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SUPPLEMENTARY INFORMATION

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ECONOMIC DEVELOPMENT AND THE CARBON INTENSITY OF HUMAN WELL-BEING

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This is a 7 page PDF that includes (1) a table that lists all nations included in each of the four regional samples ("Supplementary Table 1"), (2) a table with the full regression results for the models presented in the paper ("Supplementary Table 2"), (3) a supplementary note that describes an additional sensitivity analysis that uses an alternative dependent variable ("Supplementary Note"), (4) a table with the full regression results for the sensitivity analysis described in the supplementary note ("Supplementary Table 3"), and (5) a figure labeled "Supplementary Figure 1" that plots the effects of GDP per capita on the alternative dependent variable, derived from the estimated models presented in Supplementary Table 3.

Supplementary Table 1. Countries Included in the Study

Africa	Asia	South and Central America	North America, Europe, and Oceania
Algeria	Bangladesh	Argentina	Albania
Benin	China	Barbados	Australia
Botswana	Hong Kong	Belize	Austria
Burkina Faso	India	Bolivia	Belgium
Burundi	Indonesia	Brazil	Bulgaria
Cameroon	Iran, Islamic Rep.	Chile	Canada
Cape Verde	Israel	Colombia	Cyprus
Central African Republic	Japan	Costa Rica	Denmark
Chad	Jordan	Cuba	Finland
Comoros	Korea, Rep.	Dominican Republic	France
Congo, Dem. Rep.	Malaysia	Ecuador	Greece
Congo, Rep.	Mongolia	El Salvador	Hungary
Cote d'Ivoire	Nepal	Guatemala	Iceland
Egypt, Arab Rep.	Oman	Guyana	Ireland
Ethiopia	Pakistan	Honduras	Italy
Gambia, The	Philippines	Nicaragua	Mexico
Ghana	Saudi Arabia	Panama	Netherlands
Guinea-Bissau	Singapore	Paraguay	New Zealand
Kenya	Sri Lanka	Peru	Norway
Mali	Syrian Arab Republic	Uruguay	Papua New Guinea
Mauritania	Thailand	Venezuela	Portugal
Mauritius	Turkey		Romania
Morocco			Spain
Mozambique			Sweden
Niger			Switzerland
Nigeria			United Kingdom
Rwanda			United States
Senegal			
Sierra Leone			
South Africa			
Sudan			
Swaziland			
Togo			
Tunisia			
Zambia			
Zimbabwe			

Supplementary Table 2. Prais-Winston Two-Way Fixed Effects Elasticity Models of the Effects of GDP per capita on the Carbon Intensity of Well-Being, 1970-2009

	Africa	Asia	South and Central America	North America, Europe, and Oceania
GDP per capita	-.068**	.047***	.024*	.126***
	(.025)	(.014)	(.012)	(.018)
GDP per capita	.006**	.010***	.002	-.007***
X 1975	(.002)	(.001)	(.003)	(.001)
GDP per capita	.009*	.023***	.012***	-.007***
X 1980	(.005)	(.002)	(.004)	(.001)
GDP per capita	.005	.020***	.022***	-.018***
X 1985	(.007)	(.002)	(.004)	(.002)
GDP per capita	-.013	.027***	.040***	-.017***
X 1990	(.008)	(.002)	(.005)	(.002)
GDP per capita	-.004	.035***	.044***	-.011***
X 1995	(.009)	(.002)	(.004)	(.002)
GDP per capita	.033***	.041***	.060***	-.007**
X 2000	(.010)	(.002)	(.004)	(.003)
GDP per capita	.053***	.047***	.072***	-.006**
X 2005	(.010)	(.002)	(.004)	(.002)
GDP per capita	.062***	.043***	.082***	-.001
X 2009	(.011)	(.002)	(.003)	(.002)
R-square	.994	.996	.999	.998
N (nations/observations)	36/324	22/198	21/189	27/243
Rho	.711	.618	.512	.436

Notes:
***p<.001 **p<.01 *p<.05 (two-tailed tests);
Prais-Winston regression models with AR(1) correction;
panel corrected standard errors in parentheses;
all variables are in base 10 logarithmic form;
models include unreported unit-specific and period-specific intercepts (two-way fixed effects)

Supplementary Note

In an additional analysis I employ a different measure for the dependent variable. The different measure is calculated by regressing life expectancy on per capita carbon emissions, and using the standardized residuals from the regression as an alternative to the carbon intensity of well-being (CIWB) ratio measure. Positive residuals indicate higher well-being relative to levels of per capita carbon emissions, while negative residuals indicate lower well-being relative to levels of per capita carbon emissions. While I focus here on the analysis of the standardized residuals, the use of unstandardized residuals yields identical substantive results since the two forms of residuals from the same regression model are perfectly correlated.

