Towards a Global Carbon Dioxide Market: Shadow Pricing Carbon Dioxide Across Countries

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Introduction

International talks at the United Nations about mitigating the effects of global climate change include the discussion of a global carbon dioxide (CO_2) market

Knowledge of carbon dioxide prices could support the development and implementation of this global market and could greatly facilitate exchanges in this market

Objectives

1. Estimate shadow prices of CO_2 across countries
2. Use shadow prices in a simulated CO_2 global trading market
3. Examine whether global emissions could be reduced and shadow prices of CO_2 equalized across countries without sacrificing economic growth

Methods

Derive shadow prices through the empirical tool known as the directional distance function:

- Natural functional representation of technology
- Accounts for inefficiencies
- Estimable functional form arises out of theory
- Knowledge of all prices not needed

Theoretical Model-Output Set

Main Features:

- Two outputs: one good-RGDP (y), one bad-CO_2 (b)
- Two prices: p (price of y), s (price of b)
- Two inputs: labor (l), capital (k)
- No good (y) production without pollution (b)
- There is a cost to reducing pollution (b)

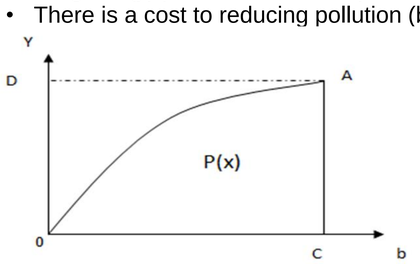
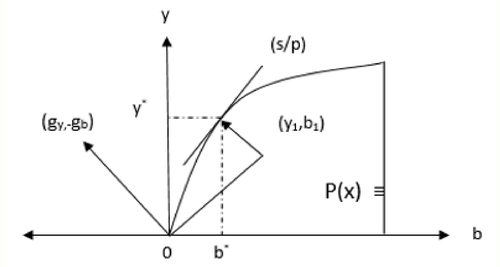


Figure 1. Output set of a polluting technology

Theoretical Model-Shadow Prices

$\vec{D}_o(x, y, b; g_y, -g_b) = \max\{\beta: (y+\beta g_y, b-\beta g_b) \in P(x)\}$



Shadow Price of CO_2: $s = -p \dfrac{\partial \vec{D}_0(x, y, b; g_y, -g_b)/\partial b}{\partial \vec{D}_0(x, y, b; g_y, -g_b)/\partial y}$

Estimation

- Quadratic functional form has been shown to accommodate the properties of the directional distance function
- Estimate the quadratic function employing ordinary least square with time and country fixed effects

Estimation Results

Parameter Estimates

Parameter	Variable	Estimates
α_1	labor (l)	-0.0516
α_2	kapital (k)	0.5669
β_1	rgdp (y)	-0.7502
$\gamma_1 = \beta_1 + 1$	co2 (b)	0.2498
α_{11}	l^2	0.0180
α_{22}	k^2	-0.0764
$\alpha_{12} = \alpha_{21}$	l*k, k*l	-0.0249
$\beta_2 = \gamma_2 = \mu$	$y^2, b^2, y*b$	-0.0176
$v_1 = \delta_1$	l*y, l*b	-0.0003
$v_2 = \delta_2$	k*y, k*b	0.0395

$$s = -p \frac{\gamma_1 + \gamma_2 b + \delta_1 L + \delta_2 k + \mu y}{\beta_1 + \beta_2 y + v_1 L + v_2 k + \mu b}$$

CO_2 Shadow Prices by Country Income Group

Income Group	Obs	Mean	Std. Dev.	Min	Max
High Income	810	772.72	266.32	601.00	3049.28
Middle Income	1242	692.95	84.33	61.18	1157.33
Low Income	486	697.78	4.80	679.19	729.48

CO_2 Market Simulation

Goals:
- Reduced global emissions of CO_2 through optimal reallocations
- Equalized shadow prices of CO_2 (s)
- Increased global RGDP (y)

CO_2 Market Simulation

Assumptions:
- Benevolent governing body
- Carbon dioxide allowances and quota set by governing body
- Allowances can be traded
- Free trade of allowances
- Two outputs: RGDP (y), carbon dioxide (b)
- Two inputs: labor (l), capital (k)

CO_2 Market Simulation Method

$$\max \left\{ \sum_{i=1}^{3} y_i : \vec{D}_{oi}(\bar{x}_{1i}, \bar{x}_{2i} y_i, b_i; 1, -1) \geq 0, \sum_{i=3}^{3} b_i \leq \bar{b}, where\ i = 1,2,3 \right\}$$

← Quadratic functional form given parameter estimates and data

← Carbon Dioxide Quota

CO_2 Market Simulation Results

country	year	l	k	b	y	b*	y*	s	s*
China	2000	41.80	13.08	22.07	13.17	14.72	15.63	320	**586**
India	2000	22.83	3.97	7.69	6.26	4.18	6.10	381	**586**
Japan	2000	3.77	15.60	7.91	11.58	18.77	17.91	2283	**586**
Totals				**37.67**	**31.01**	**37.67**	**39.64**		

- Total emissions remain stable (b*) ; total RGDP increases (y*)
- Emissions reallocated from low CO_2 price countries to higher CO_2 price country
- Shadow Prices of CO_2 equalize (s*) eliminating further arbitrage opportunities

Concluding Remarks

Shadow prices of CO_2 could be used as a guide to policy makers towards the implementation of a CO_2 global market

Shadow prices of CO_2 could be used as an aide towards the implementation of carbon tariffs

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