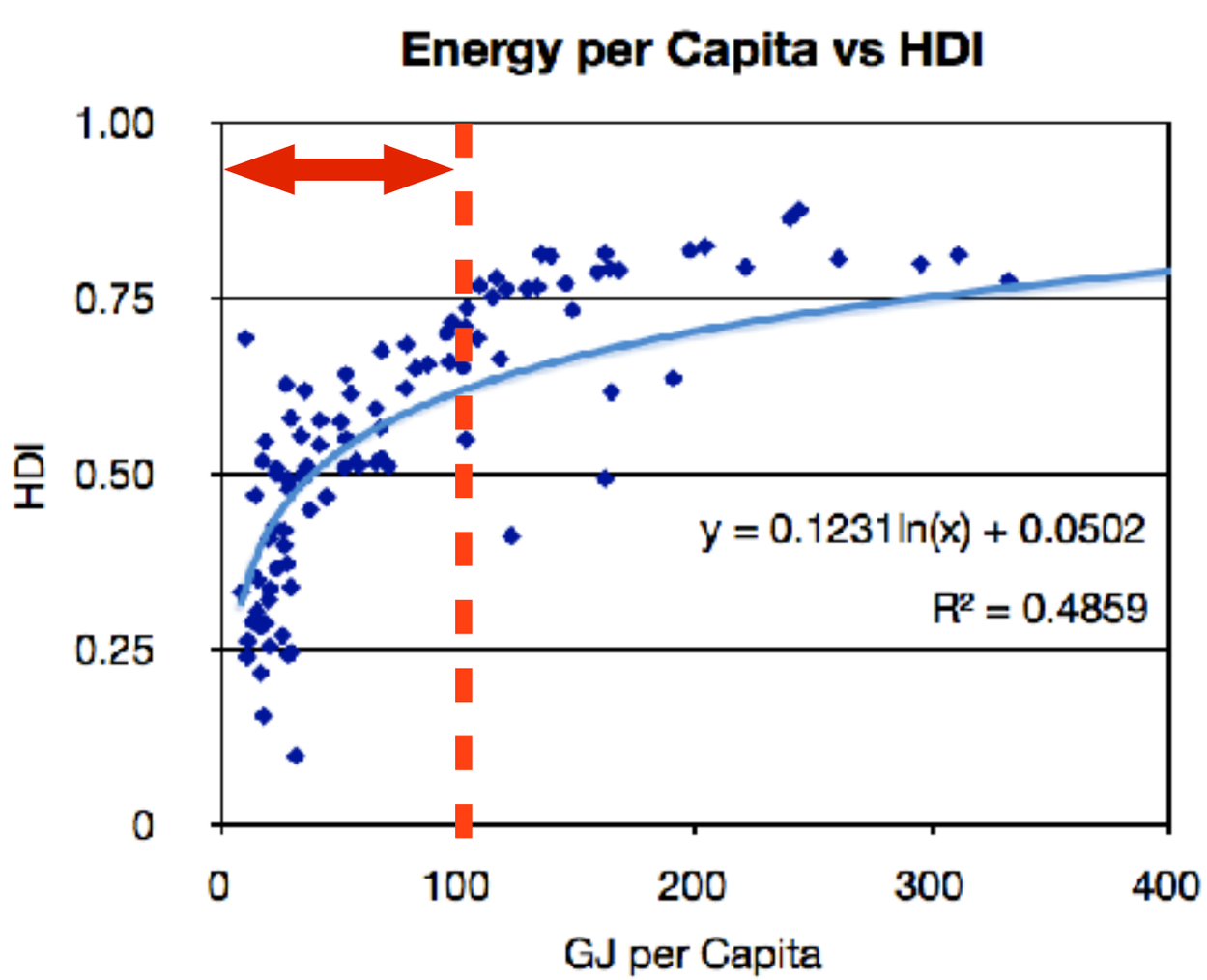




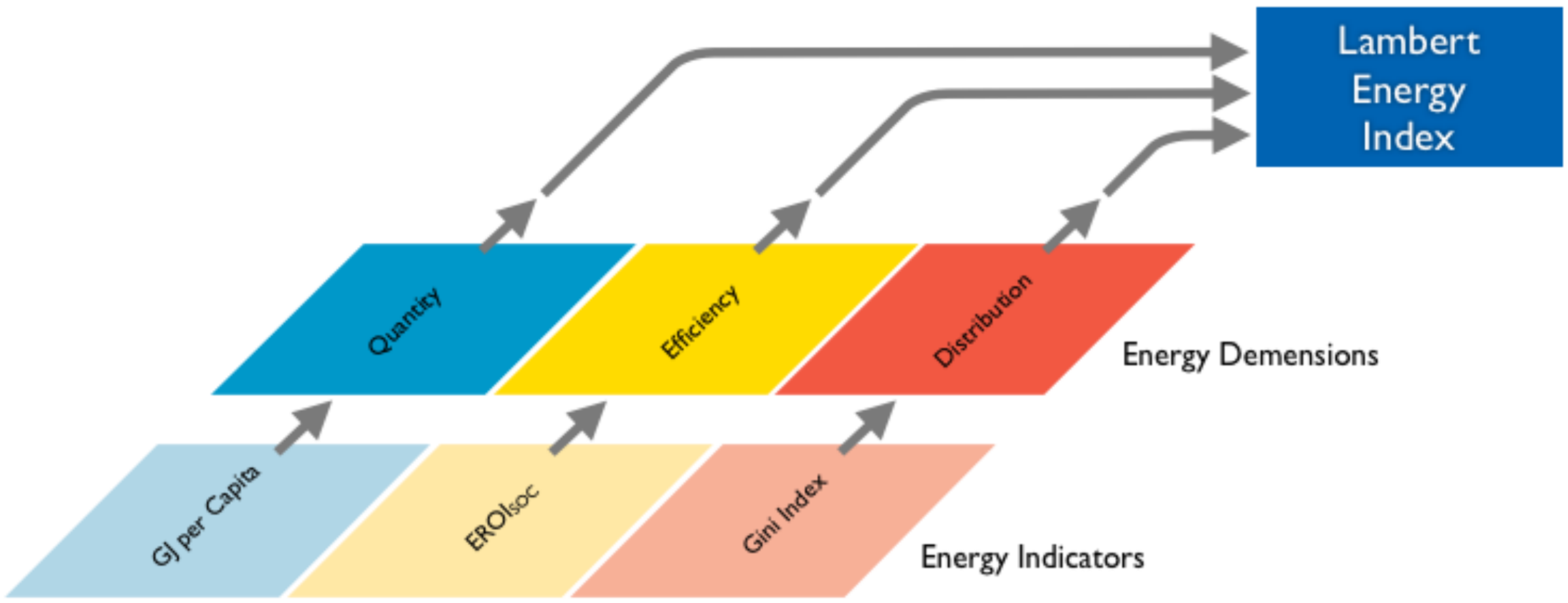

Quality of Life
ΔEROIsoc
ΔEROIsoc
Societal EROI

ENERGY AVAILABILITY & HDI





Composite Energy Index



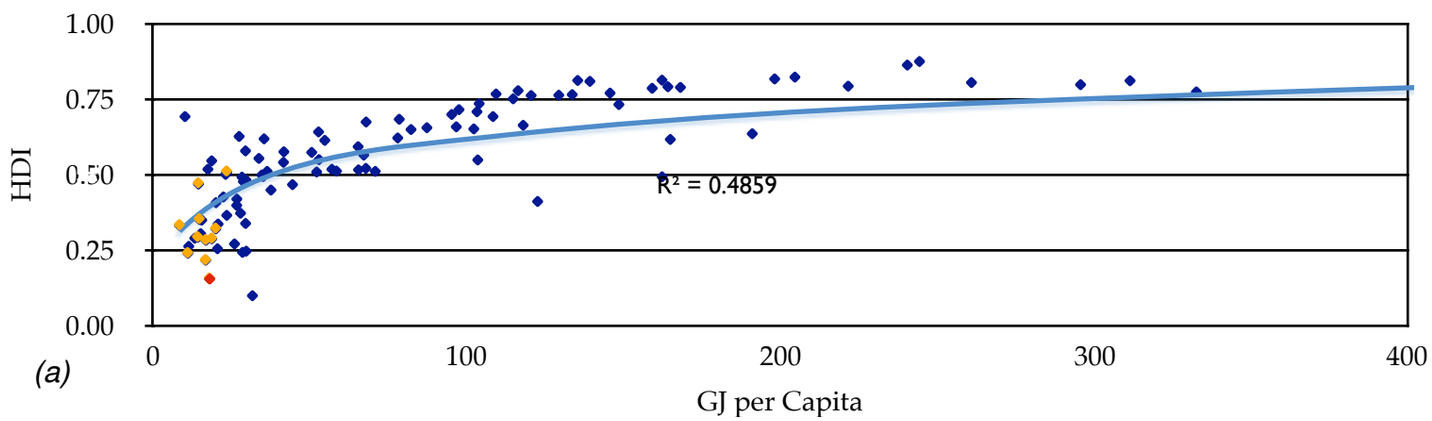
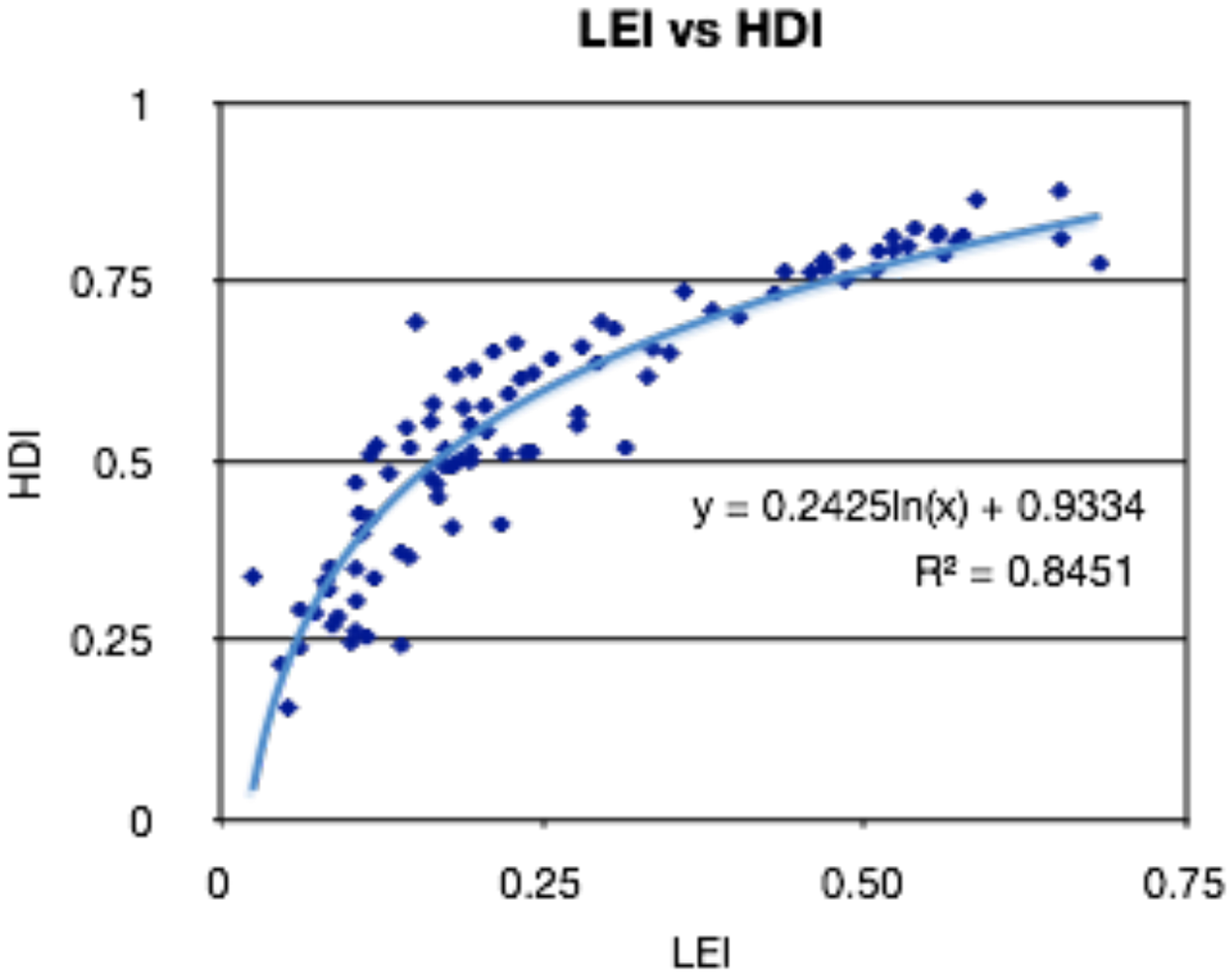
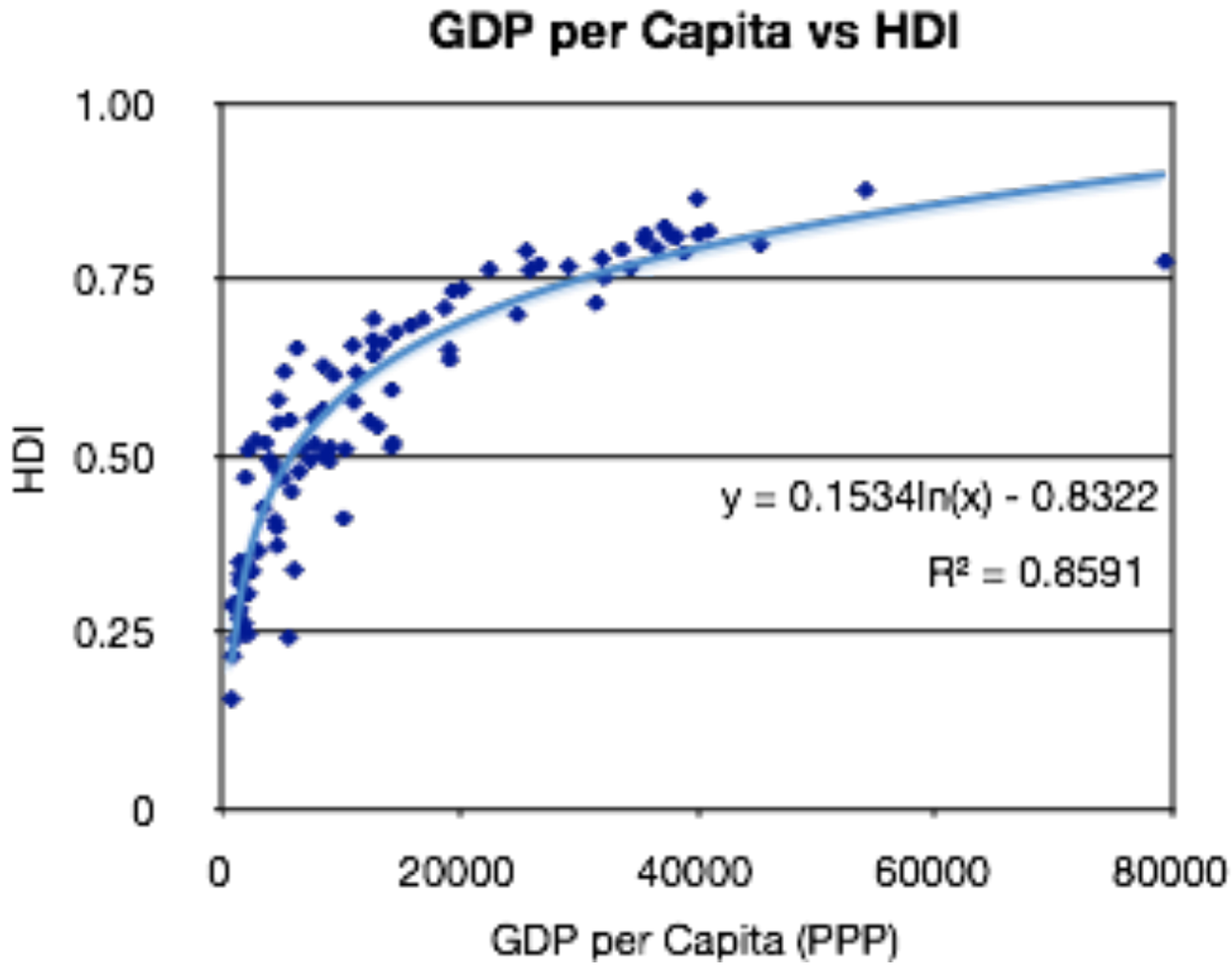


Figure 4.10: Regression of Human Development Index with (a) energy use per capita, (b) $EROI_{SOC}$ and (c) LEI values for LICs (Lambert et al. 2013).