This residual approach is used in other studies on similar topics [1], and was initially developed by urban studies scholars who study "over-urbanization" [2, 3]. Some researchers caution against relying solely on a ratio as a dependent variable in situations where an independent variable might be highly or moderately correlated with the numerator or the dominator of the ratio dependent variable [4]. This could lead to an observed strong positive or negative effect of the independent variable on the ratio dependent variable, based on such a correlation, potentially leading to questionable findings. The residual approach safeguards against this potential problem [1, 3]. Thus, I follow the suggestion of an anonymous reviewer and estimate models with the standardized residuals as the dependent variable. I treat these models as a sensitivity analysis and a robustness check for the analysis of the CIWB ratio measure.

For the CIWB ratio measure used in the analysis in the main body of the paper, higher values correspond to higher levels of emissions per unit of well being. Thus, the CIWB ratio measure should be negatively correlated with the standardized residuals, since positive values for the residuals indicate higher well-being relative to level of per capita emissions, while negative values for the residuals indicate lower well-being relative to level of per capita emissions. For the sample of 36 nations in Africa (324 total observations), the two are correlated at -.992, and for the sample of 22 nations in Asia (198 total observations), the two are correlated at -.993. For the sample of 21 nations in South and Central America (189 total observations), the two are correlated at -.996, and for the sample of 27 nations in North America, Europe, and Oceania (243 total observations), the two are correlated at -.995.

Using Prais-Winston regression with panel corrected standard errors and an AR(1) correction, I estimate models for the standardized residuals for each of the four regional samples of nations (the same model that is estimated for the CIWB ratio measure for each of the regional samples). The model includes GDP per capita (base 10 logarithm), the interaction variables between GDP per capita (base 10 logarithm) and each time point, country-specific fixed effects and year-specific fixed effects.

Supplementary Table 3 provides full information for the models of the standardized residuals from 1970 to 2009 for the four samples of nations, and Supplementary Figure 1 graphs the estimated effects of GDP per capita on the standardized residuals, based on the models reported in Supplementary Table 3. The results are very consistent with the findings for the analysis of the CIWB ratio measure.

For the sample of nations in Africa, the estimated coefficient for GDP per capita in 1970 was .769, indicating that in the year 1970, level of economic development increased the level of well-being relative to per capita carbon emissions. This relationship remained stable in value until 1990, where it increased moderately (estimated coefficient in 1990 = 1.127), and then began to become less positive from 1995 until 2009 (estimated coefficient in 2009 = .226).

The analysis reveals similar patterns for the sample of nations in Asia and the sample of nations in South and Central America. For both samples, the effect of GDP per capita on the standardized residual was negative in the year 1970 (estimated coefficient of -.647 for Asia sample, estimated coefficient of -.326 for the South and Central America sample), indicating that in 1970 level of economic development decreased the level of well-being relative to carbon emissions per capita. Through time, the effect of GDP per capita became increasingly negative for both samples of nations, lasting through the endpoint of the study, the year 2009 (estimated coefficient of -1.180 for Asia sample, estimated coefficient of -1.438 for the South and Central America sample).

For the sample of nations in North America, Europe, and Oceania, the estimated coefficient for GDP per capita in 1970 was -2.048, and became modestly less negative through 1985 (estimated coefficient = -1.654). Then from 1990 through the end of the study period the estimated coefficient became increasingly negative, with an estimated coefficient for GDP per capita of -1.871 in 2009.

Overall, the estimated panel models of the standardized residuals yield results very similar to the analysis of the effects of economic development on the CIWB ratio measure for all four regional samples of nations. This sensitivity analysis provides added validity to the findings reported in the main body of the paper, and serves as a valuable robustness check.

