Renewable Energy Investment and Carbon Finance

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Motivation

- Carbon finance is a potential source of revenue for marginal renewable energy projects in developing countries ($>$ 60% CDM pipeline)

Source	Installed capacity 2008, GW	CDM pipeline 2010, GW
Wind	24	34
Small hydro	65	45
Biomass	25	11
Solar	>0.1	0.28
Geothermal	4.8	0.66
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- But does carbon finance provide a sustainable support for renewable energy investment in developing countries in the long-run?
- This paper: Issue explored from the asset-pricing perspective

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(3) Policy:

- What are the implications of inefficient pricing?

Main Results

(1) Theoretical: cooperative option game model solved for the efficient set of payoff allocations

(2) Empirical: primary carbon is overpriced as compared to the model-implied estimates

- underestimation of volatility (fear of preemption)
- overestimation of convenience yield (driver of speculative expectations)

(3) Policy: carbon finance may or may not be a sustainable source of renewable energy investment

Outline

(1) Introduction

(2) Theory: carbon finance cooperative option game

(3) Empirics: model vs data

(4) Discussion and policy implications

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- CDM project requires an irreversible capital outlay
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- Appropriate solution methodology
  $\Rightarrow$ cooperative option games
- Add-ons: regulatory idiosyncrasies (CDM EB regulation, taxes, other transaction costs)

Renewable energy component

- Electricity revenue process, $(R_E(t))_{t \geqslant 0}$, follows a geometric Brownian motion
- Optimal project capacity is a function of $R_E(t)$: $q_E\left[R_E(t)\right]$
- Value of operating project, $V_E\left[\cdot\right]$, and initial capital outlay, $K_E\left[\cdot\right]$, are functions of $q_E\left(t\right)$ and $R_E\left(t\right)$

Carbon component

- Carbon price, $(P_C(t))_{t \geqslant 0}$, follows a geometric Brownian motion
- Quantity of CERs produced is a multiple of $q_E(t)$: $q_C(t) = \kappa q_E(t)$
- Value of operating project, $V_C[\cdot]$, is a function of $q_E(t)$, $R_E(t)$ and $P_C(t)$
- Initial capital outlay (carbon component development costs), K_C, is a constant
- $\Psi[\cdot]$ determines the project developer's compensation:
  - forward payment game: Ψ is constant over time
  - indexed payment game: Ψ is a function of carbon price
  - hybrid payment game: Ψ is partly deterministic and partly stochastic

Carbon finance cooperative option game

Find payoff allocations that satisfy all of the following conditions:

- from cooperative game theory:
  (1) collective rationality: the joint payoff of the project is maximised;
  (2) individual rationality: players' payoffs under cooperative scenario are at least as large as under a non-cooperative scenario;
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- from CDM regulations (3/CMP.1, Annex, paragraph 43):
  (6) financial additionality: "anthropogenic emissions of greenhouse gases [...] are reduced below those that would have occurred in the absence of the registered CDM project activity."

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- Core of the game can be split into two components
  - active core: project is embarked upon immediately by both parties
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- Active cores for the carbon finance are derived for;
  - forward payment game: a stream of fixed payments reduces/increases the option strike price
  - indexed payment game: solution makes use of Olsen-Stensland [1992] separation
  - hybrid payment game: an extension of the first two solutions

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Empirical objectives

- Compare model-implied results with observed CER prices in primary market (pCER prices)
- Model for forward payment contracts is tested
- Data:
  - Primary market (pCER data):
    - IDEAcarbon pCER Index (27/3/2008-10/7/2009): 67 weekly observations
    - UNFCCC hydro projects pipeline (14/3/2007-28/3/2008): 204 observations
  - Secondary market (sCER data):
    - BlueNext spot (12/8/2008-15/7/2009)
    - ECX futures (14/3/2007-15/7/2009)
    - Reuters CER Index (9/3/2007-7/7/2009)

Dependent variable

$$y(t) \equiv \frac{P_{\text{pCER}}^{\text{Observed}}(t) - P_{\text{pCER}}^{\text{Model}}(t)}{P_{\text{pCER}}^{\text{Model}}(t)},$$

where $P_{\text{pCER}}^{\text{Observed}}$ is the pCER price observed from the data at time t,

$$\begin{aligned}
P_{\text{pCER}}^{\text{Model}}(t) &= \left(P_{\text{sCER}}(t) \frac{(\beta_C(t) - 1)}{\beta_C(t)} \frac{\left(e^{-\delta_C(t)\theta_C} - e^{-\delta_C(t)(T)+\theta_C)}\right)}{\delta_C(t)} - \frac{K_C}{q_C(i)} \right) \\
&\quad \times \frac{r(t)}{\left(e^{-r(t)\theta_C} - e^{-r(t)(T+\theta_C)}\right)}, \\
\beta_C(t) &= \frac{-\left(r(t) - \delta_C(t) - \frac{\sigma_C^2(t)}{2}\right) + \sqrt{\left(r(t) - \delta_C(t) - \frac{\sigma_C^2(t)}{2}\right)^2 + 2\sigma_C^2(t)\, r(t)}}{\sigma_C^2(t)},
\end{aligned}$$

$r(t)$ is the risk-free rate at time t, $\delta_C(t)$ is carbon convenience yield at time t, σ_C is the sCER volatility, T denotes the crediting period, and θ_C is the pre-implementation time period of a CDM project.

Hypotheses

H1: The observed pCER prices do not systematically deviate from the upper boundary for pCER implied by the model, and there is no overpricing of CERs in the primary market

H2: Systematic overpricing of CERs in the primary market is not associated with underestimation of volatility of sCER prices in the secondary market and the carbon convenience yield

H3: Systematic overpricing of CERs in the primary market is not associated with project-specific factors such as host country and size

Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	IPDS	IPDS	IPDS	IPDS	UPD	UPD	UPD	UPD
Intercept	3.779*	−8.701*	7.942*	−4.648*	1.024*	−1.395*	−0.664*	−0.651*
	(6.467)	(−7.056)	(6.940)	(−4.221)	(16.025)	(−11.428)	(−3.675)	(−3.677)
sCER price volatility		26.185*		24.022*		8.189*	8.129*	8.189*
		(10.470)		(12.982)		(20.744)	(21.887)	(22.476)
Carbon convenience yield			−136.300*	−98.947*				
			(−4.053)	(−6.341)				
China dummy							−0.758*	−0.693*
							(−5.238)	(−4.836)
Project size								−0.000*
								(−3.079)
Observations	46	46	46	46	204	204	204	204
Adjusted R^2		0.707	0.255	0.845		0.679	0.716	0.728

Note: IPDS denotes the percentage price difference calculated based on the IDEAcarbon data set with varying convenience yield. UDP denotes the percentage price difference calculated based on the UNFCCC data set with constant convenience yield.
* significant at the 99% level.
t-ratios are in parenthesis.

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- Smaller projects are more additional

Discussion and policy implications

- Story 1: Results are good
  - Carbon finance has been designed to stimulate marginal projects
  - Results imply that CDM manages to capture (very) additional projects
  - There is more renewable energy investment taking place than without CDM
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- Story 2: Results are not that good
  - Carbon finance market has been driven by speculators competing for a limited number of good projects (additional + low cost)
  - Initially, it has provided an impetus for more renewable energy projects
  - But, as "low-hanging fruit" disappears, so will vanish capital inflows under carbon finance
  - In the long-run, it is not a sustainable source of renewable energy investment