LEI vs. GDP

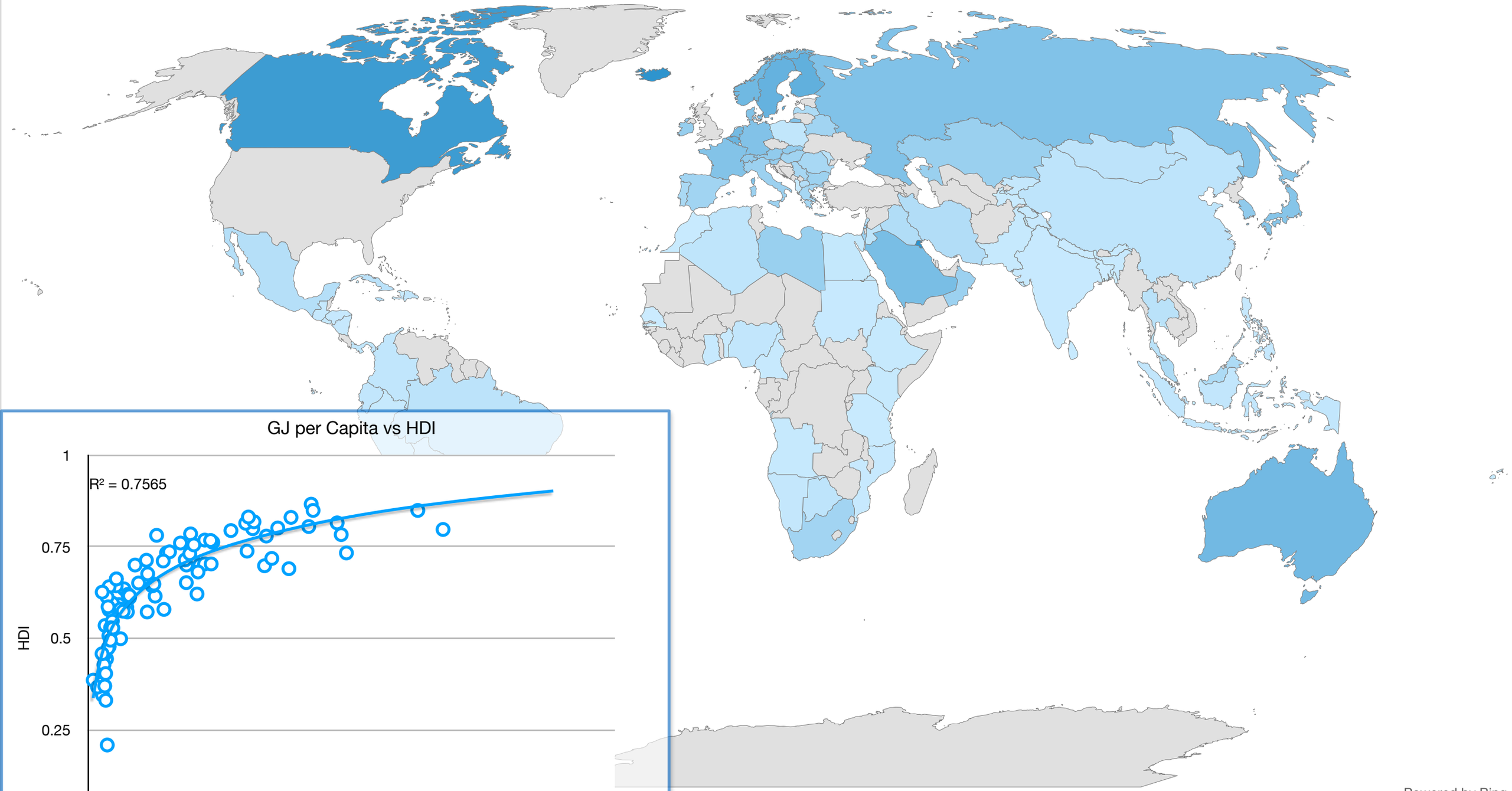

LEI vs HDI
1
0.75
0.5
0.25
0
HDI
0
0.25
0.50
0.75
LEI
y = 0.2425ln(x) + 0.9334
R² = 0.8451


GDP per Capita vs HDI
1.00
0.75
0.50
0.25
0
HDI
0
20000
40000
60000
80000
GDP per Capita (PPP)
y = 0.1534ln(x) - 0.8322
R² = 0.8591

