Country Income, Sources of Carbon Emission, and Counterfactuals

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Research question

Does Environmental Kuznet's Curve apply similarly to all countries? Studies identify considerable heterogeneity among different countries or group of countries, assuming grouping criterion is known (e.g., regions, growth). What if grouping criterion is unknown?

Major contributions of the paper to the literature

1. Determines group membership based on latent (unobserved to the econometrician) country structures.
2. Controls for unobserved country characteristics and cross-country dependence.
3. Finds evidence of Kuznet's curve, bidirectional long run causality between emission and income, and compares groups in terms of achieving zero coal consumption.

Three Step Model

Consider a panel of $i = 1, \ldots, N$ countries and $t = 1, \ldots, T$ years, where y is carbon emission per capita, β is vector of parameters to estimate, x's are GDP per capita, GDP per capita squared, energy consumption per capita, and % of population live in urban areas. μ is unobserved country-specific feature, and ϵ is normal error.

$$y_{it} = \beta_i' x_{it} + \mu_i + \epsilon_{it}$$

Step 1: Country classification

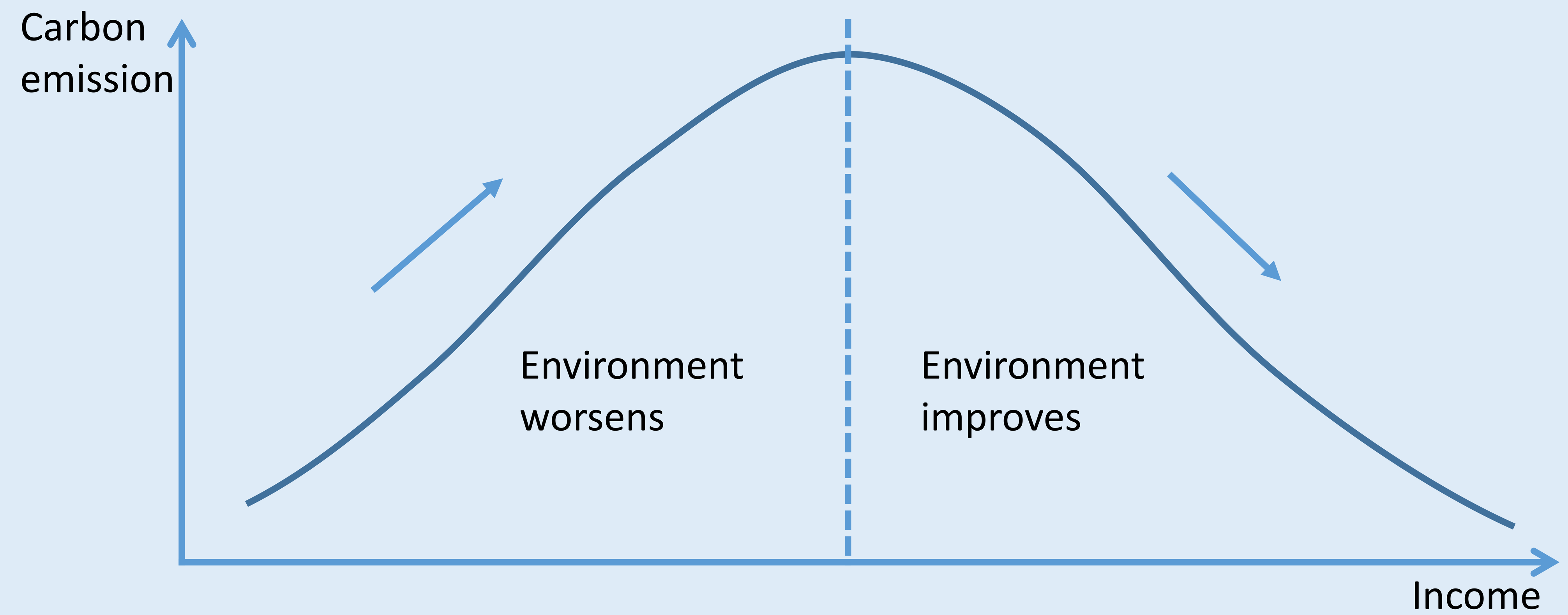
The model does not assume number of groups or group membership but finds them through penalized least squares (Su et al., 2016). We minimize the following function through iteration and solve for β and K, where K is the number of groups, α is a group-specific parameter, λ is the tuning parameter. We use half-panel Jacknife (Dhaene and Jochmans, 2015) for bias correction.