References

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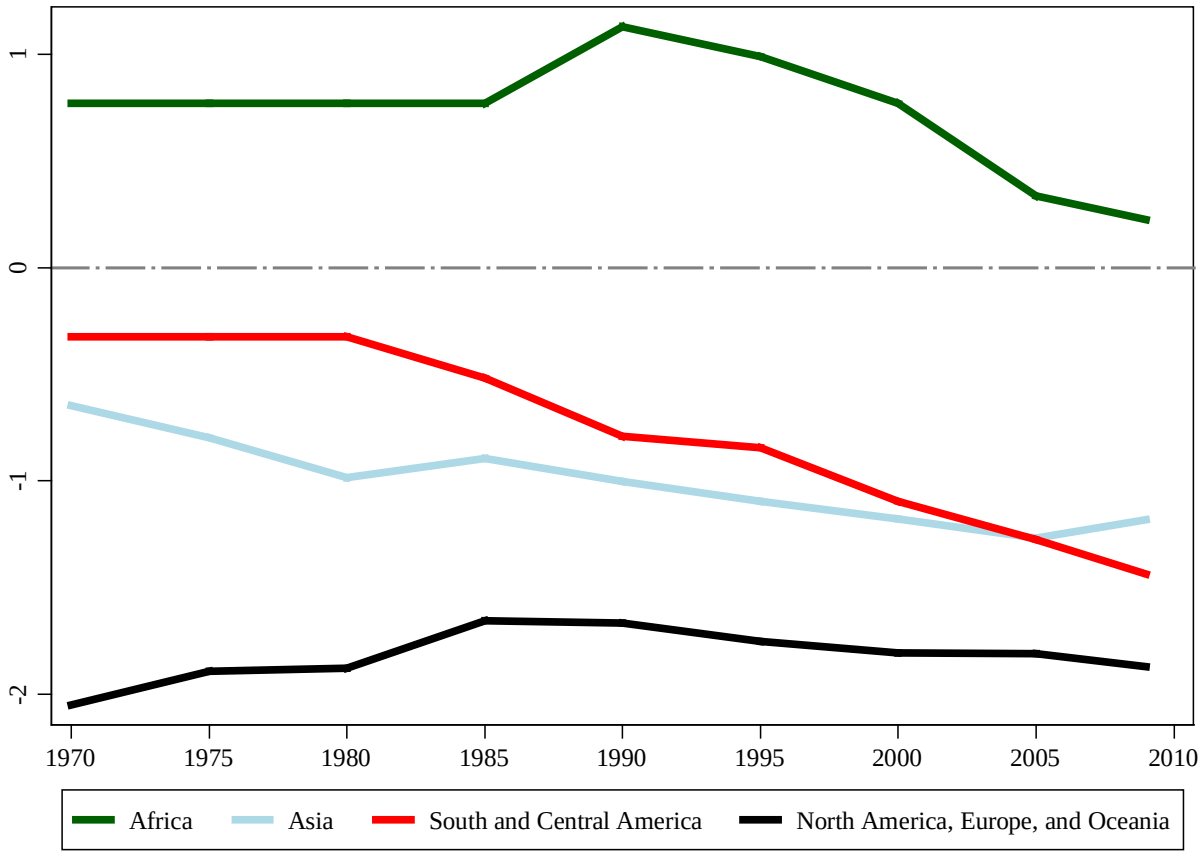
Supplementary Table 3. Prais-Winston Two-Way Fixed Effects Models of the Effects of GDP per capita on the Standardized Residuals From Life Expectancy Regressed on CO_2 per capita, 1970-2009

	Africa	Asia	South and Central America	North America, Europe, and Oceania
GDP per capita	.769*	-.647**	-.326#	-2.048***
	(.328)	(.214)	(.179)	(.274)
GDP per capita	-.024	-.150***	.040	.158***
X 1975	(.041)	(.026)	(.047)	(.014)
GDP per capita	-.001	-.338***	-.081	.169***
X 1980	(.069)	(.032)	(.058)	(.021)
GDP per capita	.084	-.248***	-.191**	.394***
X 1985	(.097)	(.033)	(.063)	(.025)
GDP per capita	.358***	-.355***	-.466***	.381***
X 1990	(.110)	(.036)	(.068)	(.035)
GDP per capita	.221#	-.450***	-.517***	.296***
X 1995	(.122)	(.037)	(.061)	(.037)
GDP per capita	-.206	-.531***	-.768***	.242***
X 2000	(.135)	(.037)	(.059)	(.044)
GDP per capita	-.432**	-.620***	-.948***	.237***
X 2005	(.139)	(.034)	(.054)	(.038)
GDP per capita	-.543***	-.533***	-1.112***	.177***
X 2009	(.142)	(.031)	(.053)	(.028)
R-square	.739	.740	.886	.904
N (nations/observations)	36/324	22/198	21/189	27/243
Rho	.714	.577	.557	.443

Notes:
***p<.001 **p<.01 *p<.05 (two-tailed tests); #p<.05 (one-tailed test);
models estimated with Prais-Winston regression with AR(1) correction;
panel corrected standard errors in parentheses;
GDP per capita in base 10 logarithmic form;
models include unreported unit-specific and period-specific intercepts (two-way fixed effects)



Supplementary Figure 1. Coefficients for the Estimated Effect of GDP per capita on the Standardized Residuals From Life Expectancy Regressed on CO_2 Per Capita, 1970-2009

Notes: the estimates are derived from 2-way fixed effects Prais-Winston regression models with panel corrected standard errors and AR(1) corrections; full information on the estimated models is provided in Supplementary Table 3; Africa sample includes 36 nations; Asia sample includes 22 nations; South and Central America sample includes 21 nations; North America, Europe, and Oceania sample includes 27 nations