1990

GJ per Capita

5.521997664 477.6518053

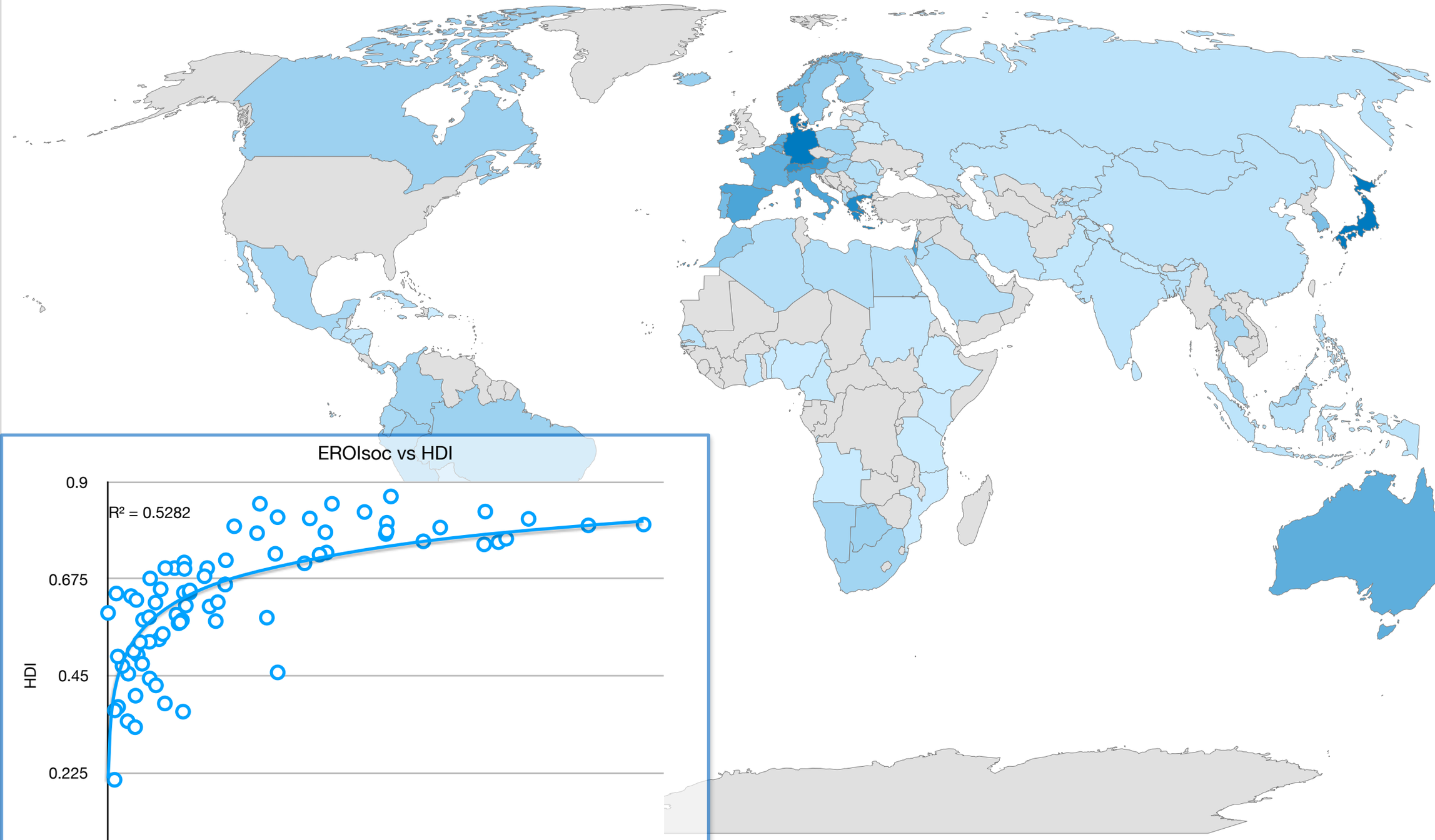


NGEI

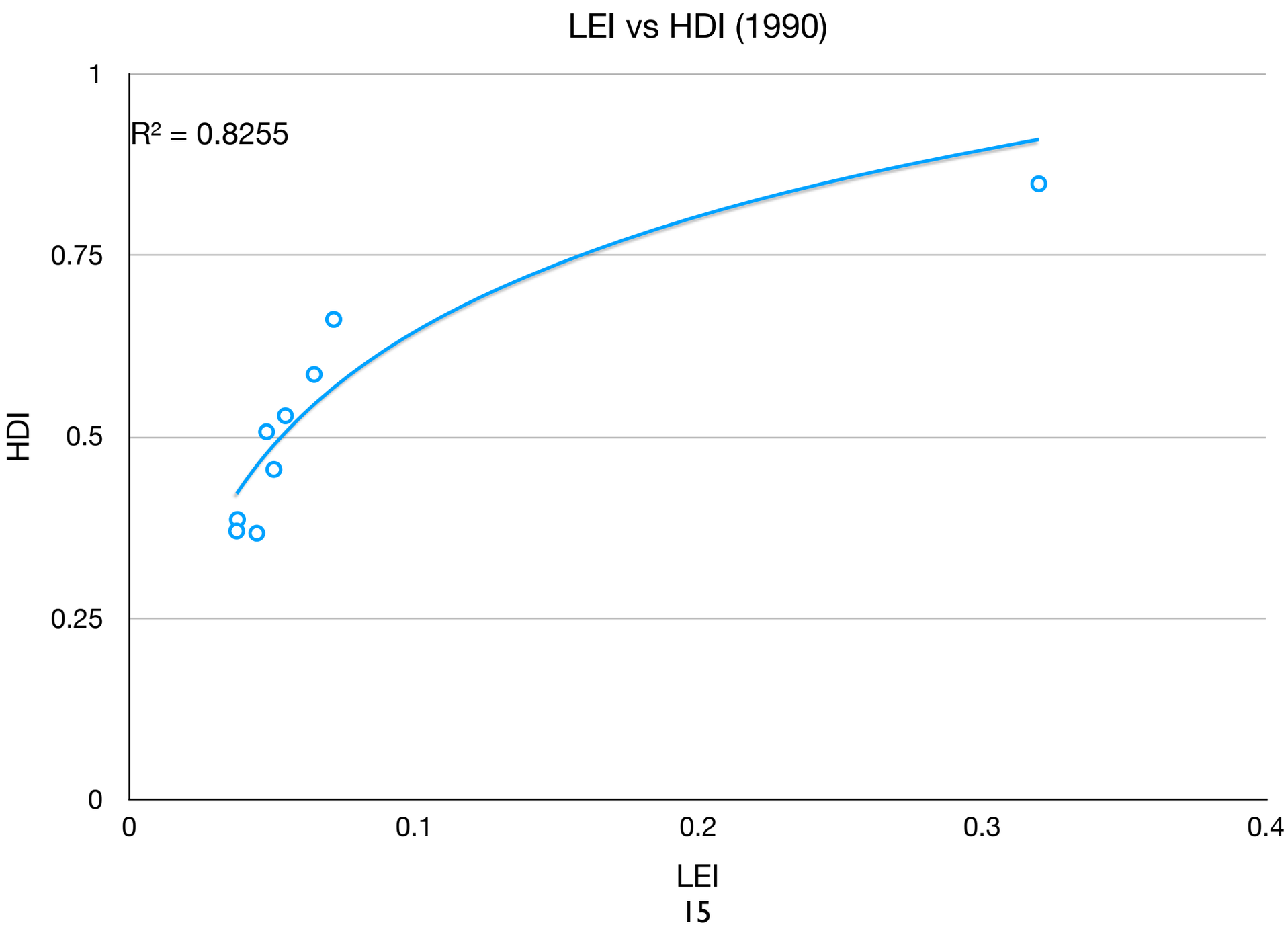
1990

EROIsoc

0.26 100



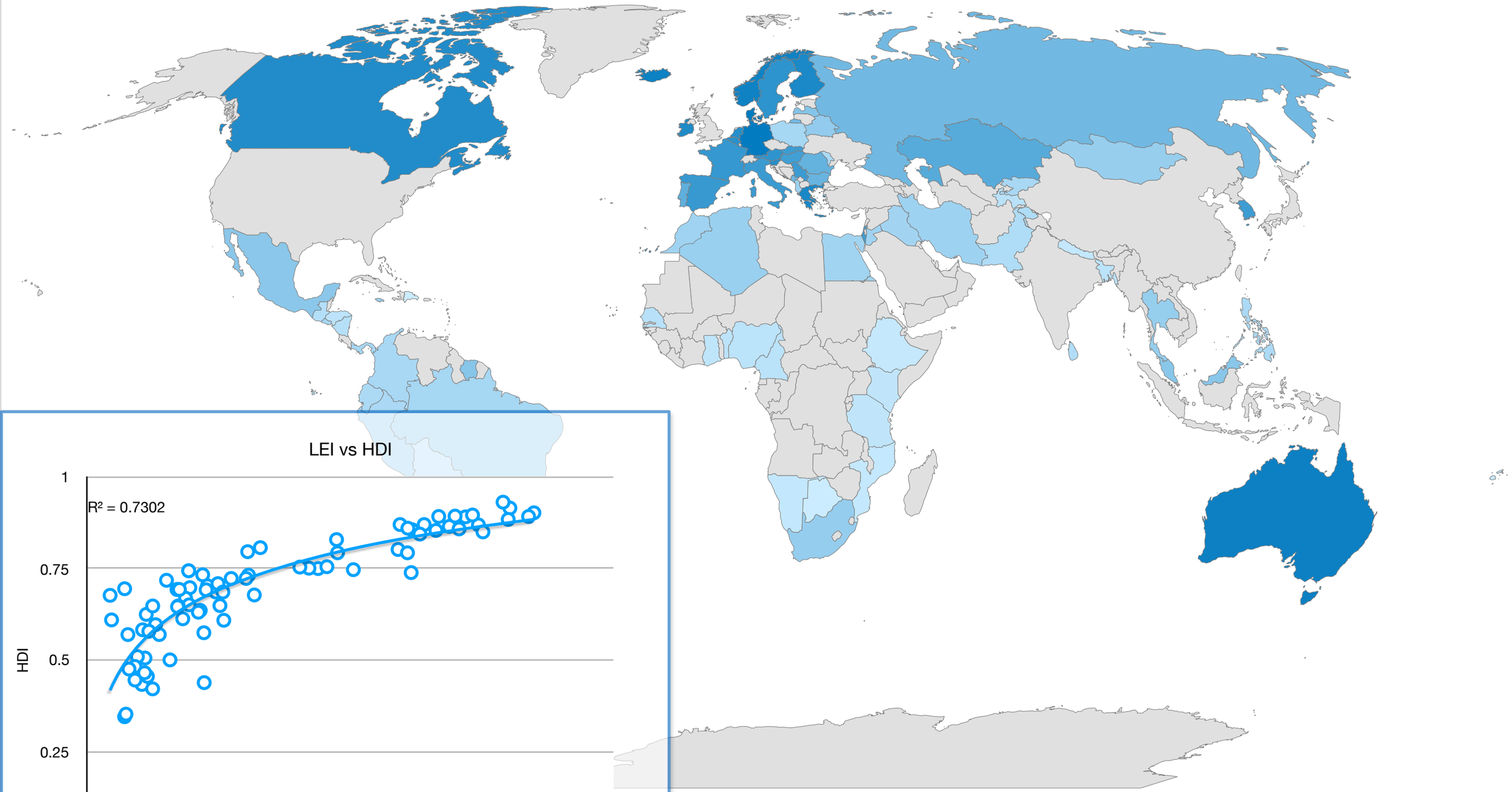
Problem: Spotty Data



2005

LEI

0.021962456 0.424637586

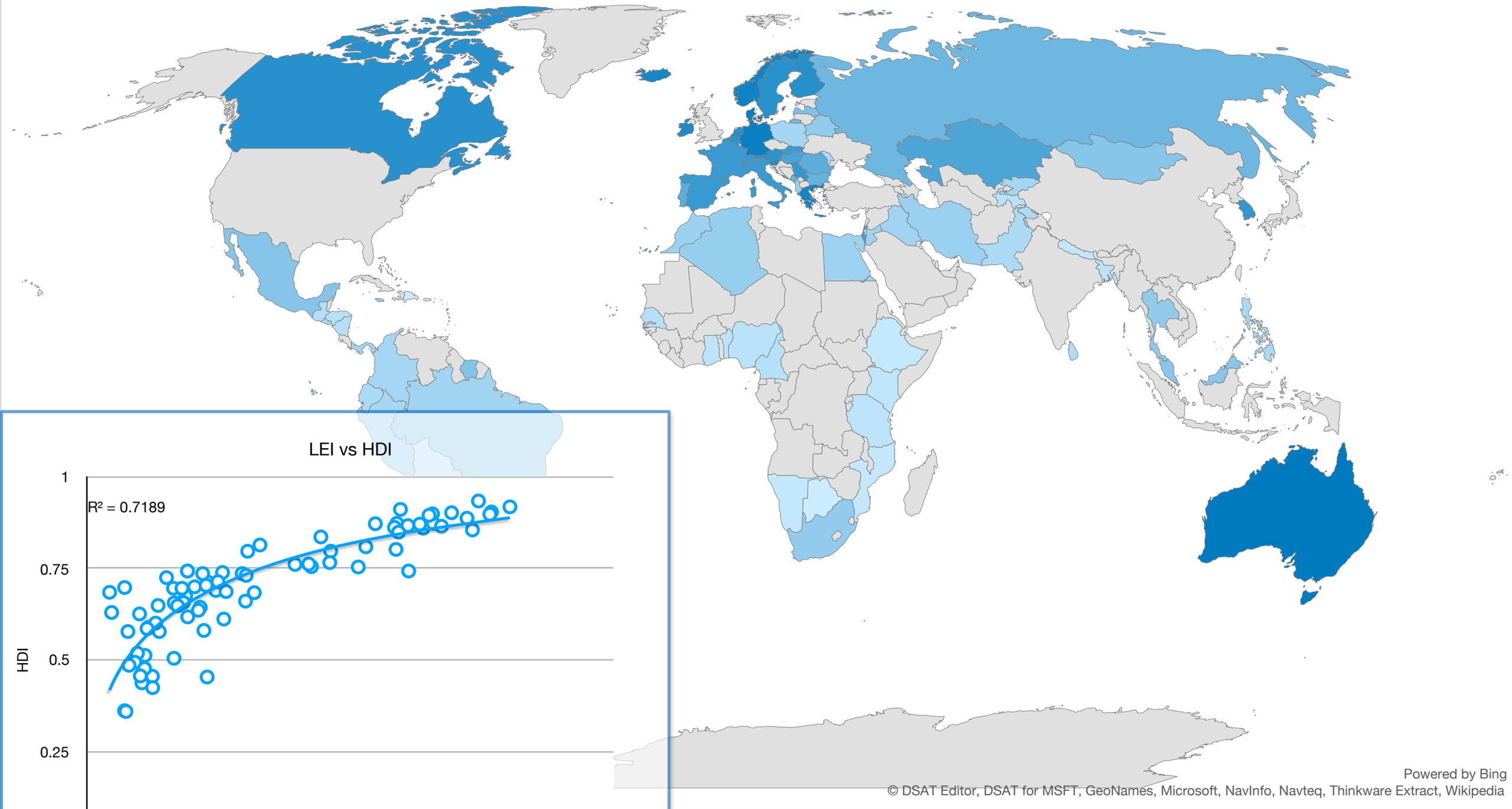


NGEI

2006

LEI

0.021438868 0.401809966

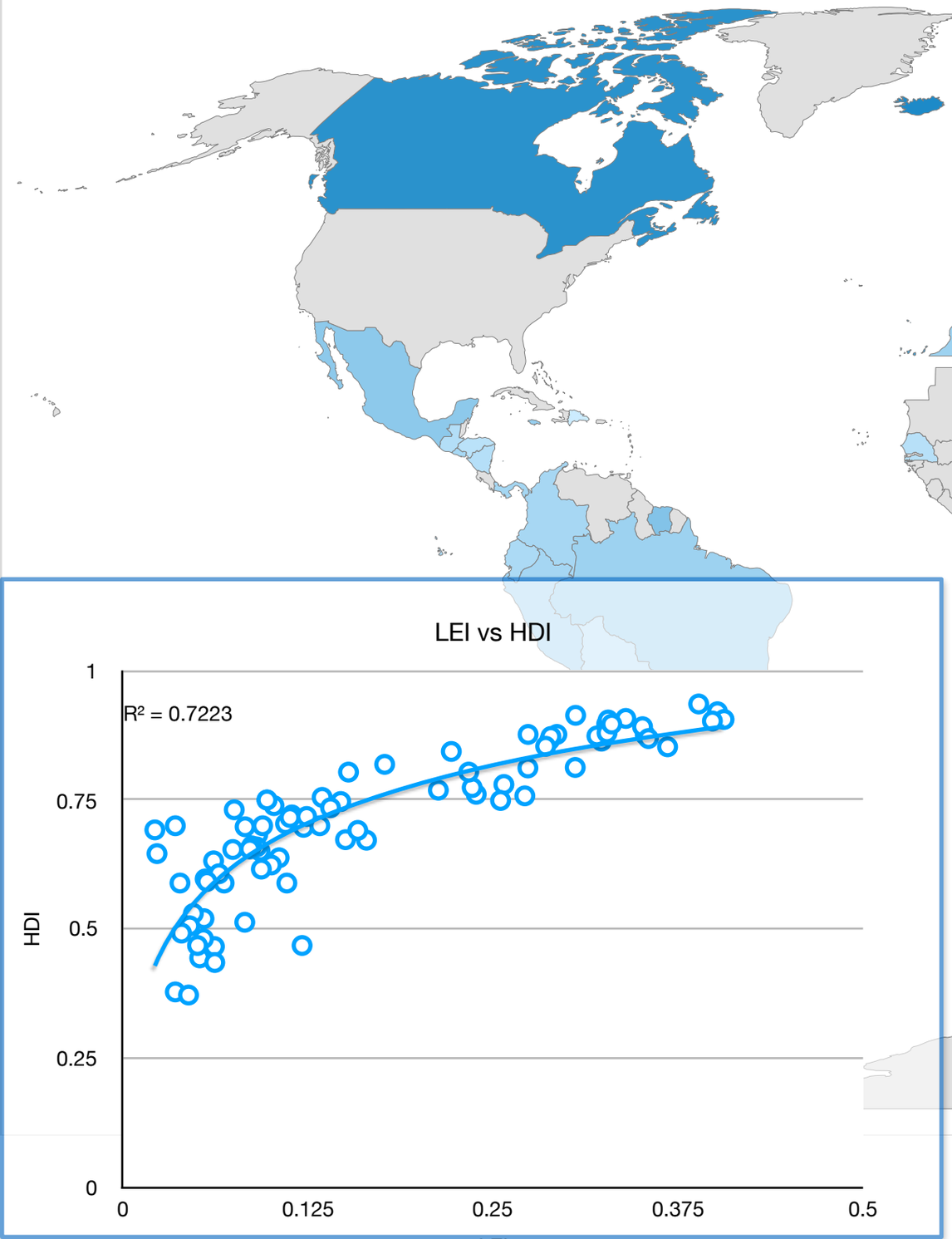


NGEI

2007

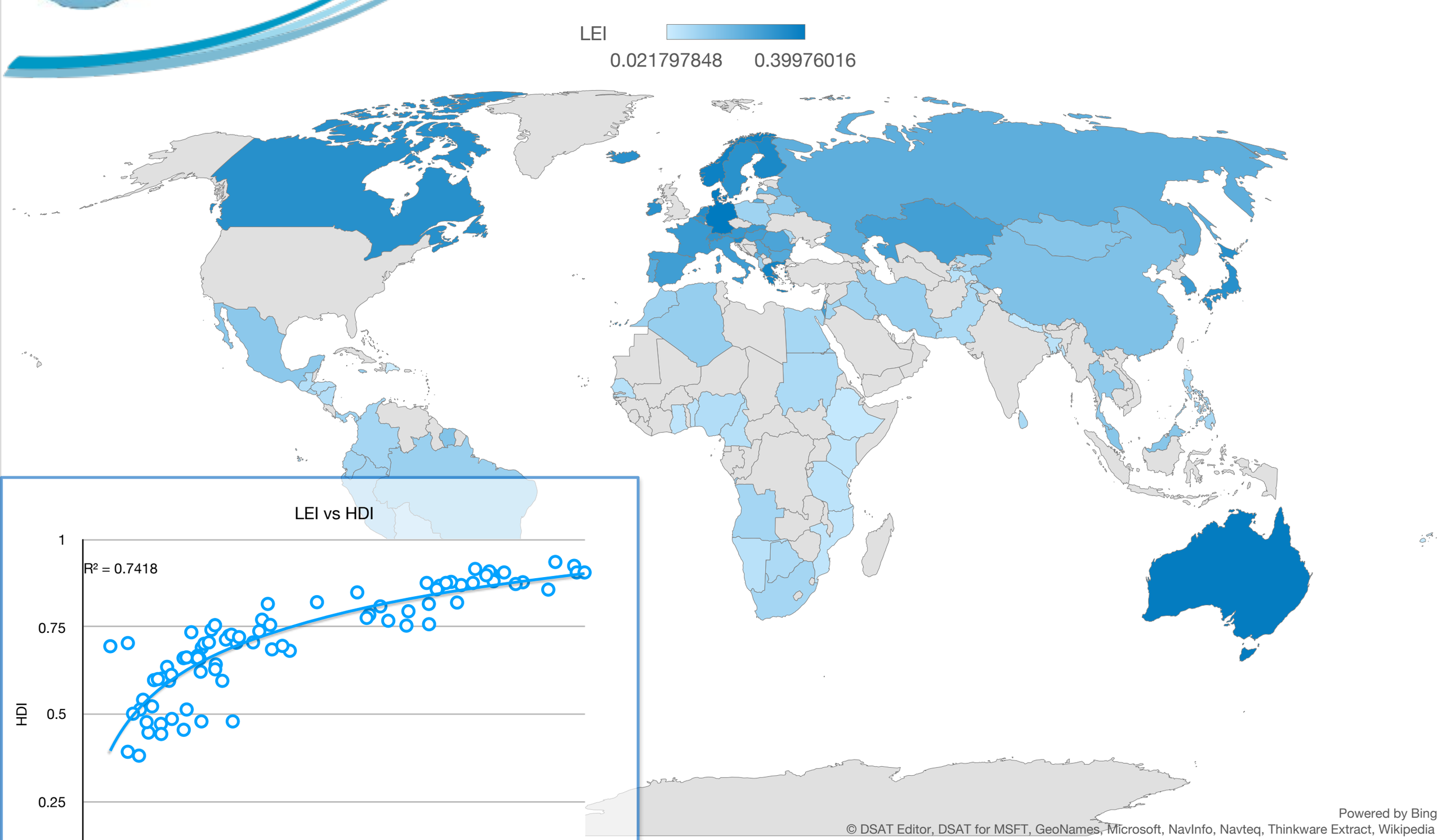
LEI

0.021896689 0.406277362



NGEI

2008

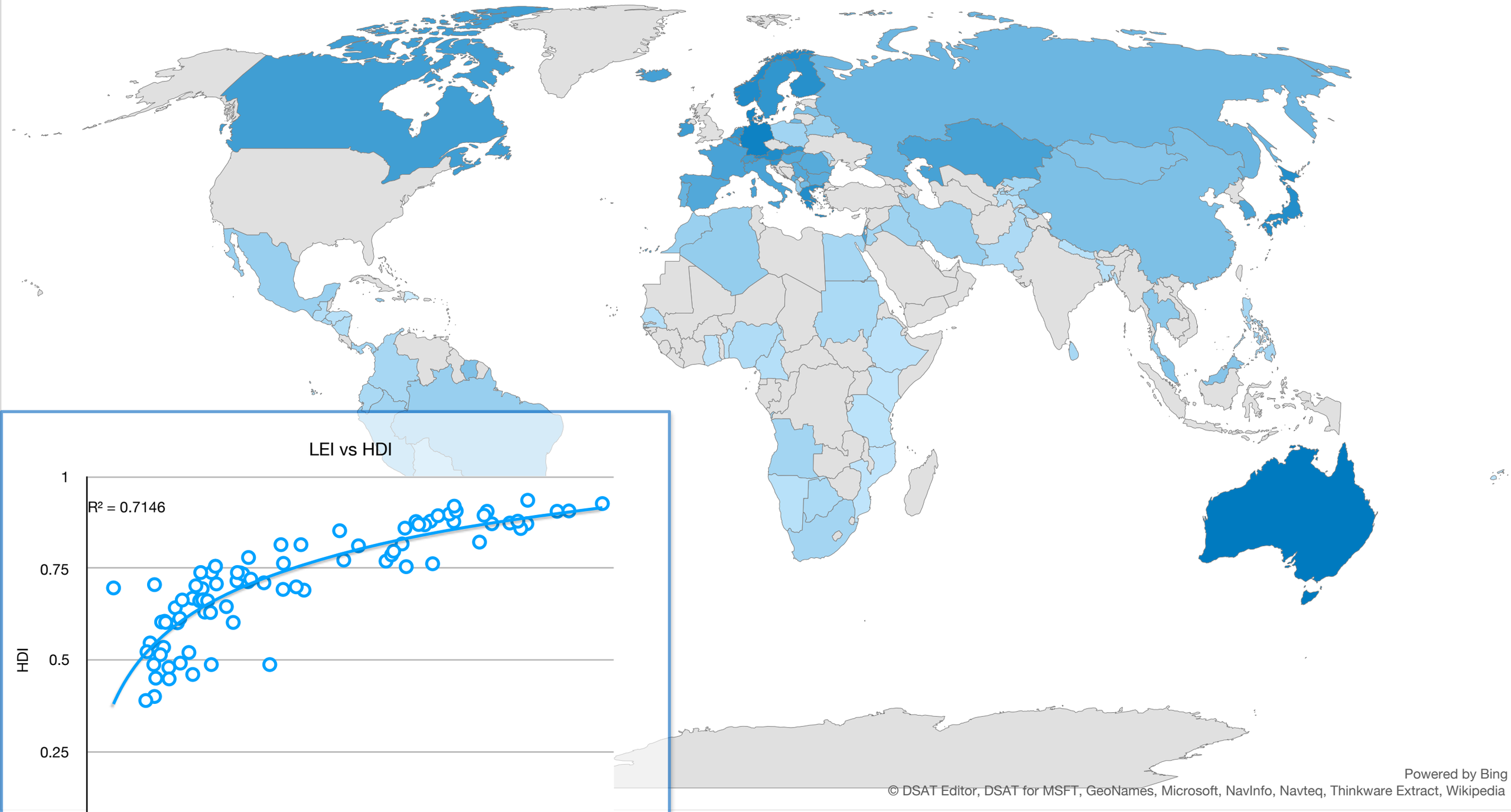

LEI
0.021797848
0.39976016
LEI vs HDI
R² = 0.7418
HDI
1
0.75
0.5
0.25
0
0
0.1
0.2
0.3
0.4
Powered by Bing
© DSAT Editor, DSAT for MSFT, GeoNames, Microsoft, Navinfo, Navteq, Thinkware Extract, Wikipedia