$$Min\ Q_{NT,\lambda}^{K}(\boldsymbol{\beta}, \boldsymbol{\alpha}) = \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}\frac{1}{2}(y_{it} - \beta_i' x_{it} - \mu_i)^2 + \frac{\lambda}{N}\sum_{i=1}^{N}\prod_{k=1}^{K}||\beta_i - \alpha_k||$$

Penalized Least Squares Estimation Results

	Dependent variable: Carbon emission per capita		
Variables	Pooled FE	Group 1	Group 2
GDP per capita	1.1653***	0.8415***	1.5598*
	(0.2677)	(0.2568)	(0.9412)
GDP²	-0.8998***	-0.4679*	-1.6625*
	(0.2626)	(0.2515)	(0.9456)
Energy cons.	0.6676***	0.6129***	0.5902***
	(0.0322)	(0.0383)	(0.0526)
Urbanization	-0.1574***	-0.0788**	-0.4973***
	(0.0366)	(0.0359)	(0.0829)

Note: *** Significant at 1%, ** significance at 5%, * significance at 10%. Standard errors in parentheses.



Carbon emission Kuznet's Curve

Major Findings

- Size and shape of Kuznet's curve vary by country groups. We derive the number and membership of groups: 95 countries fall into either of two groups below.
- Group 2 includes many of the Scandinavian countries. Member countries of Group 1 takes greater income to reach the turning point in the Kuznet's curve.
- Long run bidirectional causality between per capita income and carbon emission exists in both groups.
- Given per capita income, members of Group 2 can achieve zero coal consumption at lower level of renewable energy compared to Group 1.

Group Membership Estimated using Penalized Least Squares

Group 1 (77 countries)

Albania, Algeria, Angola, Argentina, Bahrain, Bangladesh, Benin, Bolivia, Botswana, Brazil, Bulgaria, Cameroon, Canada, Chile, China, Colombia, Congo, Dem. Rep., Congo, Rep., Costa Rica, Cote d'Ivoire, Cuba, Cyprus, Dominican Republic, Ecuador, Egypt, Arab Rep., El Salvador, Ethiopia, France, Ghana, Greece, Guatemala, Honduras, Hong Kong SAR (China), India, Indonesia, Iran, Iraq, Israel, Italy, Jamaica, Japan, Jordan, Korea, Rep., Lebanon, Luxembourg, Malaysia, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Myanmar, Nepal, New Zealand, Nicaragua, Nigeria, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Saudi Arabia, Senegal, South Africa, Spain, Sri Lanka, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, United Arab Emirates, United Kingdom, United States, Uruguay

Group 2 (18 countries)

Australia, Austria, Belgium, Brunei Darussalam, Denmark, Finland, Gabon, Iceland, Ireland, Kenya, Malta, Netherlands, Philippines, Poland, Portugal, Romania, Sweden, Switzerland

Sources of data

World Development Indicators (2016) and United States Energy Information Administration (2016). Balanced panel of 95 countries and 24 years.

Step 2: Short-run dynamics and long-run causality

This step takes 'cross-country dependence' into account and solves for Vector Error Correction Model estimates (Pesaran et al., 2006).

We also control for per capita energy consumption and % of population live in urban areas.

CCE mean-group estimation of the error correction models

	Error correction term$_{it-1}$		
Dep. variables	Pooled	Group1	Group2
Δ Carbon emission per capita	-1.516***	-1.380***	-1.714***
	(0.162)	(0.199)	(0.325)
Δ GDP per capita	-0.821***	-0.918***	-0.933***
	(0.061)	(0.093)	(0.152)

Notes: Error correction term derived from the long-run cointegrating relationship. Standard errors are in parentheses. *** Significance at 1%, ** significance at 5%, * significance at 10%.

