Adaptation for mitigation

Masako Ikefuji   Jan R. Magnus   Hiro Sakamoto

March 16, 2016

Background

Climate policy options

- Mitigation: slowing the process of climate change
  - GHG emission reduction
- Adaptation: reducing our vulnerability to impacts
  - infrastructure improvement
- Policy discussions have concentrated on mitigation

Growing interest in adaptation

- Long-term solution requires mitigation
- Yet averting damages through mitigation takes time
- Climate change is already taking a toll in many climate-sensitive regions
- $\rightarrow$ Adaptation should play an important role, especially in developing countries

Adaptation needs

Climate damages in South

- Excess deaths and health risk (WHO, 2010)
- Weather shocks lower investments in education and health (Jensen, 2000)
- School buildings destroyed by floods (Petal, 2008)
- $\rightarrow$ Negative influence on human capital accumulation, which makes the damage long-lasting

Assistance needed for South

- Resources for effective adaptation are insufficient in developing countries (World Bank, 2010)
- Even emerging economies like India and China are struggling to adapt to changing climate
- In Paris conference, adaptation assistance was a major priority for developing countries

Adaptation assistance

Limited commitment from North

- As of 2010, financing for adaptation was less than 5% of the projected needs (World Bank, 2010)
- Paris agreement boosted climate finance, yet not necessarily earmarked for adaptation
- Adaptation assistance as humanitarian aid

Economic rationale?

- Commonly perceived as a substitute for mitigation:
  - case for stringent mitigation will be weakened
  - mitigation incentive of South will be reduced
- Not seem a fair deal in the first place for North to unilaterally make a financial commitment

This paper

Dynamic consequence of adaptation

- Dynamic North-South economy where the two regions are behaving in a non-cooperative manner
- Human capital, as well as output, negatively influenced by global stock of pollution
- North can reduce the damage in South at a cost

Summary of findings

- Adaptation assistance, if targeted at human capital protection, can facilitate mitigation in the future
  $\rightarrow$ 'Adaptation FOR mitigation'
- Pollution might increase in the short run, but can decline in the long run
- North's unilateral commitment is Pareto improving

Literature

Adaptation

- Optimal level of adaptation and mitigation (de Bruin et al., 2009, Ingham et al., 2013)
- Strategic, but static analysis (Onuma and Arino, 2011; Ebert and Welsch, 2012)
- $\rightarrow$ This paper is the first to analyze adaptation in a strategic and dynamic environment

Capital destruction

- Mounting evidence of long-lasting impacts of climate change (Dell et al., 2012)
- Damage to capital and growth implies a higher SCC (Moore and Diaz, 2015; Dietz and Stern, 2015)
- $\rightarrow$ We show that the capital-destruction nature of climate change yields a qualitatively different result as well

Model

Economy and pollution

- Two sectors: production $Y_{i,t}$ and abatement $A_{i,t}$
- Human capital, $L_{i,t}$, is divided between the two sectors:

$$L_{i,t}^{y} = (1 - b_{i,t})L_{i,t}, \quad L_{i,t}^{a} = b_{i,t}L_{i,t} \tag{1}$$

- Production functions:

$$Y_{i,t} = \Omega_{i,t}e^{-\xi_{i,t}M_t}(L_{i,t}^{y})^{\alpha}P_{i,t}^{1-\alpha}, \quad A_{i,t} = \mu(L_{i,t}^{a})^{\gamma}, \tag{2}$$

  where M_t is pollution stock and $P_{i,t}$ is polluting input

- Flow damage captured by $e^{-\xi_{i,t}M_t}$ with $\xi_{i,t} > 0$
- Emission and pollution:

$$E_{i,t} = P_{i,t} - A_{i,t}, \tag{3}$$

$$M_{t+1} = (1 - \delta_m)M_t + E_{n,t} + E_{s,t} \tag{4}$$

Model (cont'd)

Another channel of damage

- A fraction of human capital destroyed:

$$L_{i,t+1} = \eta_i e^{-\zeta_{i,t} M_t} L_{i,t}, \tag{5}$$

  where $\eta_i > 0$ captures the exogenous growth

- Lasting damage captured by $e^{-\zeta_{i,t} M_t}$ with $\zeta_{i,t} > 0$
- Capital destruction in effect implies a lower growth rate

Welfare

- Welfare function:

$$W_i = \sum_{t=0}^{\infty} \beta^t U(C_{i,t}) \tag{6}$$

- Consumption equals output: $C_{i,t} = Y_{i,t}$

Assumptions

Just for simplicity

- Log utility function: $U(C) = \ln(C)$
- Three-period model:

$$W_i = U(C_{i,0}) + \beta U(C_{i,1}) + \beta^2 V_{i,2}(L_{i,2}, M_{i,2}) \tag{7}$$

- Linear value function:

$$V_{i,2}(L_{i,2}, M_{i,2}) = \phi_{i,L} L_{i,2} - \phi_{i,M} M_2 \tag{8}$$

Remarks

- All of the assumptions above will be relaxed later
- V can be properly derived if no capital damage assumed from period 2 onward
- Period 0, 1, and 2 are immediate (short-run) future, long-run future, and distant future, respectively

Modeling adaptation and assistance

Adaptation

- Lowering the damage parameters, ξ, ζ
- Adaptation policies already implemented in each region
- There remain 'adaptation gaps,' opportunities in South which can be exploited only with the help of North