NGEI

2009

LEI

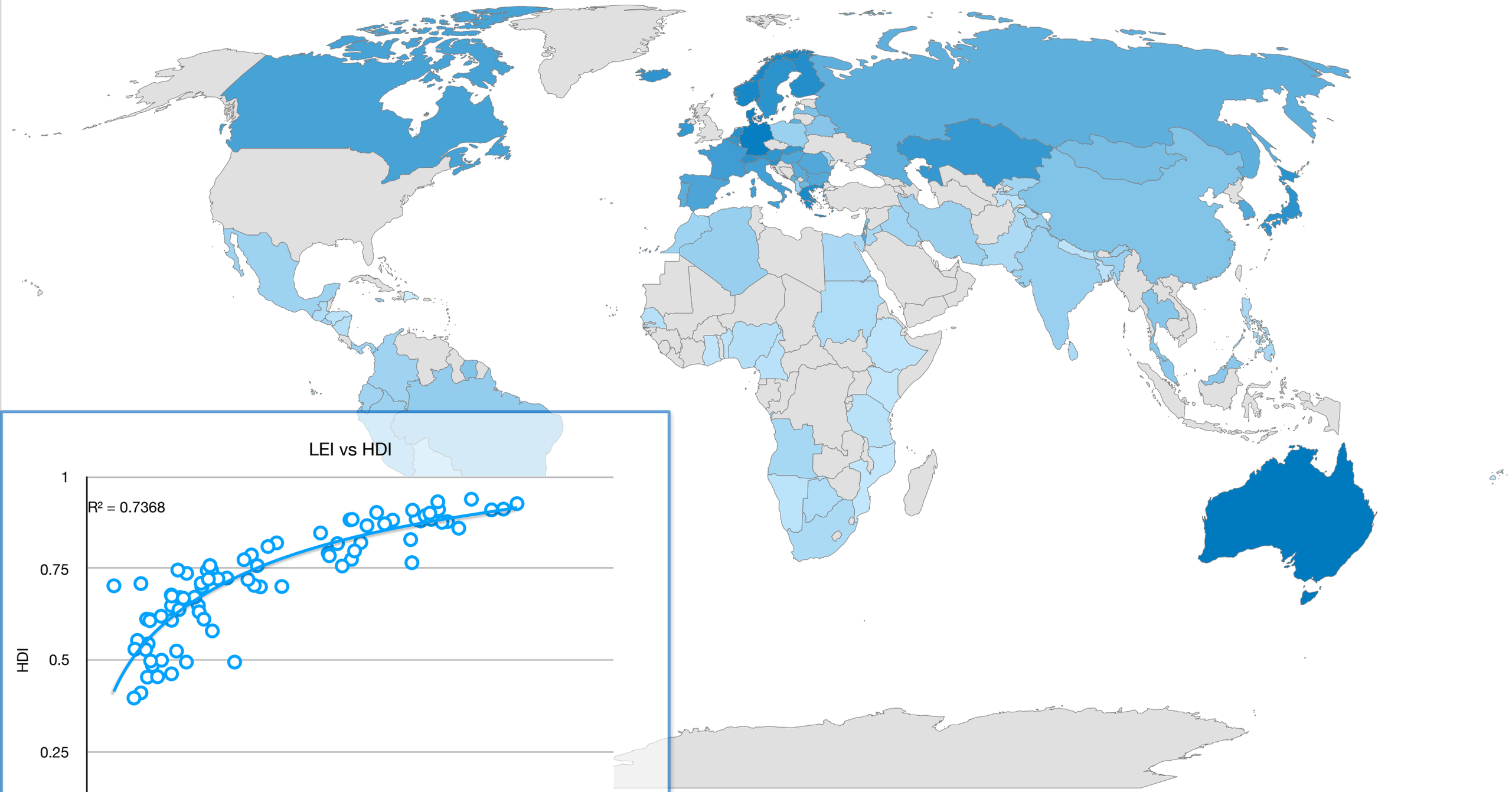
0.020118143 0.391483144



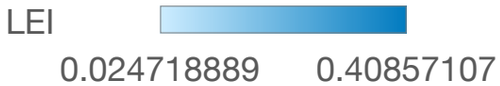
2010

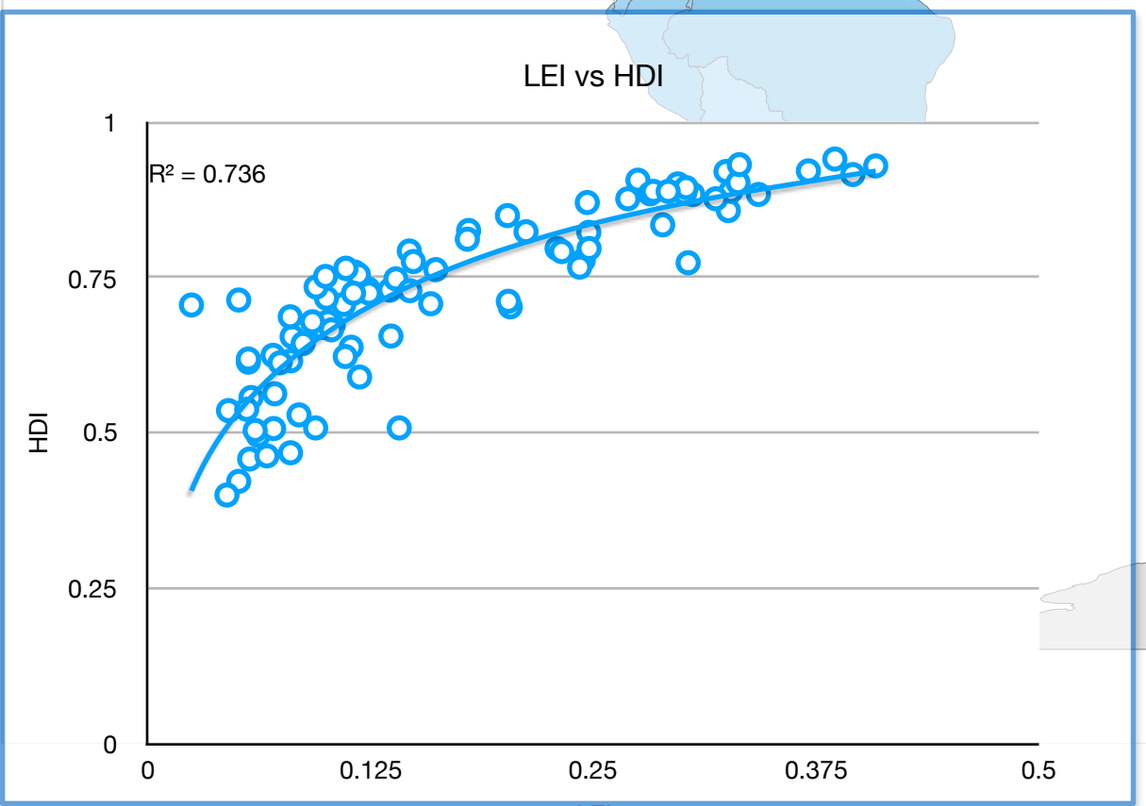
LEI

0.025568427 0.40857107



2011



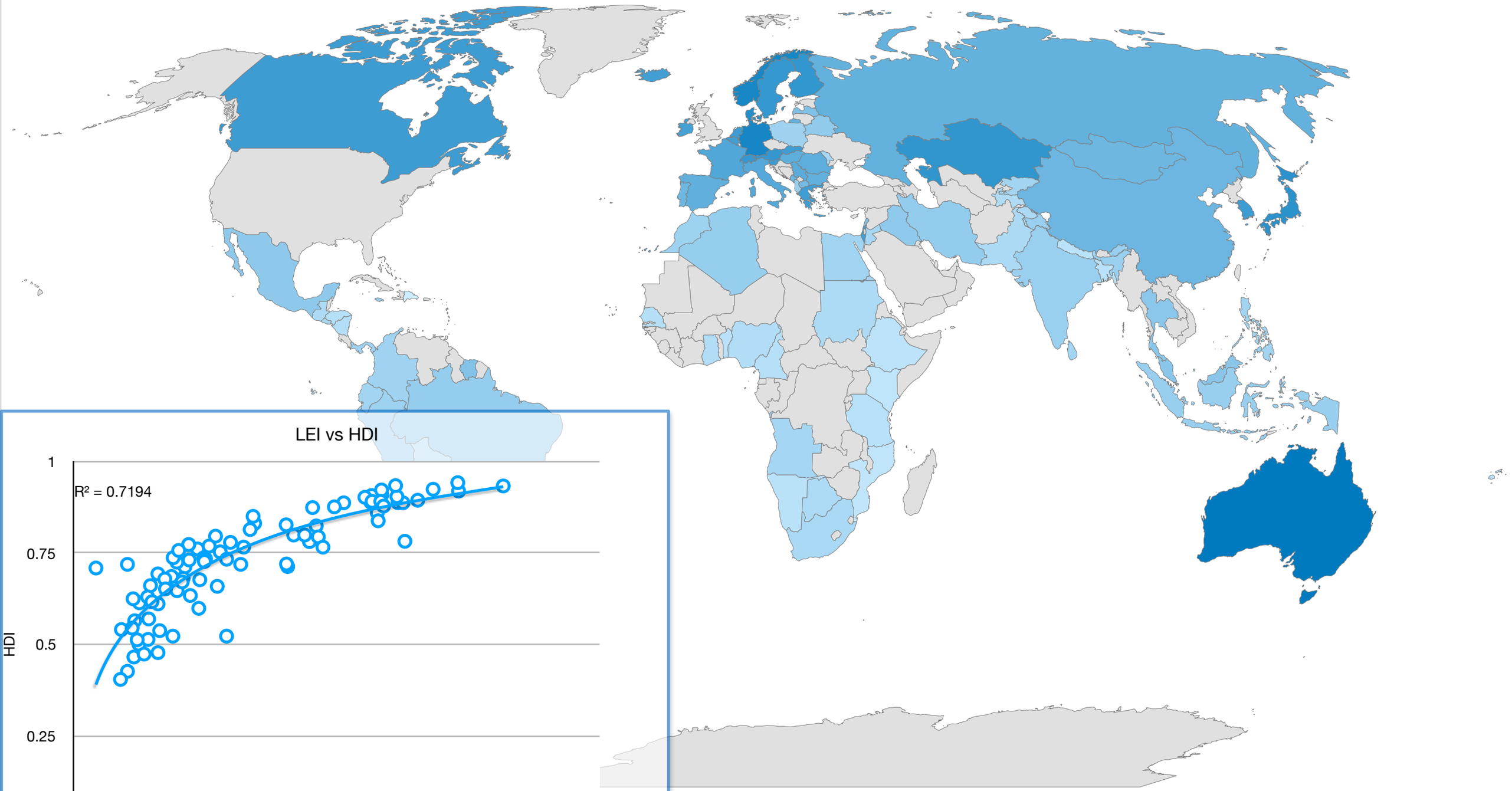


NGEI

2012

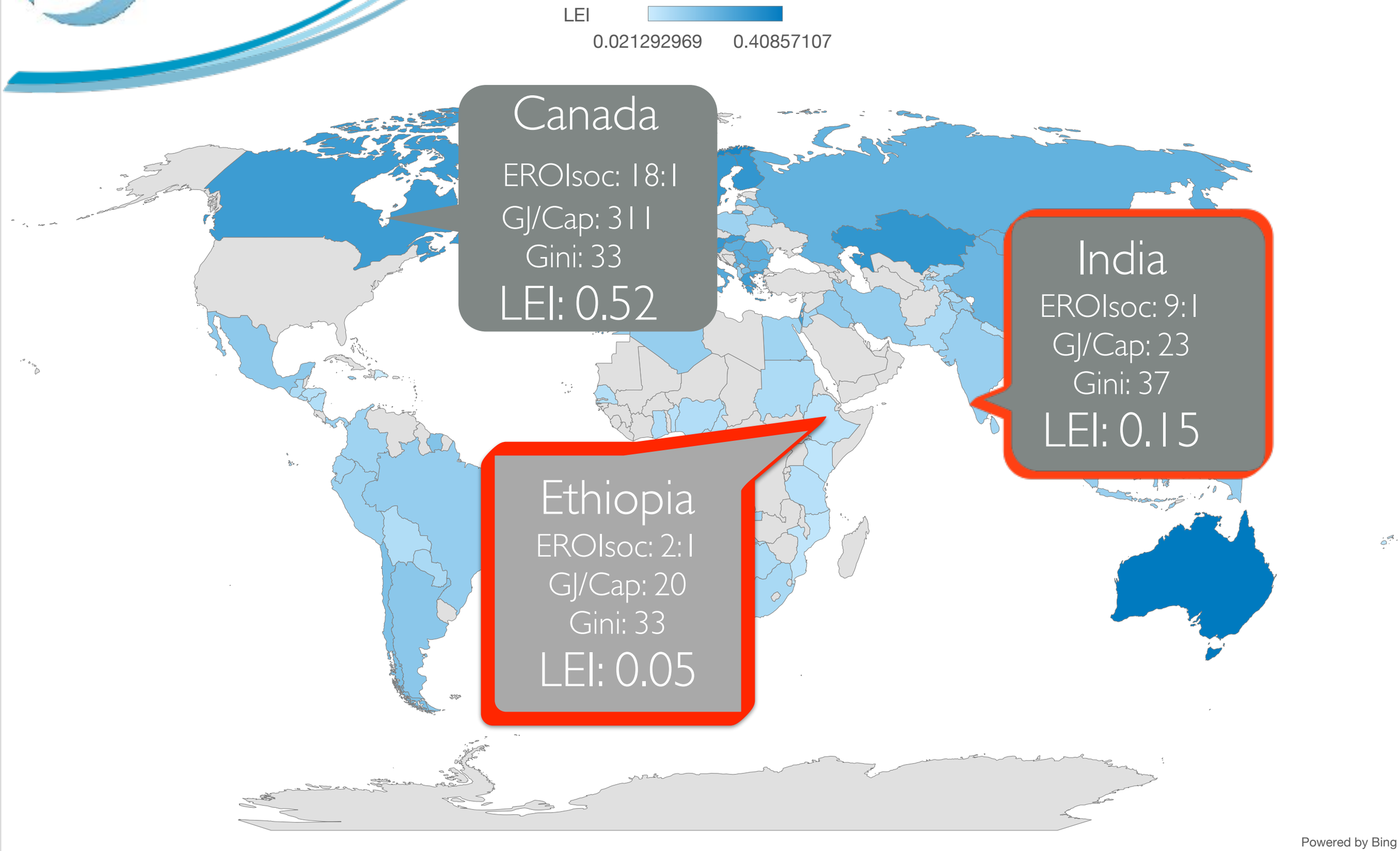
LEI

0.021292969 0.40857107

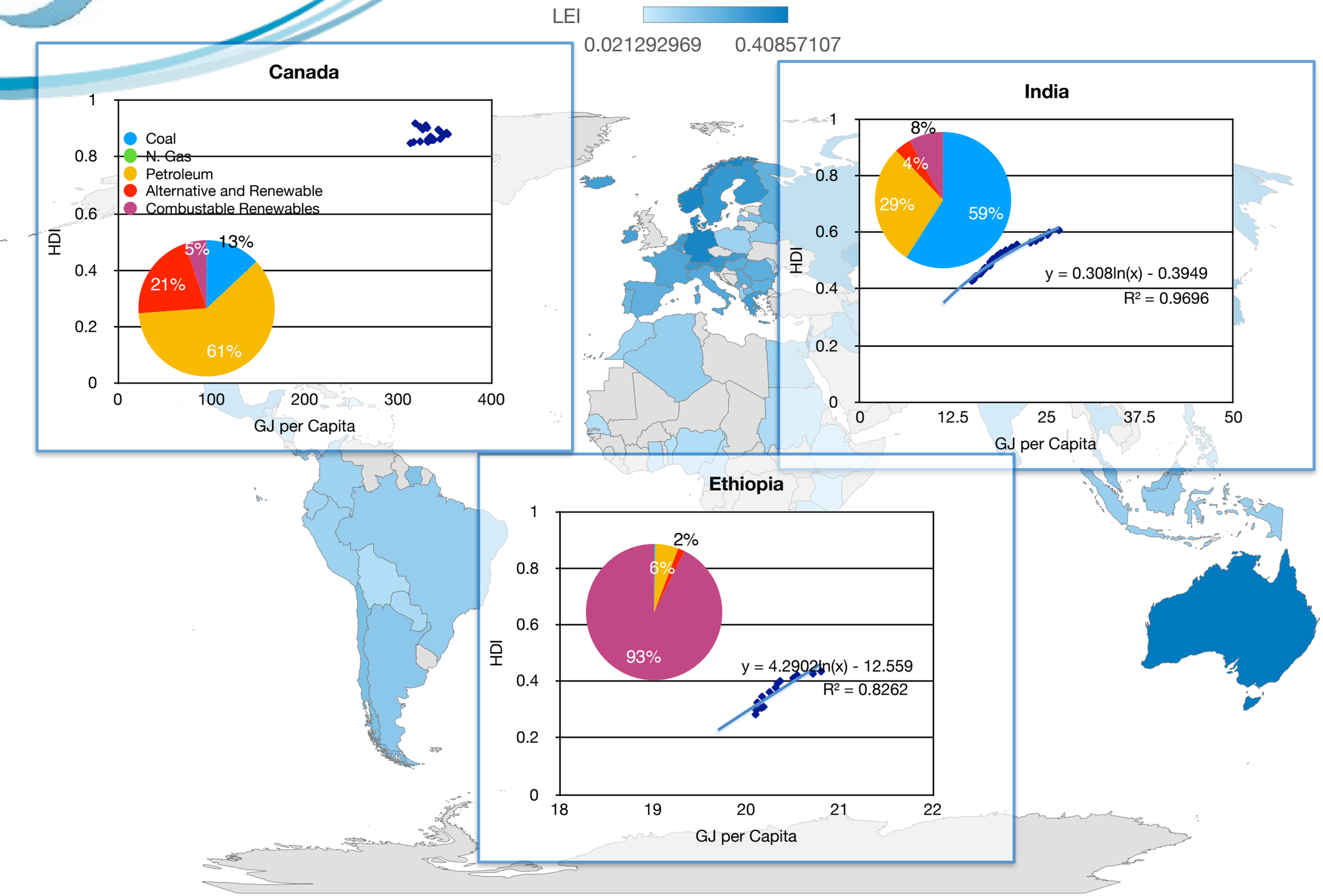


NGEI

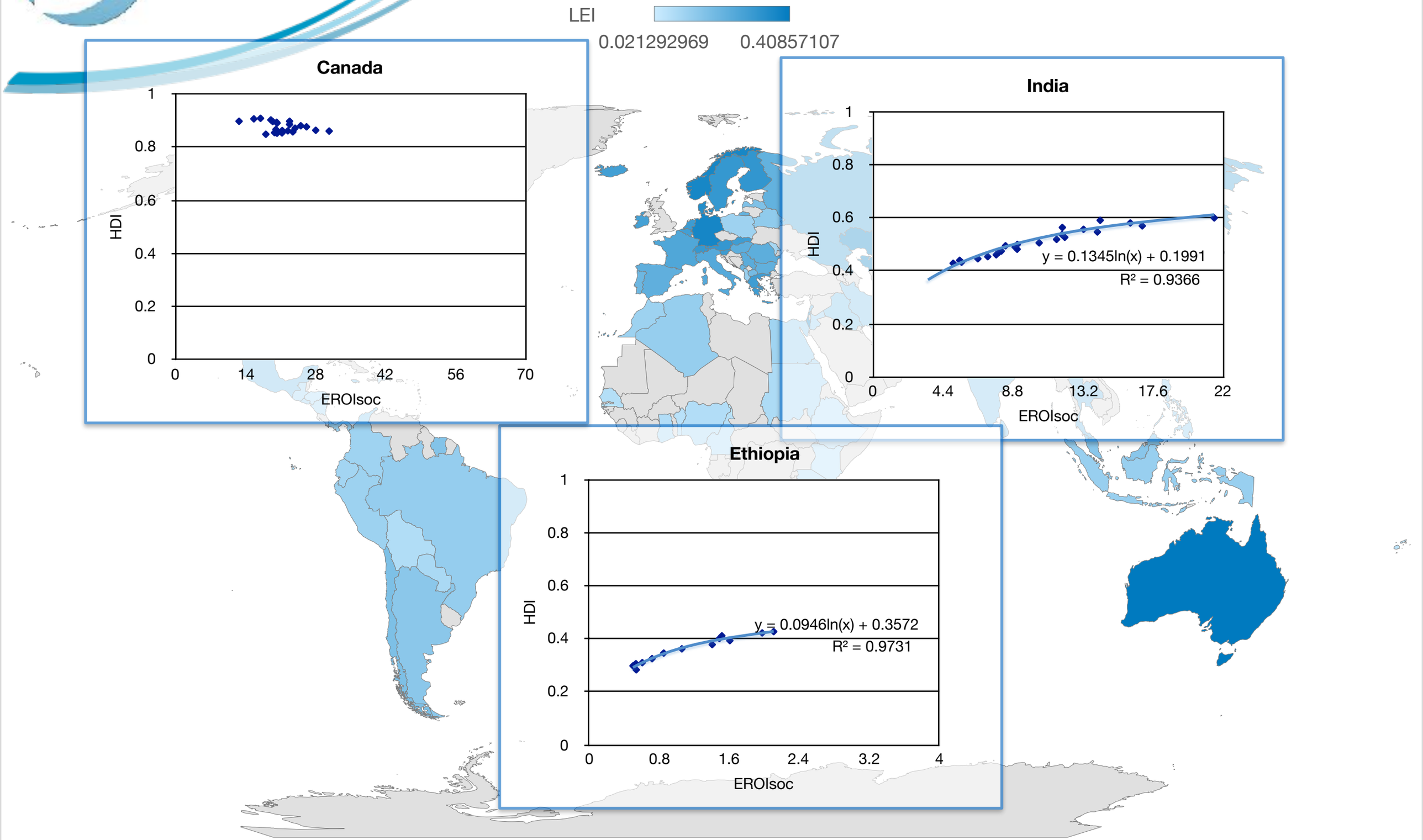
2012



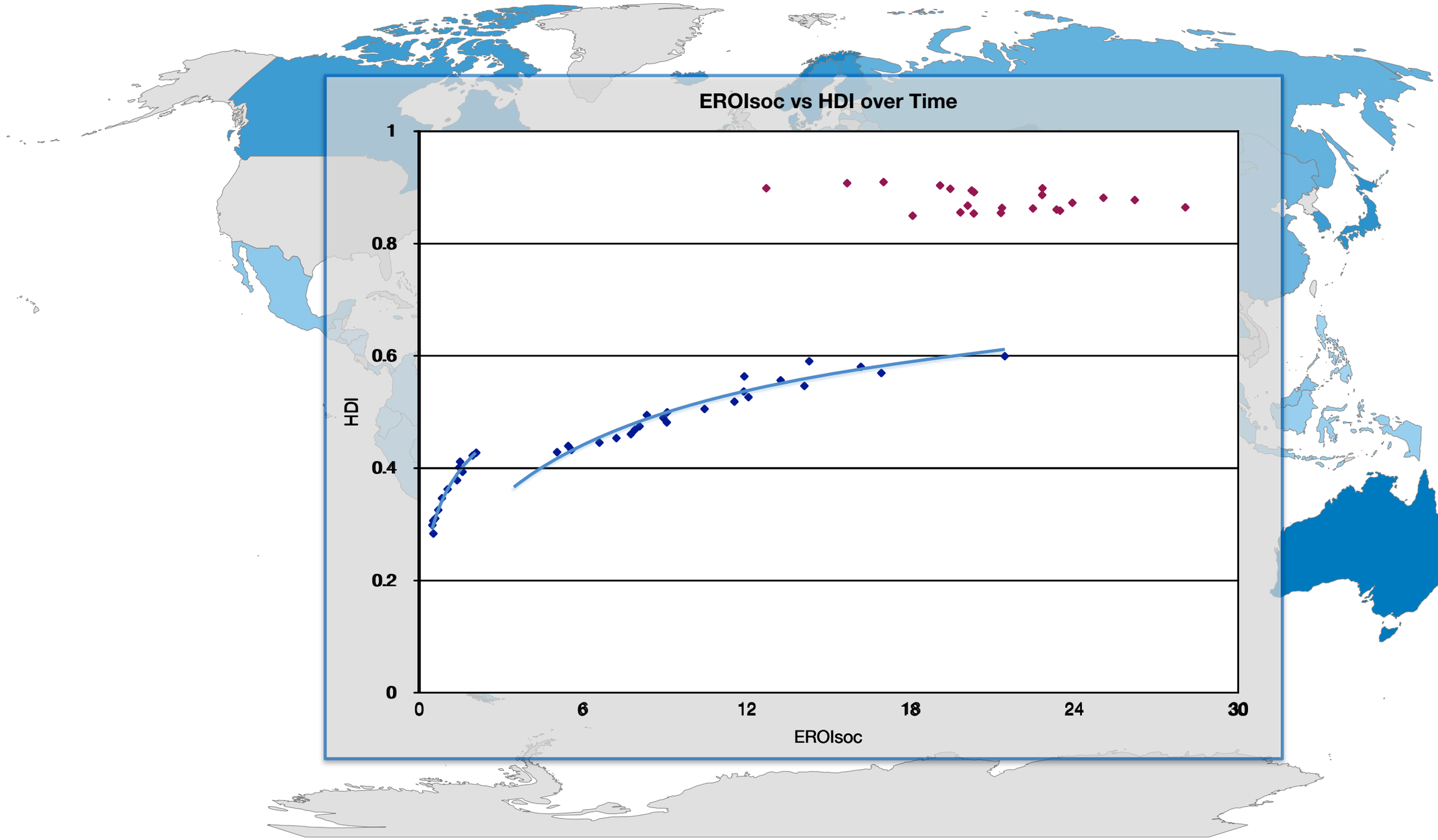
GJ per Capita vs HDI over Time



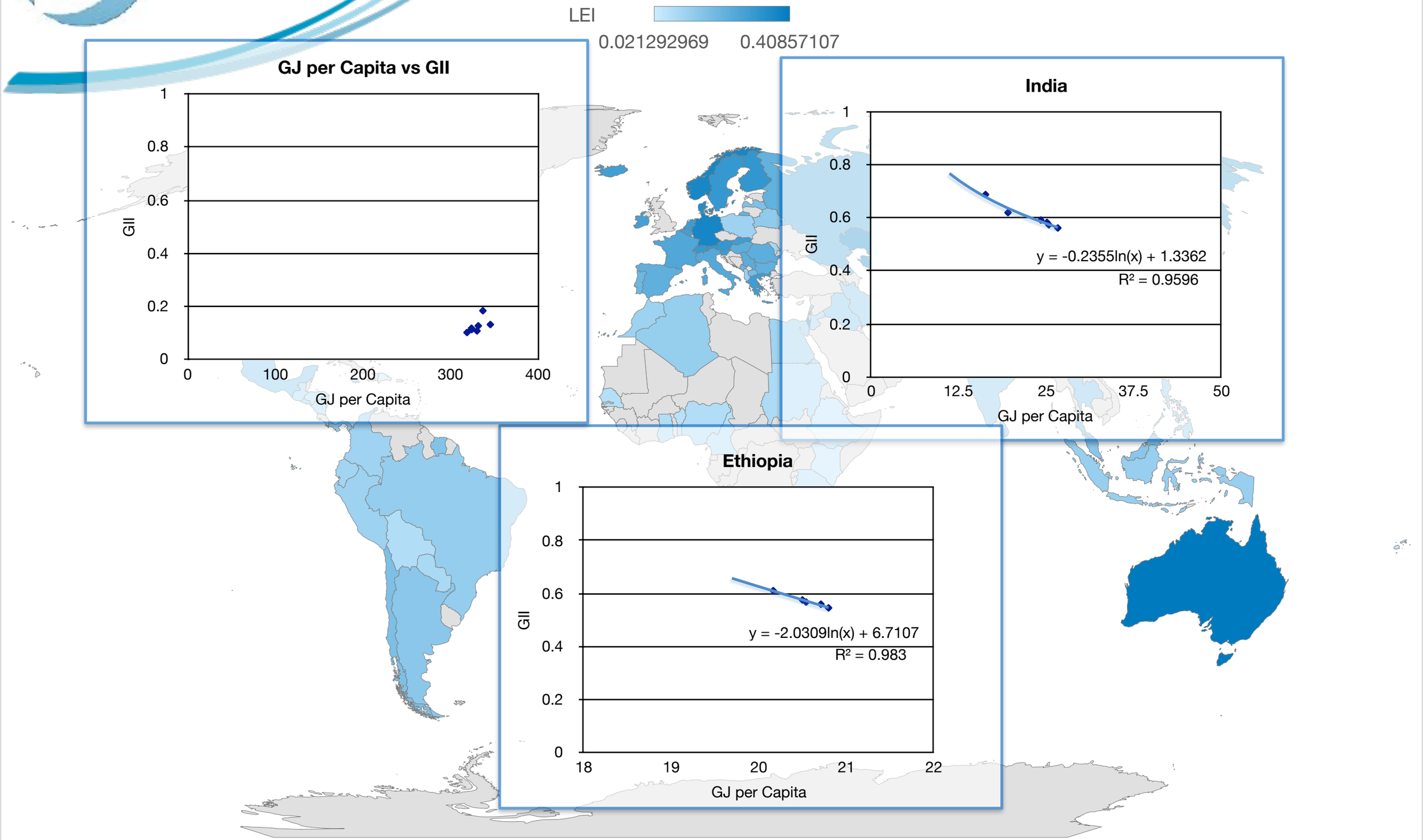
