

Revisiting carbon Kuznets curves with
endogenous breaks modeling: Evidence of
decoupling and saturation (but few
inverted-Us) for individual OECD
countries.

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Background

- Do emissions rise then fall with development?
- Might not expect an inverted-U for CO₂
- Yet, several studies found in-sample turning points
 - (Schmalensee et al. 1998; Agras & Chapman 1999; Martinez-Zarzoso & Bengochea-Morancho 2004; Galeotti et al. 2006; Dijkgraaf & Vollenbergh 2004; Azomahou et al. 2006)

Examining Nonlinearities

- Typical approach: polynomial regressions (e.g., GDP² → EKC)

$$\ln(I/P)_{it} = \alpha_i + \gamma_t + \beta_1 \ln(A)_{it} + \beta_2 (\ln(A))_{it}^2 + \beta_3 \ln(Z)_{it} + e_{it}$$
$$\tau = \exp(-\beta_1 / (2\beta_2))$$

- Inappropriate if regressor is nonstationary (e.g., income)
- Polynomial structure not flexible
 - Semi-log relationship is not nested
 - Doesn't allow for nonlinear, but always positive relationship

Literature

- Panels w/parametric methods
 - Wagner (2008): defactored regressions
 - Stern (2010): between estimator
 - Liddle (2015): heterogeneous, mean-group estimator robust to csd

Literature

- Alternative (to quadratic) nonlinear forms
 - Galeotti et al., 2006; Wang 2013
- Fully nonparametric/semi-parametric methods
 - Azomahou et al., 2006; Bertinelli & Strobl 2005
- Linear spline or additive mixed model regressions
 - Schmalensee et al., 1998; He & Richard 2010; Zanin & Marra 2012; Liao & Cao 2013

