International Technology Spillovers and Developing Country Carbon Emissions

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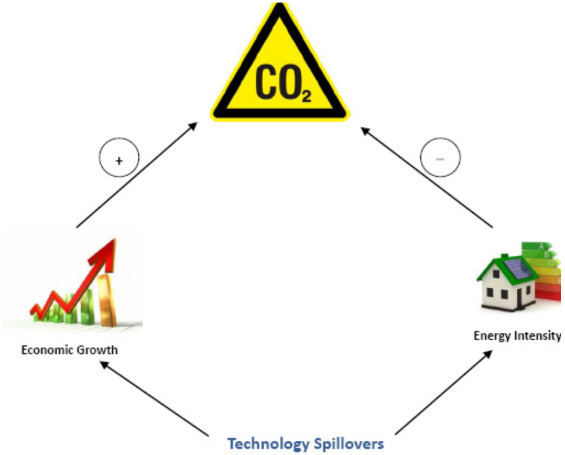
Objective

To investigate the effects of international knowledge spillovers on developing countries' CO_2 emissions



Literature review

- International technology spillovers
  - The effects of international technology spillovers on economic growth and productivity (e.g., Coe et al., 1997; Xu and Wang, 1999; Scheider, 2005)
  - Main conduits of international transmission being foreign direct investment (FDI) and trade in capital goods (equipment and machinery)
  - We focus on capital goods imports, as they are an important source of technical change (Jaffe et al., 2005)
- Empirical evidence of effects of technology transfer on energy intensity and carbon intensity are few
  - The effects of spillovers on energy intensity, not consistent results
    - Favorable effects of inward FDI (Mielnik and Goldemberg, 2002)
    - Not significant effects of inward FDI (Hübler and Keller, 2010)
  - The impact of technology diffusion on carbon intensity are even fewer (Kretschmer et al., 2010)
- The effects of endogenous technical change on the environment through international spillovers have been examined by the modelling community in the field of climate change economics (e.g. Bosetti et al., 2008; Leimbach and Baumstark, 2010)

Approach

- Our strategy: an empirical approach, focusing on developing countries
  - Develop empirically-grounded spillover functions
    - Technology assumed to spill over from developed country i to developing country j in year t in proportion to the $i \rightarrow j$ "total factor productivity (TFP) gap": $A_{i,t}/A_{j,t}$
    - With $i \rightarrow j$ capital goods trade $M_{i,j,t}$, year-t technology spillover is $X_{i,j,t} = M_{i,j,t} \max[1, A_{i,t}/A_{j,t}]$
    - Cumulative impact of embodiment of imported technology in durable capital goods given by a perpetual inventory formulation of a country-specific "spillover stock": $S_{j,t+1} = \sum_i X_{i,j,t} + (1 - \delta^M) S_{j,t}$
  - Technology spillovers raises the productivity of receiving countries' aggregate capital stock, therefore we assume that the key effect will be the interaction term

    Carraro and De Cian (2012) find that capital goods imports from OECD countries are an important source of technical change and 1% increase in machinery imports boosts capital-augmenting technical change by 0.027%

Approach

- Our starting point is the Kaya Identity:

$$\underbrace{C}_{\substack{CO_2\\ \text{Emissions}}} = \underbrace{C/E}_{\substack{\text{Emission}\\ \text{Intensity}}} \times \underbrace{E/Y}_{\substack{\text{Energy}\\ \text{Intensity}}} \times \underbrace{Y/L}_{\substack{\text{Labor}\\ \text{Productivity}}} \times \underbrace{L}_{\substack{\text{Labor}\\ \text{Supply}}}$$

- A panel of 56 developing countries over the period 1972-2009.

Model

$$\log{(C/E)}_{i,t} = \alpha_i^{CE} + \theta_t^{CE} + \beta_1^{CE} \log{(Y/L)}_{i,t-1} + \beta_2^{CE} \log{(Y/L)}_{i,t-1}^2 + \beta_3^{CE} \log K_{i,t-1} + \beta_4^{CE} S_{i,t-1} + \beta_5^{CE} S_{i,t-1} \cdot \log K_{i,t-1} + \mathbf{Z}\boldsymbol{\gamma}^{CE} + \varepsilon_{i,t}^{CE} \quad (1a)$$

$$\log{(E/Y)}_{i,t} = \alpha_i^{EY} + \theta_t^{EY} + \beta_1^{EY} \log{(Y/L)}_{i,t-1} + \beta_3^{EY} \log K_{i,t-1} + \beta_4^{EY} S_{i,t-1} + \beta_5^{EY} S_{i,t-1} \cdot \log K_{i,t-1} + \mathbf{Z}\boldsymbol{\gamma}^{EY} + \varepsilon_{i,t}^{EY} \quad (1b)$$

$$\log{(Y/L)}_{i,t} = \alpha_i^{YL} + \theta_t^{YL} + \beta_1^{YL} \log L_{i,t-1} + \beta_2^{YL} \log K_{i,t-1} + \beta_3^{YL} S_{i,t-1} + \beta_4^{YL} S_{i,t-1} \cdot \log K_{i,t-1} + \mathbf{Z}\boldsymbol{\gamma}^{YL} + \varepsilon_{i,t}^{YL} \quad (1c)$$