EROIsoc vs HDI over Time



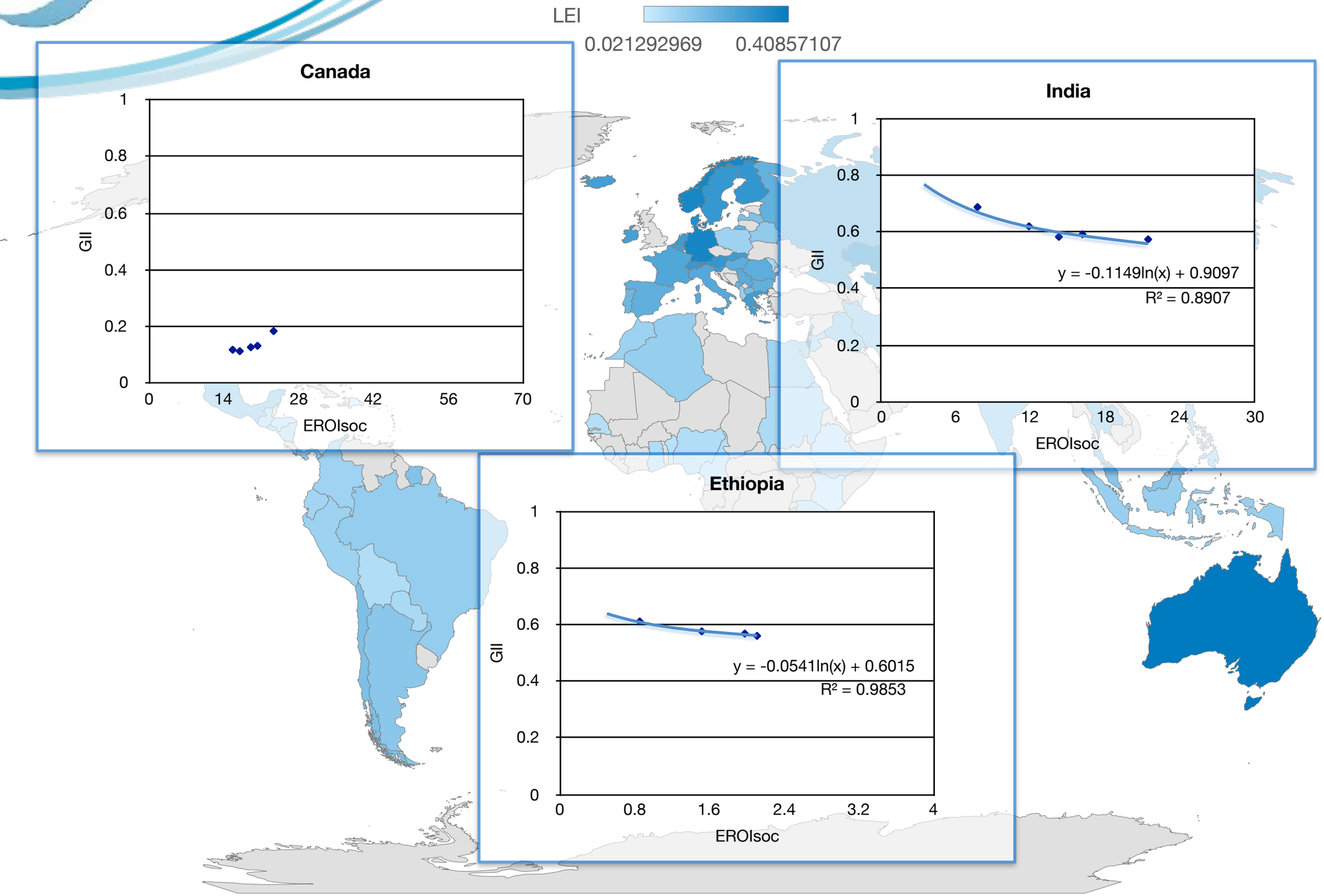
EROIsoc vs HDI over Time



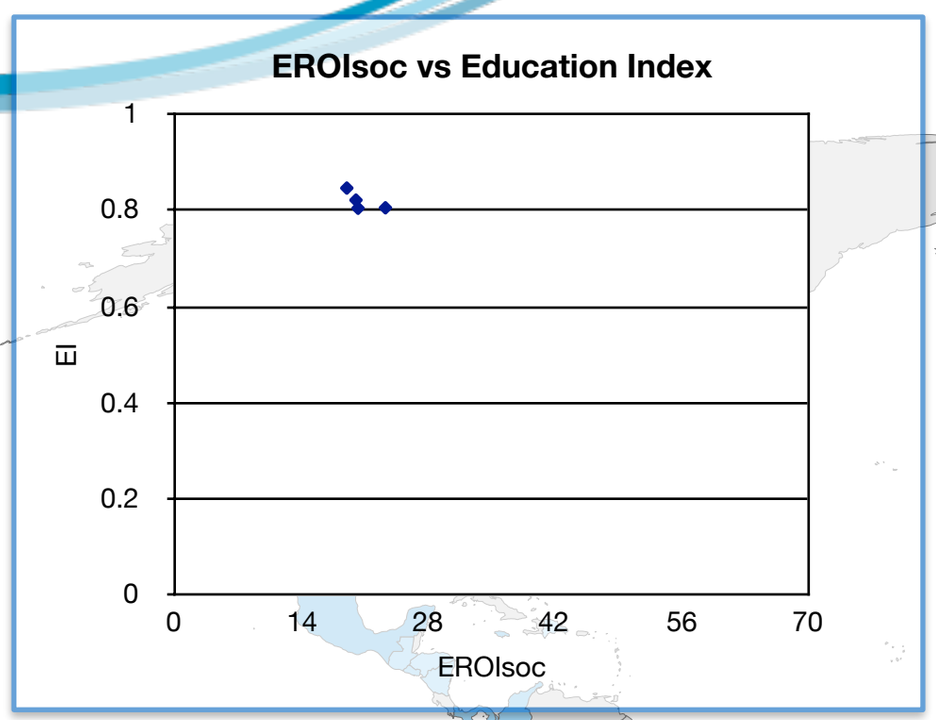
GJ vs GII over Time

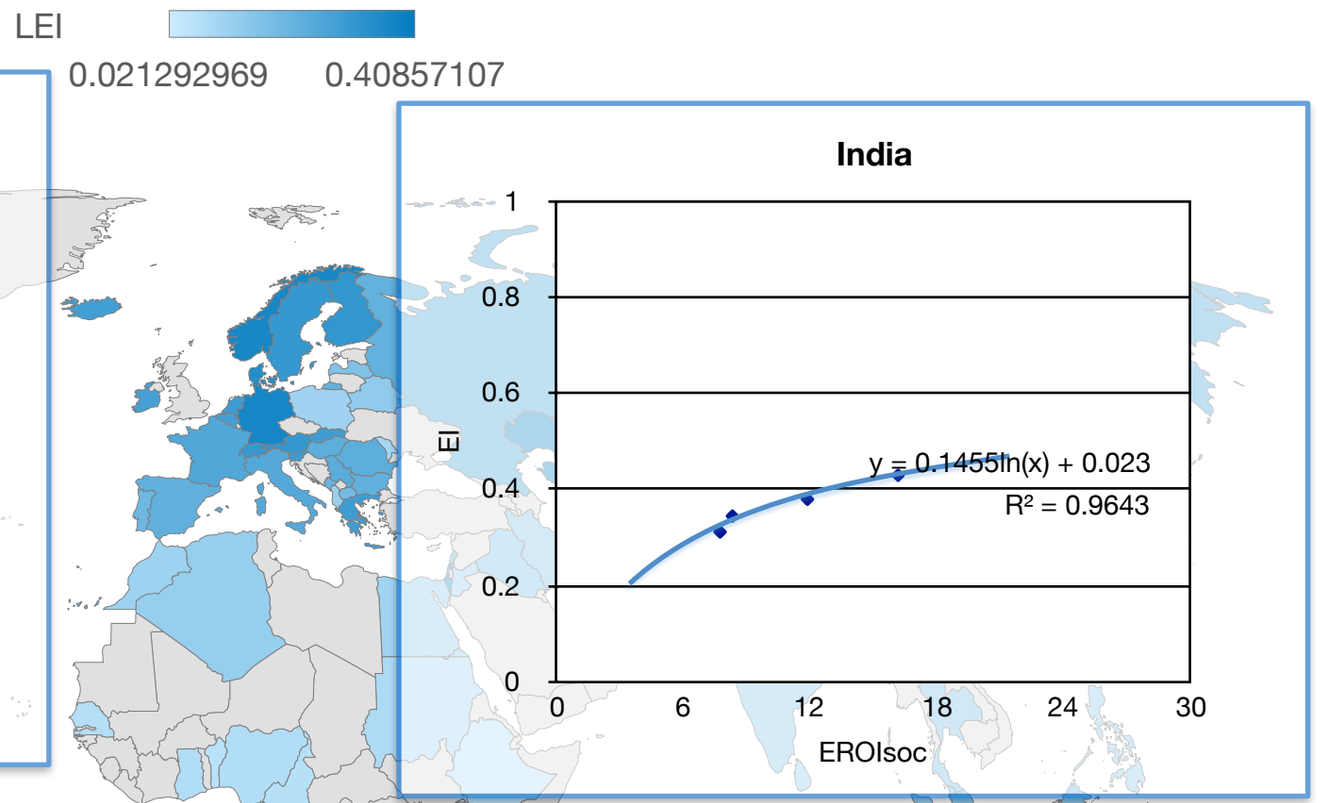


EROIsoc vs GII over Time

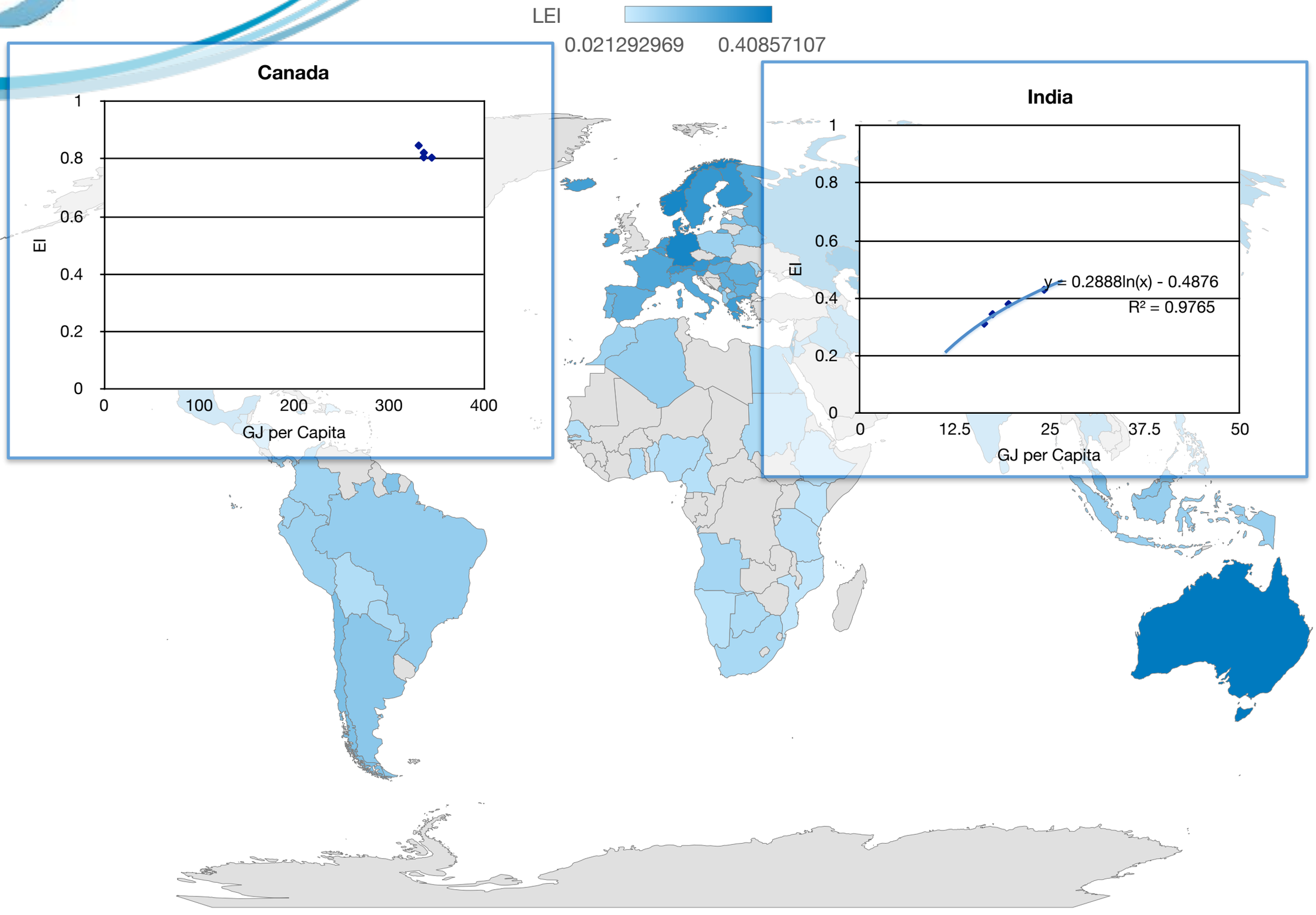


EROIsoc vs EI over Time

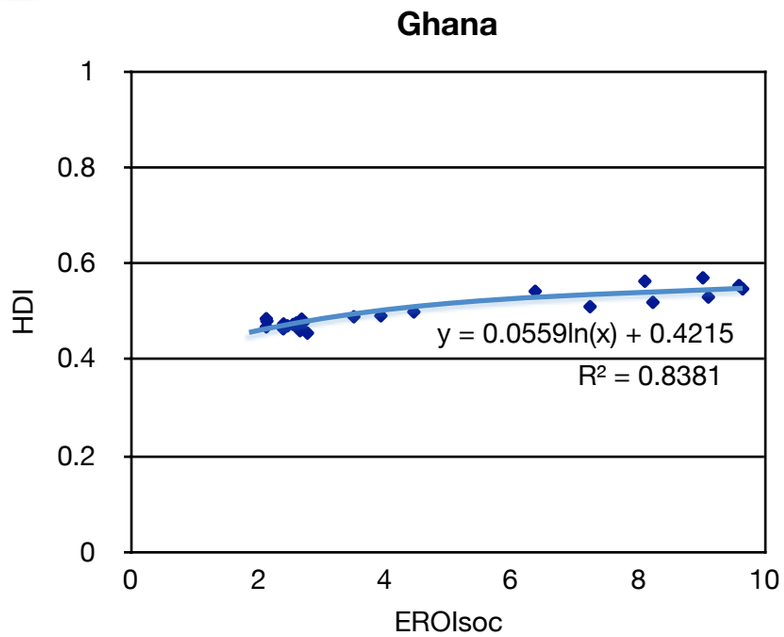


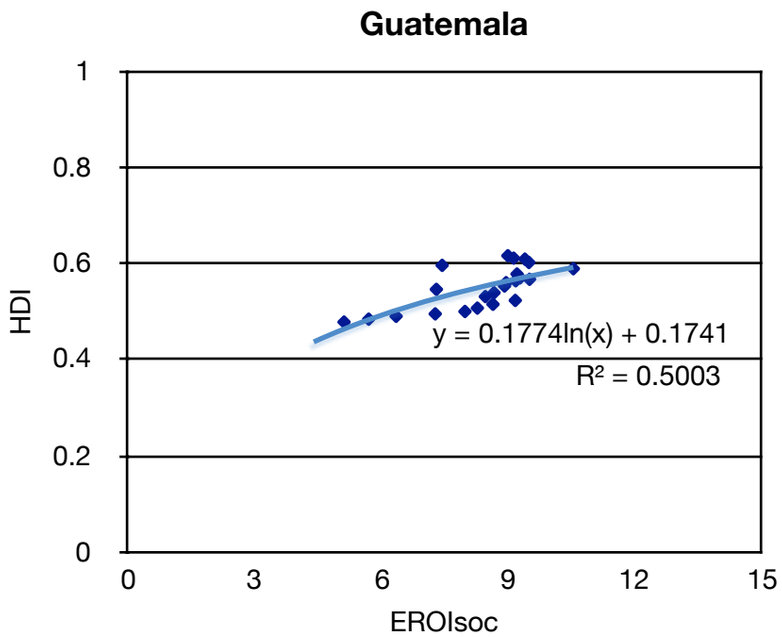


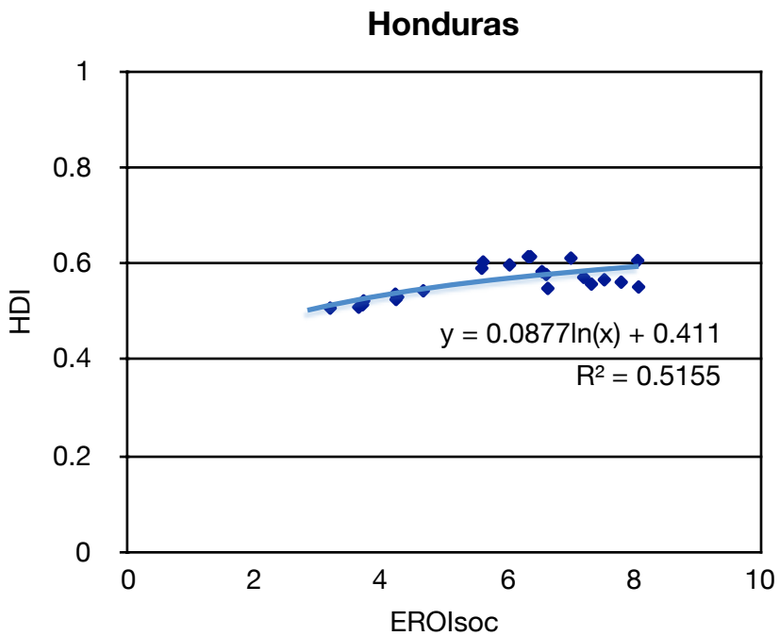
GJ vs EI over Time

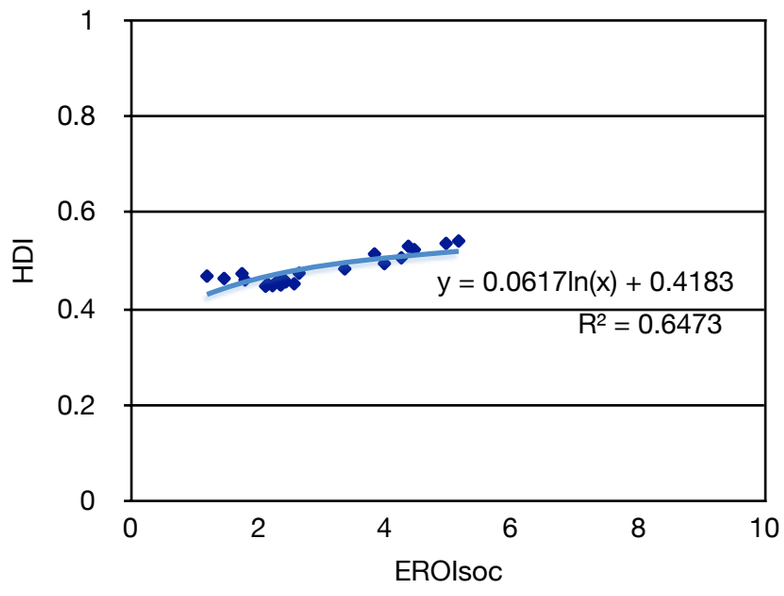


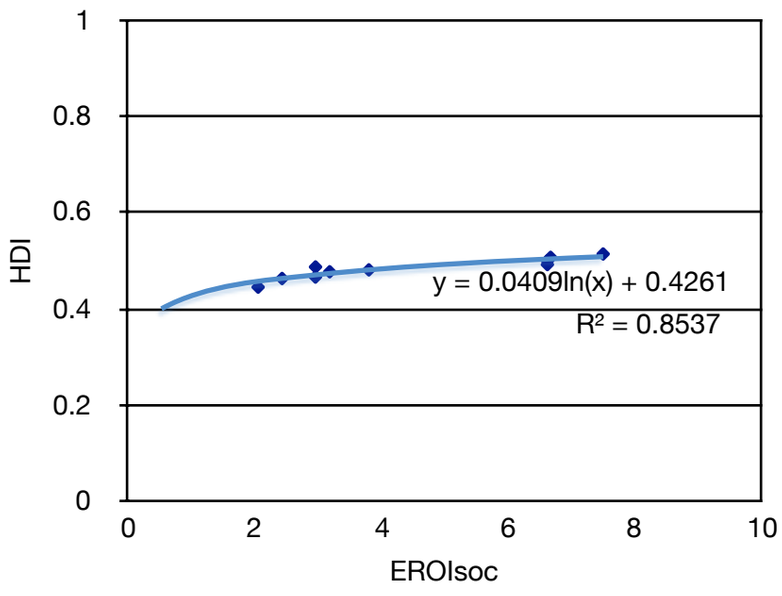
EROIsoc vs HDI

