Mitigation and adaptation are not enough: turning to emissions reduction abroad

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1. Mitigation refers to “an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases” (IPCC, 2007).
   - Domestic mitigation
   - Emissions reduction abroad: International agreements/CDM

2. Adaptation concerns measures that reduce the vulnerability of natural and human system.
First, a focus on mitigation, then some interest for adaptation

- Mitigation is already so difficult to organize because it deals with a global and intertemporal problem.
- Mitigation is viewed as a proactive policy

- Adaptation may be efficient even if implemented in a decentralized uncoordinated way
Adaptation effectiveness may be limited

- It may be too costly to adapt to a too large climate change: 100 billions USD per year for the adaptation cost between 2010 and 2050 to an only 2°C warmer world by 2050 (World Bank, 2009).
- Some catastrophic consequences often described (Keller et alii. Climatic change, 2008) seems difficult to cope with.
- De Bruin (2009): the higher the current value of climate damage, the less important adaptation is as a policy option.
Until recently, in the European Union, mitigation policy has been conducted separately from adaptation strategies (water management, coastal management, agriculture and public health).

The second phase of the European Climate Change Programme (ECCP) :+ impacts and adaptation in one working groups. Adaptation can contribute to mitigation objectives (EEA, 2005).

Most Least-Developed Countries are concerned primarily with adaptation and its links with development.

The Asia-Pacific Partnership on Clean Development and Climate only refers to mitigation.

UK Climate Change Programme, which includes adaptation and mitigation (DETR, 2000).
Optimal control problems with **pollution accumulation and both adaptation and mitigation investment.**

1. Arbitrage between abatement and adaptation investments
   - What are the optimal pollution/adaptation/mitigation accumulations
   - Analysis of the economy’s dynamics
   - Impact of higher ROW emissions
   - How do these instruments allow avoiding an "adaptation threshold"?

2. Introducing a third instrument: CDM.
Related literature

- Brechet et alii (2013): Accumulation in physical capital, GHG, and adaptation capital. Substitutability between the two instruments depends on the stage of development.
- Tsur and Withagen (2012): Uncertain pollution damage, with no endogenous pollution accumulation (no mitigation). Optimal ex-ante adaptation is larger in a growing economy.
- Zemel (2014): adaptation in the presence of an uncertain pollution damage. No mitigation capital that accumulates, adaptation is bang-bang.
- IAMs: dominated by mitigation, adaptation is "ad hoc" (Corfee-Morlot and Agrawala, 2004; Fisher et al., 2007). Better in Agrawala et al. (2010).
- With some concerns for international agreements (Benchekroun et al, 2011): increase in effectiveness of adaptation $\Rightarrow$ increase in the gains from global cooperation over GHGs emissions.
Mitigation/adaptation/pollution accumulations in a simple model

- Instantaneous utility depends on consumption and on pollution damages that can be reduced through adaptation.
- Adaptation infrastructures accumulation (dykes).
- Mitigation capital accumulation (double-glazing).
- Pollution accumulation that depends on domestic emissions (consumption), mitigation capital and ROW emissions.
- Constant income.
Program and specifications

\[
\max_{\{c, \theta\}} \int_{0}^{+\infty} \exp^{-\rho t} U(c, S, A) dt
\]

subject to \( \dot{S}_t = \beta c_t - M(K_t) + \bar{E} - \sigma S_t \),

\[
Y + R_t = c_t + I_{Kt} + I_{At} \quad \text{with} \quad R_t = c_t \quad \text{and} \quad Y = I_{Kt} + I_{At}
\]

\[
\dot{A}_t = \left[(1 - \theta_t) Y\right]^\alpha A - \delta_A A_t \quad \text{and} \quad \dot{K}_t = (\theta_t Y)^{\alpha M} - \delta_M K_t
\]