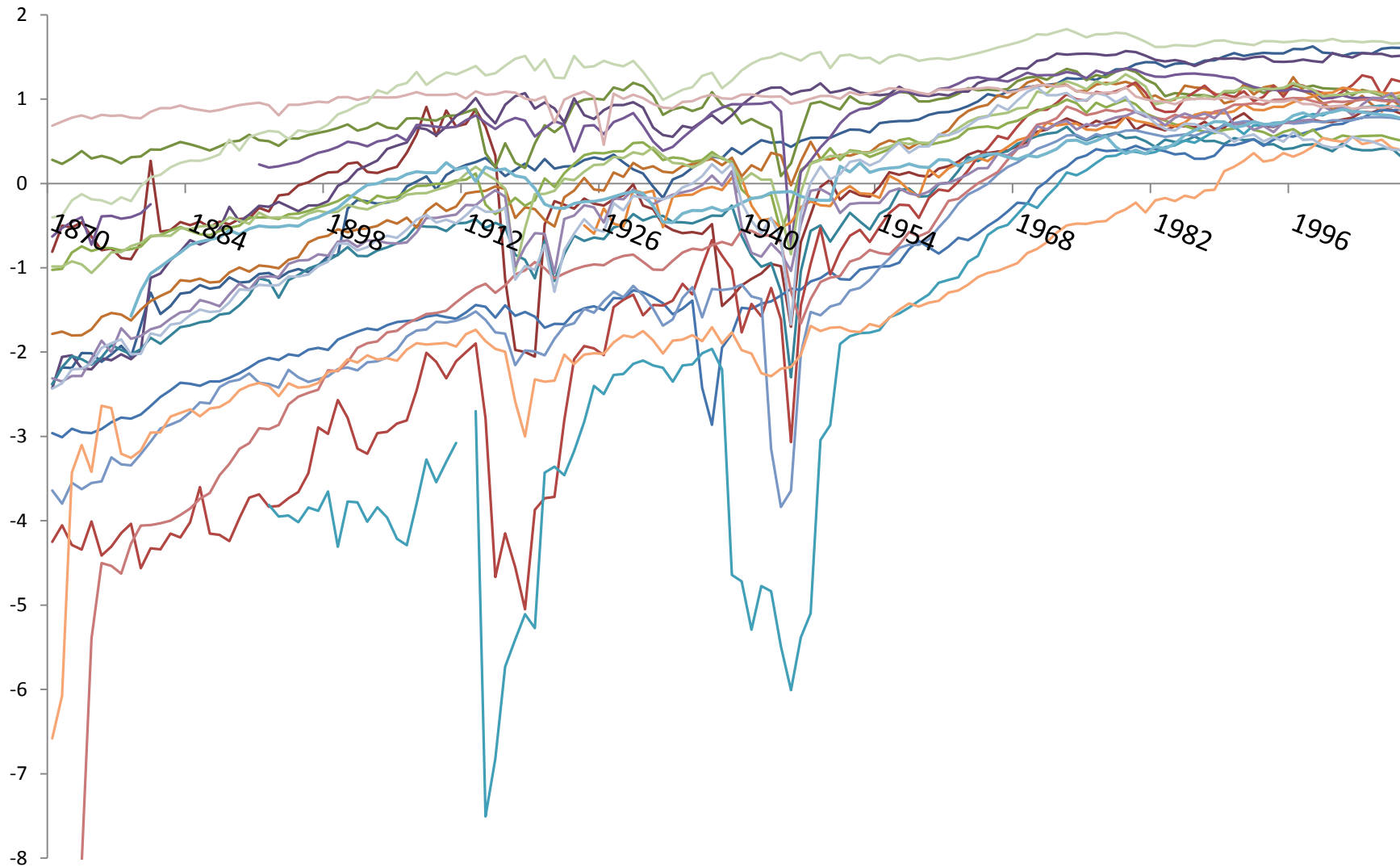
Our Proposal

- CO₂ emissions per capita & GDP per capita relationship individually, for 23 OECD countries
- Reduced-form, linear model that allows for multiple endogenously determined breaks