- α: Country effects
- θ: Year effects
- Y/L: GDP per labour
- S: Embodied spillover stocks
- K: Physical capital stocks
- Control variables Z γ:
  - Sectoral (agriculture, industry, service, transportation sector)GDP shares, United Nations data
  - Human capital, Barro and Lee(2010)
  - POLITY2 (proxy for institutional quality), Marshall et al.,(2010)

Key Hypotheses

1. Spillovers' positive impacts on developing nations' economic expansion have exerted a first-order positive effect on their emissions through the growth channel
   - We would expect to see a large and positive coefficient on spillover-capital interaction in the Y/L regression
2. Spillovers have undoubtedly contributed to energy efficiency improvements in developing countries, but the extent of this effect has not previously been characterized
   - We hope to see a negative and significant coefficient on spillover-capital interaction in the E/Y regression
3. The effects of spillovers on the mix of fuels used in developing countries is unknown
   - No prior for the spillover-capital interaction in the C/E regression
4. Developing countries' emissions have expanded faster than those of developed nations, so we would expect effect (1) to dominate effect (2)

Estimation Results

Dependent variable: Log E/Y

	(1)	(2)	(3)	(4)
Log GDP Per Worker (-1)	-0.485***	-0.481***	-0.483***	-0.400***
	(0.0641)	(0.0643)	(0.0642)	(0.0848)
Log K Stock (-1)	0.134***	0.131***	0.133***	0.0528
	(0.0635)	(0.0628)	(0.0634)	(0.0957)
Trade Spillover Stock (-1)	-0.0892***	0.193		
	(0.0345)	(0.377)		
Trade Spillover Stock (-1)		-0.0177	-0.00572***	-0.00606***
$\times$ Log K Stock (-1)		(0.0225)	(0.00202)	(0.00232)
Polity2	-0.00322	-0.00344	-0.00329	-0.00191
	(0.00309)	(0.00307)	(0.00310)	(0.00191)
Human Capital	0.0495	0.0485	0.0493	0.0246
	(0.0380)	(0.0378)	(0.0380)	(0.0293)
FDI Spillover Stock(-1)				0.000000317
				(0.00000120)
Sectoral Industry Shares	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes
Observations	2089	2089	2089	1196
Number of groups	56	56	56	55
R-sq.	0.153	0.155	0.153	0.185

Within-group estimator; Robust standard errors in parentheses; * $p < 0.1$, *** $p < 0.05$

Estimation Results

Dependent variable: Log C/E

	(1)	(2)	(3)
Log GDP Per Worker (-1)	-1.444***	-1.506***	-1.346***
	(0.270)	(0.280)	(0.222)
Log GDP Per Worker (-1) Sq.	-0.149***	-0.157***	-0.141***
	(0.0266)	(0.0277)	(0.0202)
Log K Stock (-1)	0.271***	0.261***	0.184
	(0.0887)	(0.0867)	(0.127)
Trade Spillover Stock (-1)	-0.0496	0.817***	0.652*
	(0.0426)	(0.334)	(0.326)
Trade Spillover Stock (-1) × Log K Stock (-1)		-0.0546***	-0.0374*
		(0.0213)	(0.0190)
Polity2	0.000131	-0.000533	-0.000228
	(0.00336)	(0.00344)	(0.00339)
FDI Spillover Stock (-1)			-0.00000279*
			(0.00000155)
Sectoral Industry Shares	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
R-sq.	0.303	0.315	0.297
Observations	2089	2089	1196
Number of groups	56	56	55

Within-group estimator; Robust standard errors in parentheses; * $p < 0.1$, *** $p < 0.05$

Estimation Results

Dependent variable: LogY/L

	(1)	(2)	(3)	(4)
Log K Stock (-1)	0.407***	0.409***	0.406***	0.401***
	(0.0691)	(0.0688)	(0.0689)	(0.0625)
Log Population (-1)	-0.890***	-0.873***	-0.882***	-0.628***
	(0.174)	(0.175)	(0.175)	(0.121)
Trade Spillover Stock (-1)	0.123	-0.518		
	(0.0819)	(0.589)		
Trade Spillover Stock (-1)		0.0402	0.00802*	0.0105***
$\times$ Log K Stock (-1)		(0.0348)	(0.00469)	(0.00454)
Polity2	-0.00443	-0.00389	-0.00432	-0.00336
	(0.00306)	(0.00311)	(0.00306)	(0.00297)
FDI Spillover Stock (-1)				
Human Capital	0.0149	0.0164	0.0147	
	(0.0310)	(0.0309)	(0.0311)	
Sectoral Industry Shares	Yes	Yes	Yes	Yes
Yes				
Time effect	Yes	Yes	Yes	No
Observations	2099	2099	2099	2099
Number of groups	56	56	56	56
R-sq.	0.466	0.469	0.468	0.637