\( S_0, A_0, K_0 \) given

\[
u(c) = c^\omega, \quad 0 < \omega < 1
\]

\[
M(K) = K^m, \quad m \leq 1
\]

\[
D(S, A) = A^{-\gamma} S \quad \gamma > 0
\]

\[
\alpha_A = \alpha_M; \quad \delta_A = \delta_M
\]
Solution

A steady-state would be defined by:

\[ K^* = \bar{K}\theta^*\alpha = K^*(\theta^*) \quad \text{with} \quad \bar{K} = Y^\alpha / \delta \]
\[ A^* = (1 - \theta^*)^\alpha \bar{K} = A^*(\theta^*) \]
\[ c^* = ((\rho + \sigma)\omega A^*(\theta^*)\gamma / \beta)^{\frac{1}{1-\omega}} = c(\theta^*) \]
\[ S^* = \frac{1}{\sigma} \beta \left( \frac{(\rho + \sigma)\omega\bar{K}^\gamma}{\beta} \right)^{\frac{1}{1-\omega}} (1 - \theta^*)^{\frac{\alpha\gamma}{1-\omega}} - \bar{K}^m \theta^*\alpha m + E \]
\[ \sigma S(\theta^*) = \frac{\sigma m\bar{K}^m}{\gamma(\rho + \sigma)} (1 - \theta^*)\theta^*\alpha m - 1 \]

\[ G(\theta^*) \]
Existence and uniqueness of the SS

\[ \sigma S(\theta^*) = G(\theta^*) \]

\[ NSC : \sigma S(1) > 0 \iff \overline{E} > \overline{K}^m \]
Increase in ROW emissions (analytically)

Decrease in mitigation.
Increase in income

\[ \sigma S(0) \uparrow \text{ and } \sigma S(1) \downarrow \text{ while } G(\theta^*) \text{ shifts upwards} \]

For a large initial \( \theta^* \), one cannot rule out a larger share devoted to mitigation.
Effect of a higher efficiency in adaptation (analytically)

- $G(\theta^*)$ shifts downwards and $\sigma S(\theta^*)$ rotates clockwise around $\hat{\theta} = 1 - K^{-1/\alpha}$
- For $\theta^* < \hat{\theta}$, a more efficient adaptation unambiguously decreases the share of income devoted to mitigation
- For $\theta^* > \hat{\theta}$, ambiguous, more efficient adaptation could lead to less adaptation (Benchekroun, 2011)
Definition of the adaptation threshold

- For $S > \bar{S}$, adaptation becomes fully inefficient
- We assume $S^* > \bar{S}$
- Irreversible solution: the threshold is crossed
- Focus on reversible solutions
Solving the model

Hamiltonian associated with the program before the threshold:

\[ H = c^\omega - A^{-\gamma}S + \mu \left[ \beta c - \sigma S - K^m + \bar{E} \right] + \lambda_A \left[ (1 - \theta)Y^\alpha - \delta A \right] + \lambda_M \left[ (\theta Y)^\alpha - \delta K \right] + \xi(\bar{S} - S) \]

New optimality conditions

\[ \frac{\dot{\mu}}{\mu} = \rho + \sigma + A^{-\gamma}/\mu + \xi \]
\[ \xi((\bar{S} - S) = 0, \xi \geq 0 \]

- If \( \xi = 0 \), the solution reduces to the one without threshold. Since \( \bar{S} < S^* \), the threshold cannot be avoided.
Solving the model (f’d)

If $\xi > 0$, $S_t = \overline{S}$: the consumption growth rate is such that

$$\frac{\dot{c}}{c} = \frac{-1}{\eta(c)} \left[ (\rho + \sigma) - A^{-\gamma} \beta c^{1-\omega} / \omega + \xi \right]$$

The Lagrange multiplier $\xi$ affects the arbitrage through the marginal value of the stock ($\dot{\mu}$ is larger and $\mu_0$ is smaller since $S_t = \overline{S}$ see also Amigues and Moreaux, 2012). Again, the threshold cannot be avoided.