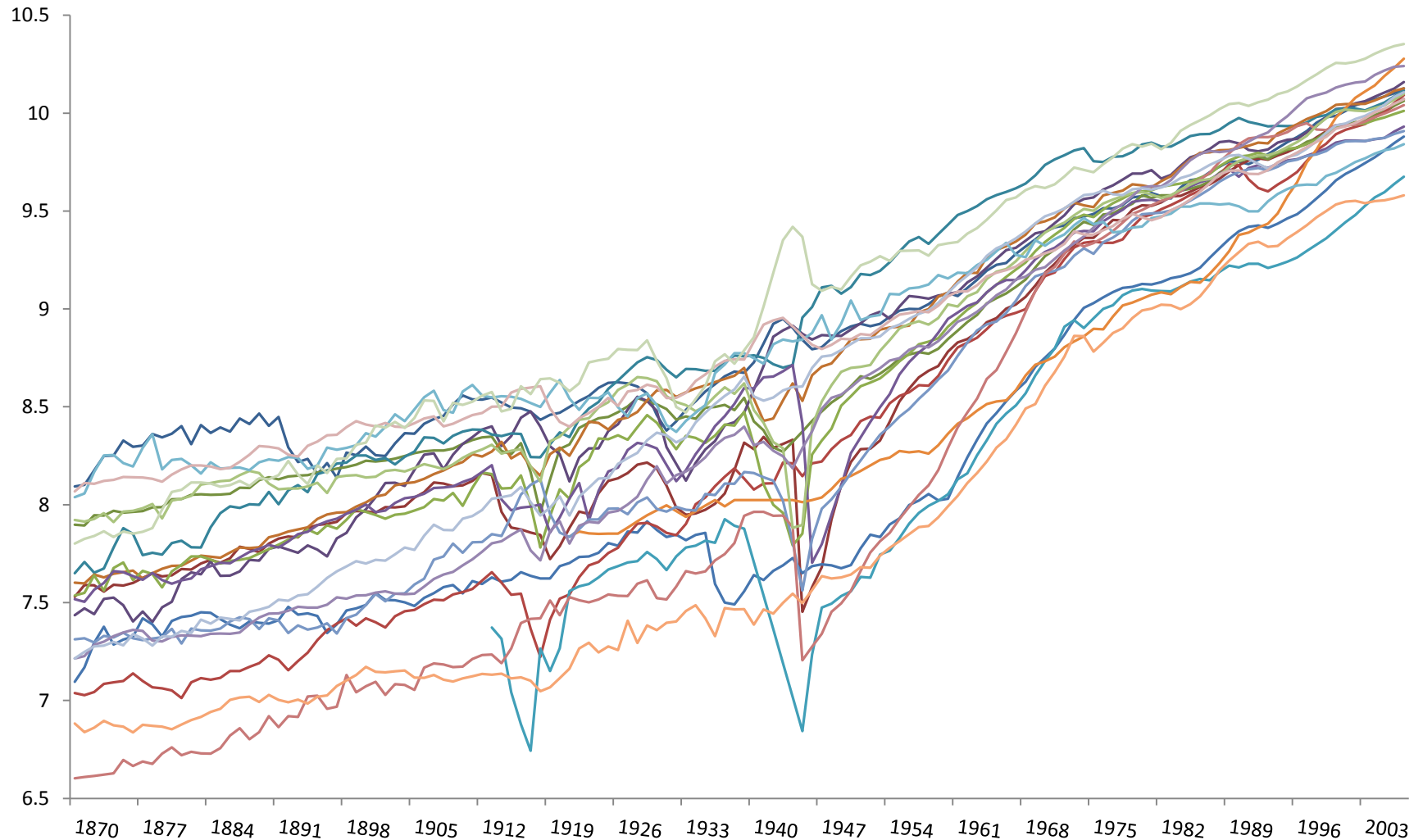
Advantages

- Highly flexible; does not presume relationship *a priori*
- Avoids nonlinear transformation of integrated income
- Accounts for nonstationarity & cointegration
- Regime change more realistic model of transitions than smooth, continuous curvature
- Analyze individual countries' evolution of environment-income relationship
 - Avoids heterogeneity & cross-sectional dependence

NL CO₂ emissions per capita 1870-2007



NL real GDP per capita 1870-2007



Data

- 23 OECD countries
- 1950-2010
- CO₂ emissions per capita—Carbon Dioxide Information Analysis Center
- Real GDP per capita—Penn World Tables
- Natural logs


Methods & Procedure

- Harvey et al. (2013) unit root test
 - Two endogenous breaks of different magnitudes
- If series different order of integration
 - Decoupling already occurred → no further analysis
- If both $I(0)$
 - Bai & Perron (1998, 2003) estimation with multiple endogenous breaks
 - stationary regressors
- If both $I(1)$
 - Kejriwal & Perron (2010) update
 - $I(1)$, cointegrated regressors

Unit Root Test Results

- CO₂ & GDP different order of integration
 - Australia, Denmark, Finland, France, & Sweden
- CO₂ & GDP both $I(0)$
 - Austria & Switzerland

Endogenous breaks regressions, LN GDP p.c. & LN CO₂ p.c., 1950-2010

		Regime 1	Regime 2	Regime 3	Descriptive pattern
	Breaks	δ_1	δ_2	δ_3	
Austria	1980	0.79**	0.32**		Saturation
Canada	1969, 1981	0.92**	0.24*	0.22**	Saturation
Greece	1982, 1995	1.48**	2.51**	0.42**	Saturation
Ireland	1970	1.16**	0.33**		Saturation
Italy	1971	1.83**	0.30**		Saturation
Japan	1977	1.10**	0.41**		Saturation
New Zealand	1984	0.64**	0.47**		Saturation
Netherlands	1981	1.19**	0.11*		Saturation
	1981, 1996	1.18**	0.50**	-0.07	Saturation → decoupling
Hungary	1962, 1989	1.24**	0.61**	-0.04	Saturation → decoupling
USA	1969, 1979	0.58**	0.03	0.02	Decoupling

Endogenous breaks regressions, LN GDP p.c. & LN CO₂ p.c., 1950-2010

		Regime 1	Regime 2	Regime 3	Descriptive pattern
	Breaks	δ_1	δ_2	δ_3	
Belgium	1981, 1997	0.38**	0.18#	-1.05**	CKC
Germany	1962, 1978	0.68**	0.22**	-0.80**	CKC
Switzerland	1974, 1993	1.69**	0.01	-0.54**	CKC
UK	1973	0.18**	-0.23**		CKC
Poland	1989	0.88**	-0.19**		CKC
	1989, 1999	1.13**	-1.92**	3.29**	N