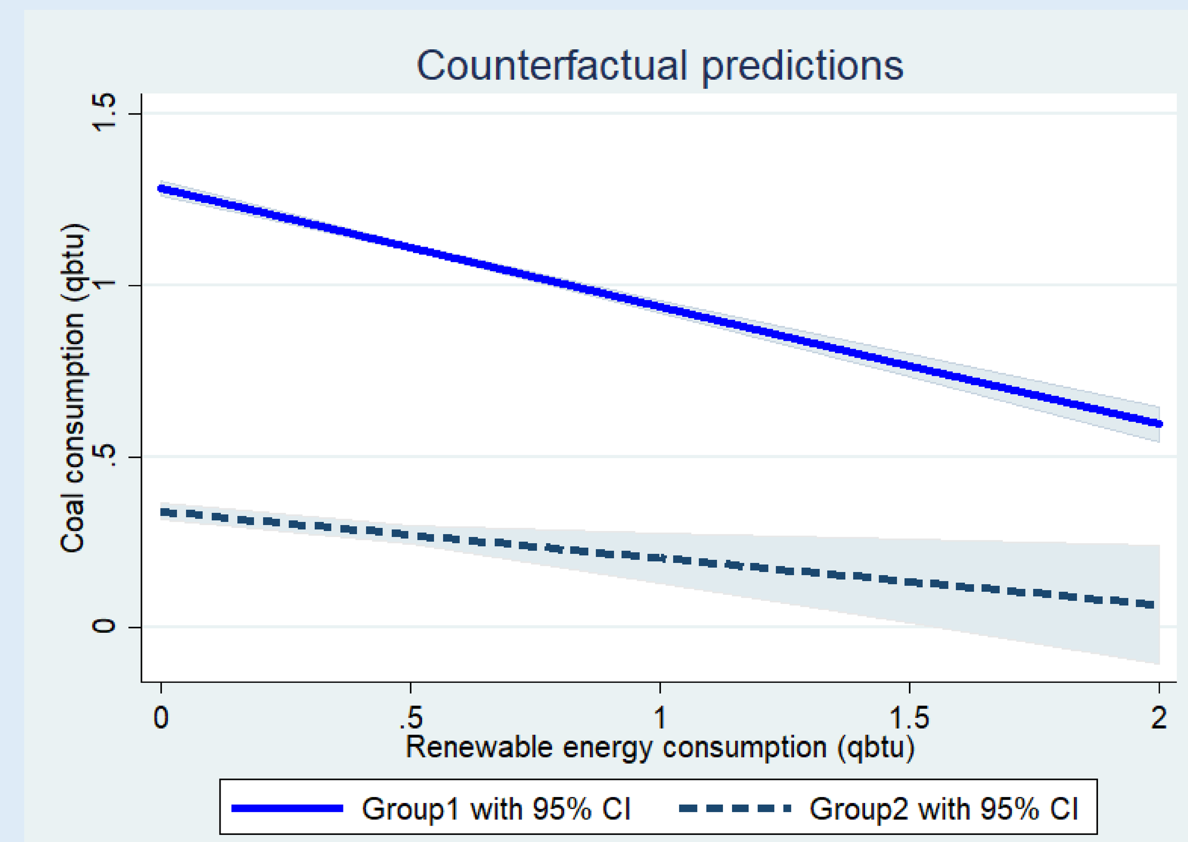
Step 3: Counterfactual

This part asks 'How much of renewable energy does a country need to reduce her coal consumption to zero?' We use individual dynamics model (Arellano and Bond, 1991) to find the trade-off.

Counterfactual estimates

	Dep. variable : Coal consumption (qbtu)		
Variables	Pooled	Group 1	Group 2
GDP per capita	0.048***	0.116***	0.023*
	(0.013)	(0.027)	(0.014)
Natural gas consumption (qbtu)	-0.085***	-0.088***	-0.052*
	(0.010)	(0.013)	(0.028)
Renewable energy consumption (qbtu)	-0.352***	-0.344***	-0.136***
	(0.014)	(0.018)	(0.05)
Oil consumption (qbtu)	0.204***	0.186***	0.025
	(0.009)	(0.013)	(0.023)

Notes: Qbtu stands for quadrillion British thermal unit. *** Significance at 1%, ** significance at 5%, * significance at 10%.



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