→ threshold always reached.
→ add one more policy: CDM
Assumptions

- Costly
- Trade-off between mitigation/adaptation/CDM
- A first look: (i) $\partial S^*/\partial Y$ joint with (ii) $\partial S^*/\partial \bar{E}$? Recall before:
  - (i) may generate a smaller share for mitigation
  - (ii) generates more mitigation + the direct effect of $\bar{E}$ on $S$

$\rightarrow$ formally take CDM into account
The model

Endogenous ROW emissions

\[ E_t = \bar{E} - \left[ (1 - \phi_t) Y \right]^s e \quad s > 1 \]

\[ \dot{A}_t = \left[ \phi_t (1 - \theta_t) Y \right]^{\alpha} - \delta A_t \]

and \[ \dot{K}_t = \left( \phi_t \theta_t Y \right)^{\alpha} - \delta K_t \]

\[ S_0, A_0, K_0 \text{ given} \]

One more control variable.
Steady-state

\[
\frac{(\rho + \delta)}{\alpha m} \bar{e} Y^{s-\alpha} (1 - \phi^*)^{s-1} K^{1-m} = (\phi^* \theta^*)^{\alpha m - 1}
\]

\[\Rightarrow \frac{d\phi^*}{d\theta^*} > 0 \text{ iff } \phi^* > \tilde{\phi} \text{ with } \tilde{\phi} = \frac{1 - \alpha m}{s - \alpha m} < 1 \text{ since } \alpha m - 1 < 0\]

- If \( \phi^* > \tilde{\phi} \) : \( \theta^* \) increases, then \( (1 - \phi^*) \) decreases: more mitigation at home goes with few mitigation abroad
- If \( \phi^* < \tilde{\phi} \) : mitigation home and abroad are complements
Steady-state existence

\[
\sigma S(\theta(\phi^*), \phi^*) \phi^{* - \alpha m} \leq \frac{\sigma mK^m}{\gamma (\rho + \sigma)} (1 - \theta(\phi^*)) \theta(\phi^*)^{\alpha m - 1}
\]

\(G(\theta(\phi^*))\) is hump-shaped with a max in \(\tilde{\phi}\).

\[
\lim_{\phi^* \to \phi} G(\phi^*) = 0 \quad \text{and} \quad \lim_{\phi^* \to \bar{\phi}} G(\phi^*) = 0
\]

\[
\lim_{\phi^* \to \phi} F(\phi^*) > 0 \quad \text{and} \quad \lim_{\phi^* \to \bar{\phi}} F(\phi^*) > 0
\]

Therefore there exist at least 2 SS iff \(G(\tilde{\phi}) > F(\tilde{\phi}). (\bar{E} \text{ not too large})\).
Effect of a larger exogenous part of ROW emissions

\[
\frac{\partial \phi^*}{\partial E} = \frac{\phi}{\sigma S} \left( \frac{\varepsilon_G}{\phi} - \left(\frac{\varepsilon_S}{\phi} - \alpha m\right) \right)
\]

Illustration:

\[
\frac{\partial \phi^*}{\partial E} > 0 \text{ iff } \varepsilon_G/\phi > 0. \text{ For } \alpha m = 1, \text{ (income } Y \text{ has a linear impact on pollution accumulation), } G'(\theta^*) < 0 \text{ and } F'(\theta^*) < 0 \text{ that leads to a unique steady state.}
\]
Effect of a more efficient adaptation

Illustration

- $G(\phi)$ downwards but $\partial F(\phi)/\partial \gamma > 0$ iff
  $\phi^*(1 - \theta(\phi^*)) > K^{-1/\alpha}$. In particular,
  $\partial F(\phi)/\partial \gamma|_{\phi=\phi} < 0$ and $\partial F(\phi)/\partial \gamma|_{\phi=\bar{\phi}} > 0$

- $\phi^* < \tilde{\phi}$, more home policies and more adaptation
- $\phi^* > \tilde{\phi}$, less home policies and more adaptation
Introducing CDM

Effect of more efficient CDM:

- \( \phi^* > \tilde{\phi} \): less pollution
- \( \phi^* < \tilde{\phi} \): ambiguous
Conclusion

- **Mitigation/Adaptation**
  - an increase in ROW’s emissions reduces mitigation and increases adaptation
  - a larger income may lead to a larger share of this income to be devoted to mitigation.
  - contrary to what Benchekroun (2011) obtains, a more efficient adaptation does not necessary lead to a substitution of adaptation for mitigation

- **Mitigation/Adaptation/CDM**: may be a means to reduce SS pollution, opening therefore the possibility to avoid an adaptation threshold

- **Extensions**: mitigation rather than abatement + uncertainty on the threshold