Endogenous breaks regressions, LN GDP p.c. & LN CO₂ p.c., 1950-2010

		Regime 1	Regime 2	Regime 3	Descriptive pattern
	Breaks	δ_1	δ_2	δ_3	
Norway	1969, 1989	0.70**	2.48**	1.37**	?
Portugal	1988	1.09**	0.99**		?
Spain	1969, 1985	0.80**	1.36**	0.85**	?

Summary of Results/Patterns

- Saturation (8)
 - Austria, Canada, Greece, Ireland, Italy, Japan, Netherlands (1 break), New Zealand
- Decoupling (8)
 - Australia, Denmark, Finland, France, Hungary, Netherlands (2 breaks), Sweden, USA
- Carbon Kuznets Curve (4)
 - Belgium, Germany, Switzerland, UK
- No transition, still strong positive relationship (4)
 - Norway, Poland, Portugal, Spain

Endogenous breaks regressions, LN GDP p.c. & LN SO₂ p.c., 1950-2005

	Breaks	Regime 1	Regime 2	Regime 3	Descriptive pattern
		δ_1	δ_2	δ_3	
Belgium	1969, 1982	1.12**	-1.56**	-3.71**	SKC
Canada	1972, 1992	-0.04	-2.01**	-0.72**	SKC
Denmark	1976, 1993	0.89**	-3.14**	-11.41**	SKC
Finland	1976, 1991	0.90**	-2.60**	-1.22**	SKC
France	1975, 1988	0.63**	-6.81**	-5.23**	SKC
Germany	1989	-0.13	-14.13**		SKC
Hungary	1965, 1988	1.06**	-0.59**	-2.29**	SKC
Ireland	1967	1.87**	-0.84**		SKC
Italy	1975, 1988	1.93**	-2.34**	-6.14**	SKC
Japan	1969, 1981	0.96**	-4.93**	-0.82**	SKC
Korea	1975, 1992	2.542**	0.20	-2.54**	SKC
Luxembourg	1978, 1993	2.49**	-0.90**	-2.97**	SKC
Netherlands	1967, 1981	1.69**	-3.10**	-3.87**	SKC
Norway	1969, 1981	0.63**	-2.27**	-2.67**	SKC
Poland	1989	0.92**	-1.91**		SKC
Portugal	1992	0.98**	-0.67#		SKC
Sweden	1973, 1989	0.34#	-6.40**	-3.45**	SKC
UK	1988	-0.68**	-3.73**		SKC
USA	1969, 1986	0.32**	-1.93**	-1.98**	SKC

Timing of Breaks

- 18 Countries produced 29 breaks
- 12 Breaks during global/regional shocks
 - 1989, fall of Berlin Wall
 - 1973-1974, 1st oil crisis
 - 1979-1981, 2nd oil crisis
 - 1975-1978, intervening period of high oil prices
- 8 Breaks occurred in 1971 or earlier
- Shared timing/external shocks important
 - (Moomaw & Unruh 1997; Volleberg et al. 2009; Stern 2010; He & Richard 2010; Liddle 2012)

Conclusions

- Endogenous breaks modeling
 - Does not impose functional form *a priori*
 - Estimates elasticities for different regimes
 - Robust to nonstationarity & cointegration
 - Avoids nonlinear transformation of $I(1)$ income
 - Analyzes countries individually

Conclusions

- Most OECD countries exhibit either decoupling or saturation
- Importance of shared timing
- Finding of CKC is country specific

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- USAEE Working Paper No. 14-178. Available via SSRN. <http://ssrn.com/abstract=2513514>
- Liddle & Messinis. Revisiting sulfur Kuznets curves with endogenous breaks modeling. Economic Modelling, 49, 278-285.
<http://authors.elsevier.com/a/1R4VcyGFs2Kyj>

Panel Analysis: Liddle. 2015. What are the carbon emissions elasticities for income and population? Global Environmental Change, 31, 62-73.