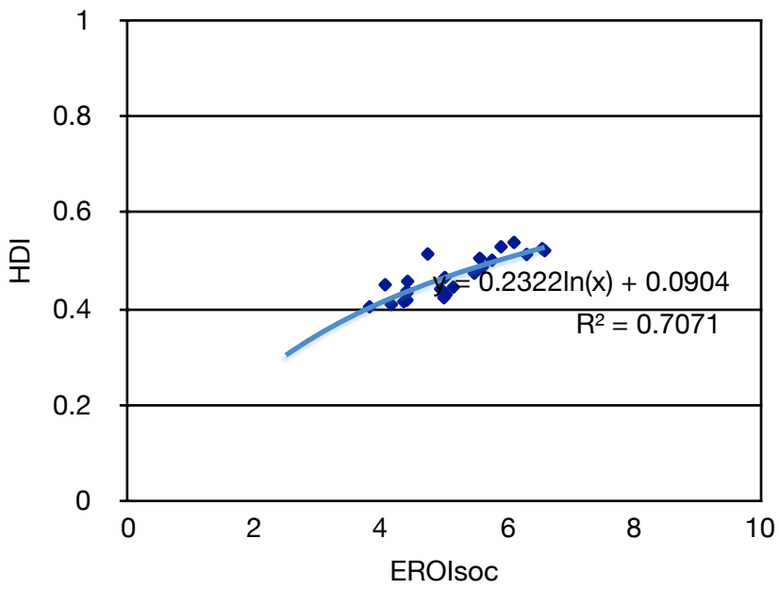




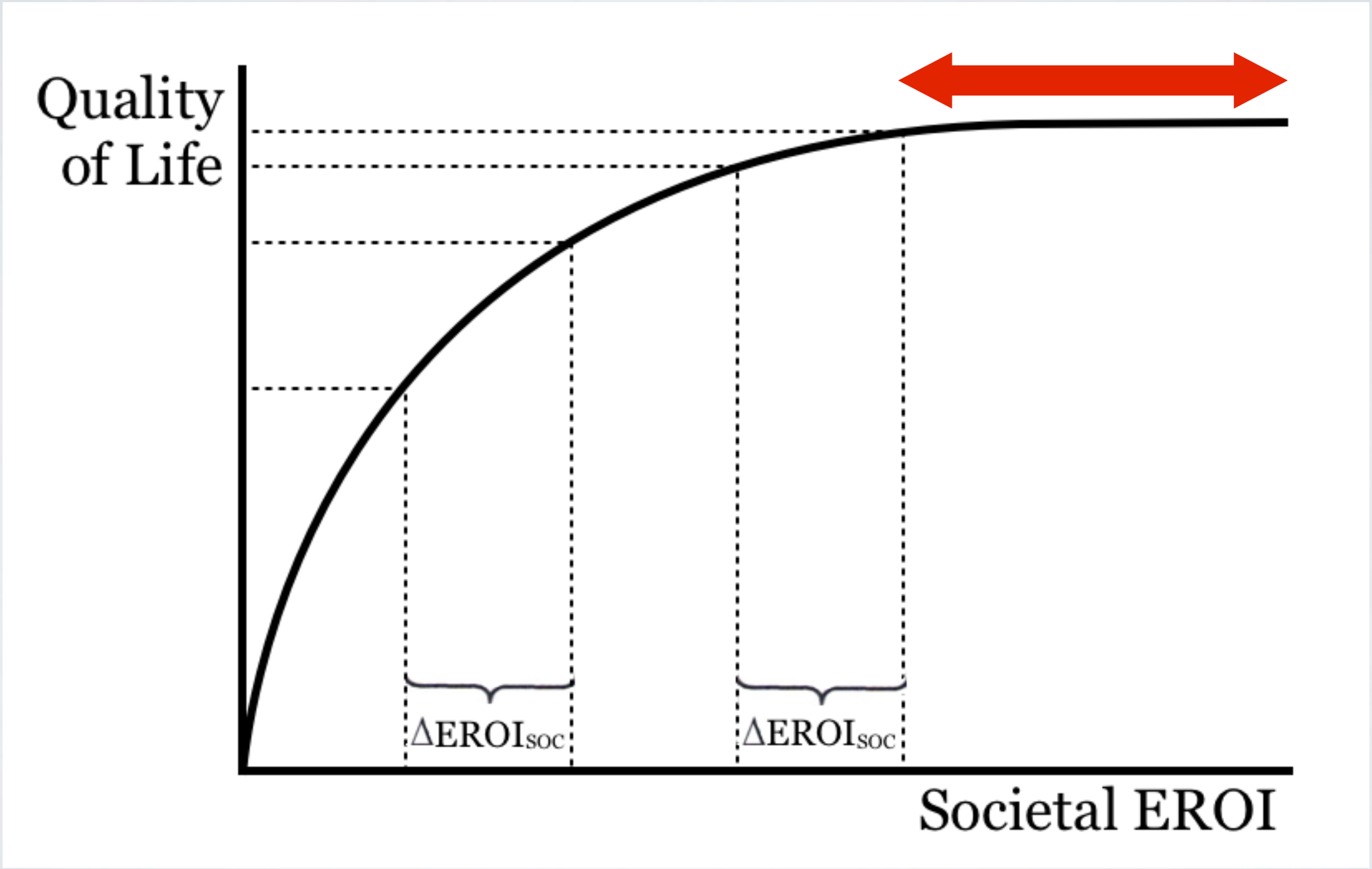




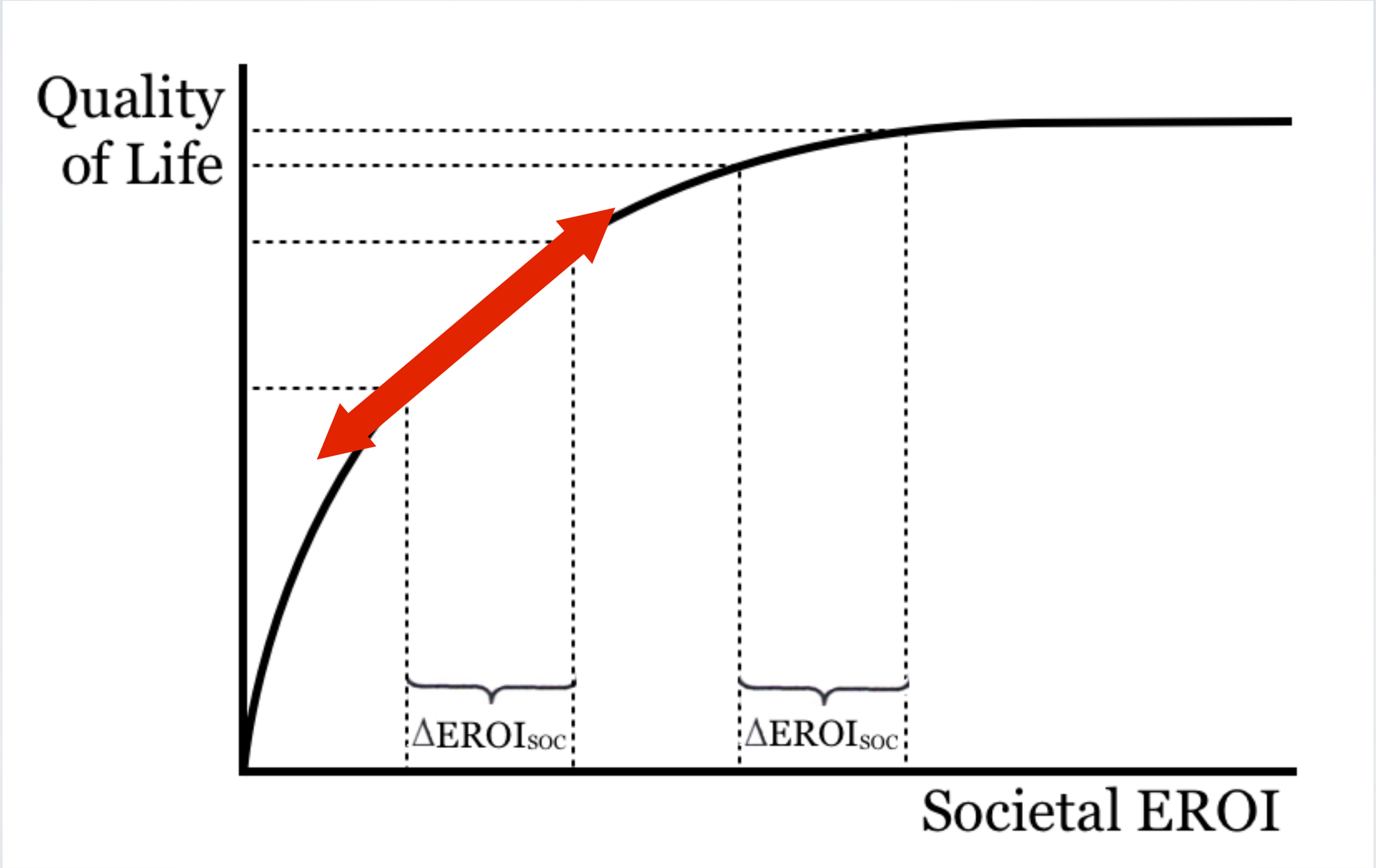




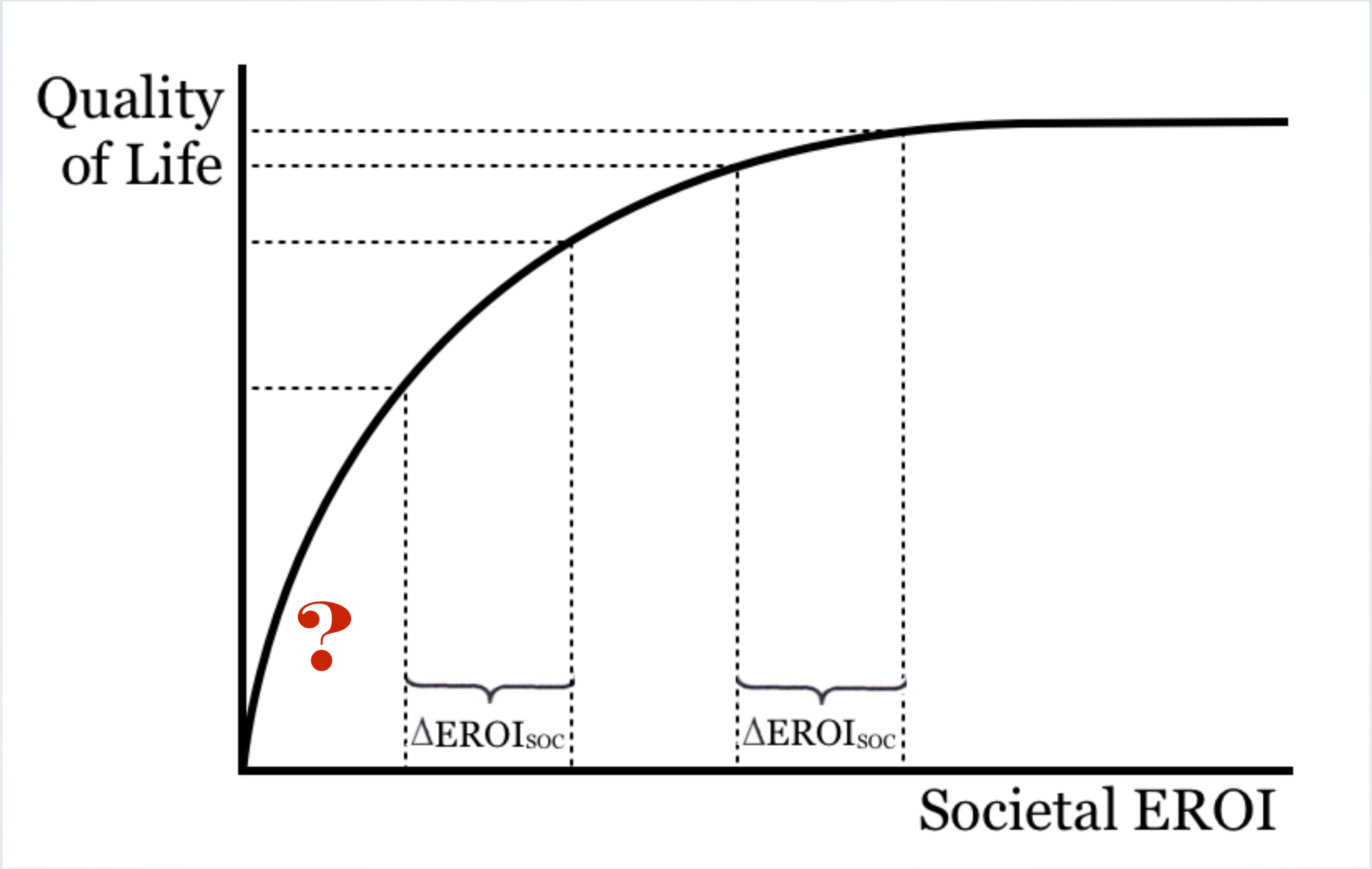
EROI AND THE DEVELOPED WORLD



EROI AND THE DEVELOPING WORLD

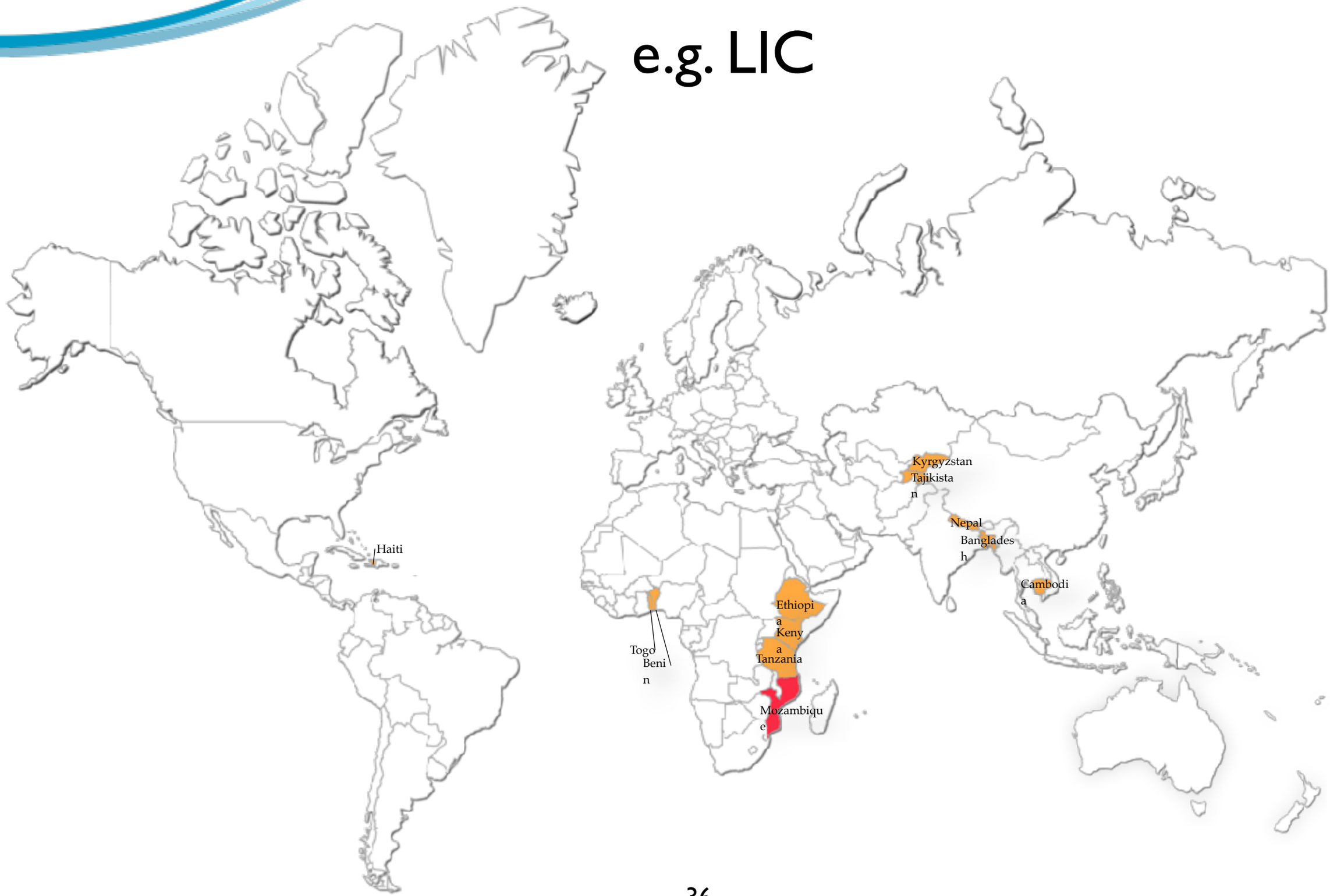


EROI AND THE DEVELOPING WORLD



Income Classifications

e.g. LIC



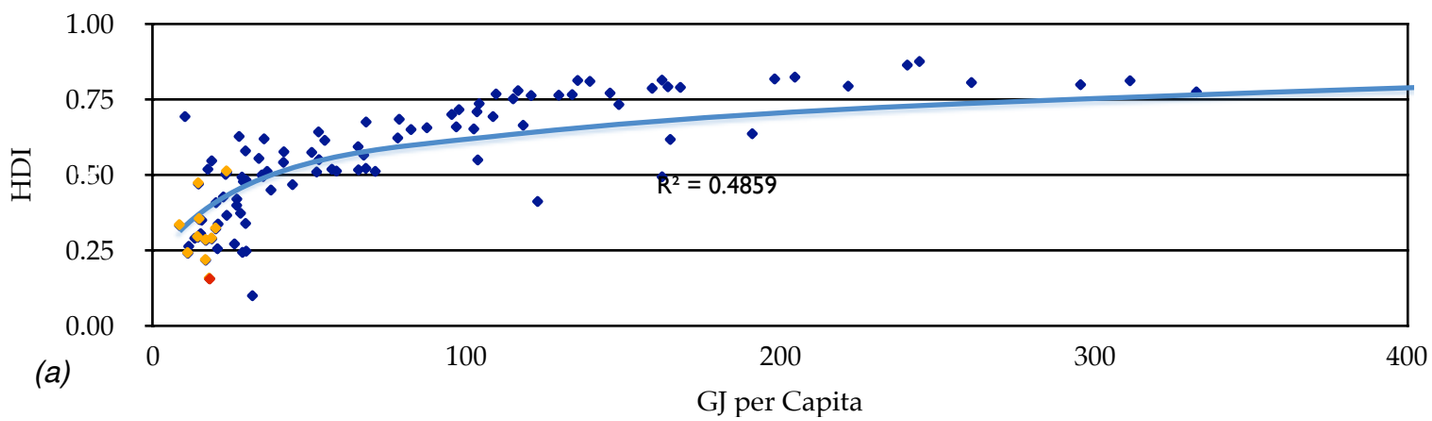


Figure 4.10: Regression of Human Development Index with (a) energy use per capita, (b) $EROI_{SOC}$ and (c) LEI values for LICs (Lambert et al. 2013).

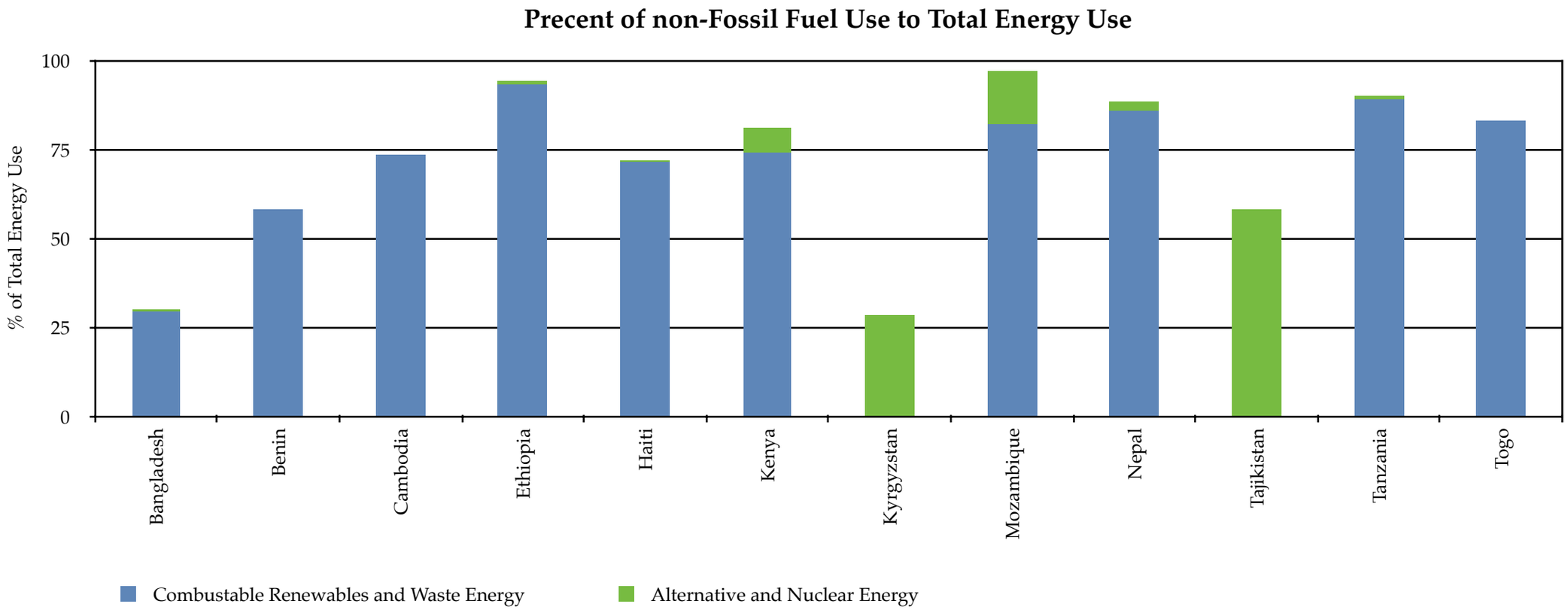