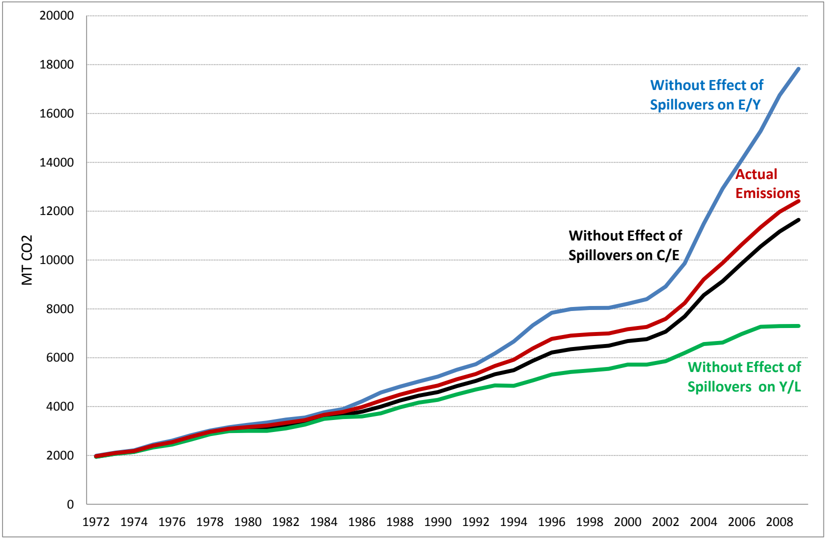
Within-group estimator; Robust standard errors in parentheses; * $p < 0.1$, *** $p < 0.05$

Implications

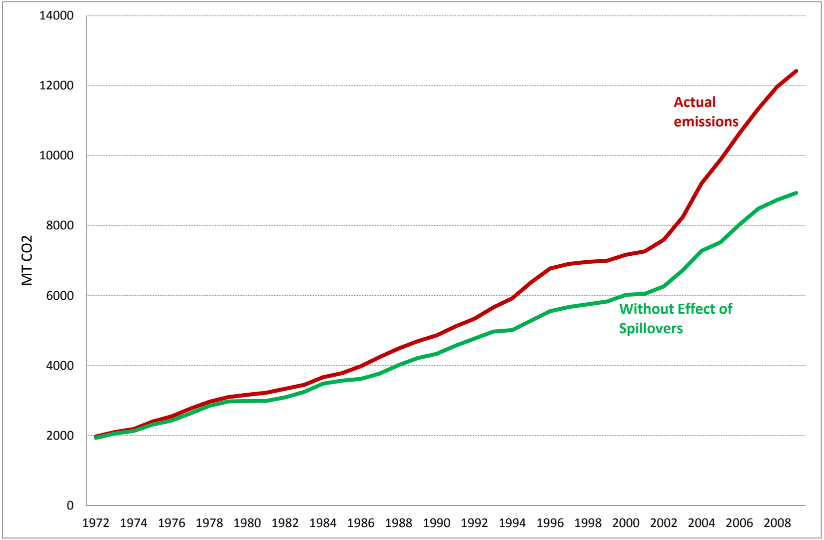
To assess the implications of our econometric results we subtract the estimated contributions of spillovers to each of the Kaya components above, and use the result to generate counterfactual emissions series for each of our 56 developing countries:

$$\widetilde{C}_t = \sum_j \Big[C_{j,t} \times \exp\Big\{ -\log S_{j,t-1} \left(\beta_S^{C/E} + \beta_{S-K}^{C/E} \log K_{j,t-1} \right) \Big\} \times \exp\Big\{ -\beta_{S-K}^{E/Y} \log S_{j,t-1} \cdot \log K_{j,t-1} \Big\} \times \exp\Big\{ -\beta_{S-K}^{Y/L} \log S_{j,t-1} \cdot \log K_{j,t-1} \Big\} \Big]$$

Technology Spillovers: Channels of Impact on CO_2 Emissions in 56 Developing Countries



Technology Spillovers: Overall First-Order Impact



Conclusion and Future Research

Conclusion

- Technological spillovers appeared to lead to higher carbon emissions than if no spillovers occured
  - International knowledge spillovers will lead to energy efficiency improvement and productivity enhancement, mainly through improving the receiving countries' capital productivity
  - International knowledge spillovers has adverse effects on carbon intensity of developing countries
- Policy implication: better technology does not necessarily imply a cleaner environment

Future research

- Investigating which sectors (e.g. agriculture, industry, transportation, services) and types of equipment and machinery are driving the results
- Tests for interregional differences in the value of spillover elasticities (e.g., due to capability to absorb foreign technology)

Thank you for your attention

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