Table 4.2: Summary of energy availability indicators for net energy importing LIC nations (2009).

Country	Energy Use per Capita	$EROI_{SOC}$	Gini-Index	LEI	HDI
Bangladesh	8	9:1	31	0.08	
Benin	17	5:1	39	0.09	0.282
Cambodia	15	5:1	44	0.09	
Ethiopia	16	2:1	30	0.05	0.216
Haiti	11	6:1	60	0.06	
Kenya	20	4:1	48	0.08	
Kyrgyzstan	23	5:1	33	0.12	0.508
Nepal	14	4:1	47	0.06	
Tajikistan	14	7:1	34	0.10	0.469
Tanzania minus Zanzibar	19	3:1	n.a.	n.a.	
Togo	19	3:1	34	0.07	
Mean	**16**	**5:1**	**40**	**0.08**	
Median	**16**	**5:1**	**37**	**0.08**	
Standard Deviation	**4**	**2**	**10**	**0.02**	

Table 4.3: Summary of energy availability indicators for the net energy exporting LIC nation (2009).

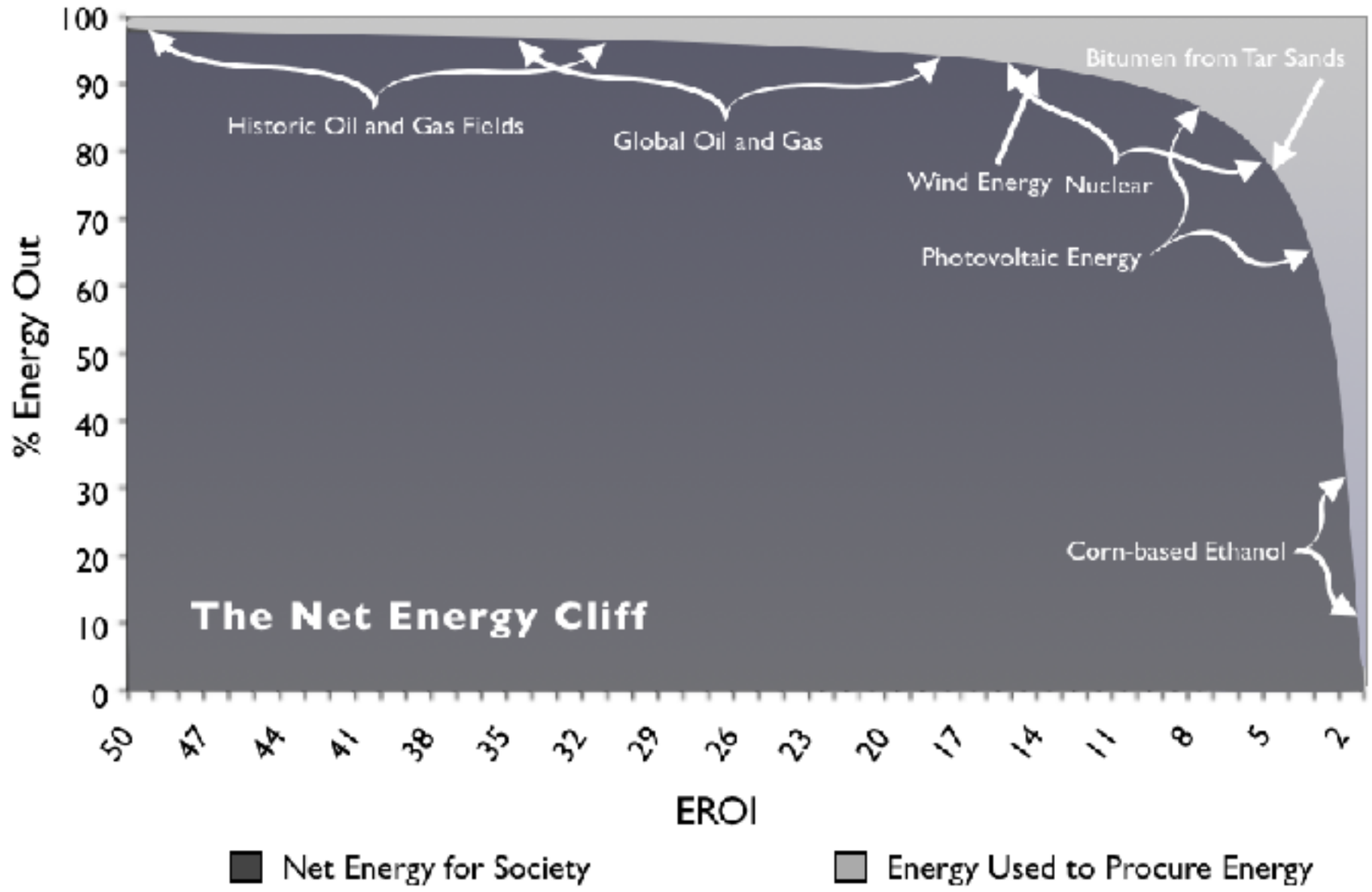
Country	Energy Use per Capita	$EROI_{SOC}$	Gini-Index	LEI
Mozambique	18	3:1	46	0.05

Energy /EROI makes the Difference



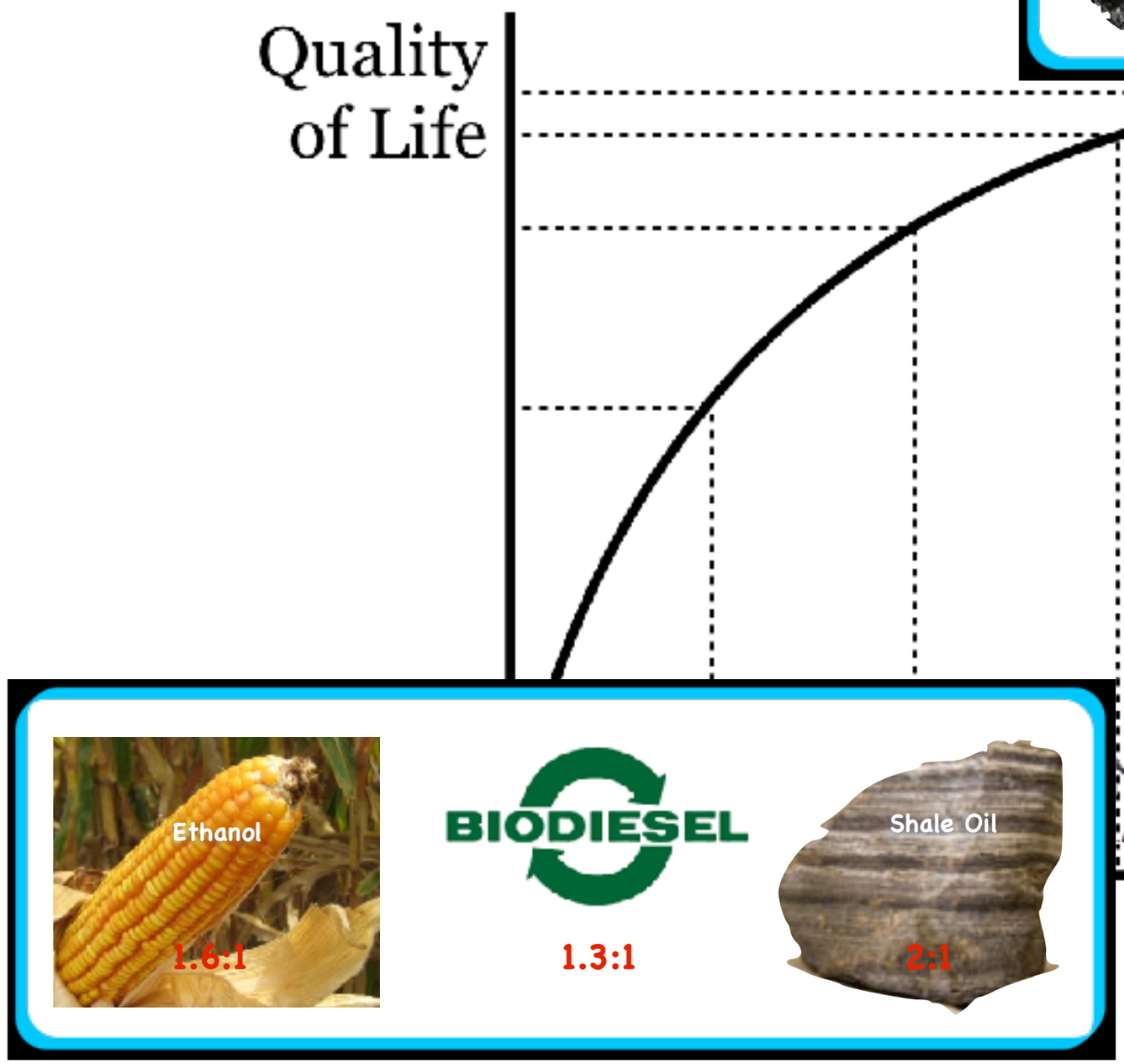
- they have lower population density
- lower population growth rates
- high EROI domestic energy

What does this mean for society?



NGEI

Quality of Life



$\Delta EROI_{SOC}$

Societal EROI

Questions and Comments