Assistance

- 'Adaptation capital,' R, lowers the damage parameters:

$$\xi_{s,t} = \xi_s(R_t), \quad \zeta_{s,t} = \zeta_s(R_t) \quad (\xi_s', \zeta_s' < 0) \qquad (9)$$

- A fraction of North's output can be invested in R:

$$R_0 = \tau Y_{n,0}, \quad \tau \in [0,1) \qquad (10)$$

- Depreciation of adaptation capital:

$$R_1 = \delta R_0, \quad R_2 = 0 \qquad (11)$$

Equilibrium

Non-cooperative game

- In two stages:

    1. $\tau \in [0,1)$ chosen by North (one-off investment)
    2. $(P_{i,t}, b_{i,t})$ simultaneously chosen by North and South with τ taken as given

- Open-loop Nash (effective commitment assumed)
- Solved backwardly

Notes

- Analysis of the 2nd stage reveals how the capital-destruction externality affects the game
- In the 1st stage, we are interested in:
    - if $\tau > 0$ (incentive compatible);
    - if $dW_i/d\tau > 0 \,\forall i \in \{n, s\}$ (Pareto improving)

Second stage

Regional efforts to reduce emission

- Typically strategic substitutes (i.e., free-riding)
- In this model, however, emission reduction can be strategic complements!
- This makes the net impact of adaptation unambiguous at the global level

But why?

- Dynamic complementarity effect:
  - mitigation as an 'investment' in capital
  - emission reduction in one region increases the shadow value of capital in another region
- This dynamic channel of strategic interaction changes the nature of the game

Dynamic complementarity effect
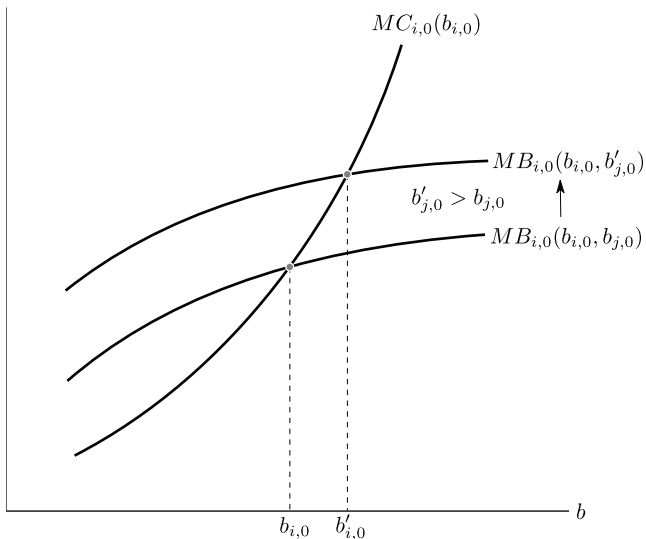
Impact of adaptation

Three distinct effects

- Substitution effect: less damage, less need to mitigate
- Complementarity effect:
  - bumps up the baseline level of human capital
  - provides an extra incentive to keep the growth rate from falling due to pollution
- Cost-reduction effect: due to enhanced human capital

Net effect on pollution

- Complementarity/cost-reduction effects dominate if adaptation is sufficiently effective for protecting capital
- Global emission is in parallel with regional emission
- Complementarity/cost-reduction effects remain even after adaptation capital depreciates

Reaction of short- and long-run pollution

short-term pollution hike
followed by long-term decline

pollution decline
both in the short- and long-run

0

$|\widetilde{\zeta_s}'|$

$|\bar{\zeta_s}'|$

$|\zeta_s'(0)|$

pollution increase
both in the short- and long-run

dM_1/dR_0

dM_2/dR_0
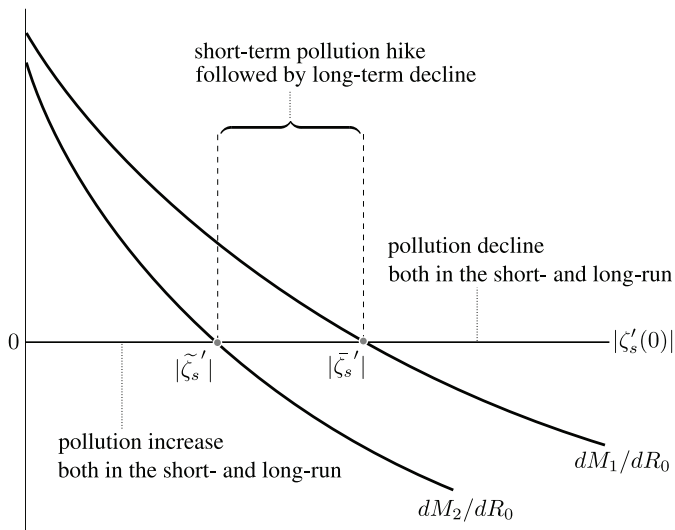
First stage

Should North provide assistance?

- Unilateral adaptation assistance at the cost of suppressed consumption today
- Benefit of assistance (if any) obtained in the subsequent periods

Welfare implication

- North's welfare is increased by assistance if
  - adaptation is effective for capital protection, and
  - North is wealthy enough
- South's welfare is always increased
- → Incentive compatible and Pareto improving if the assistance is targeted at capital protection and is provided by wealthy countries

Welfare implication to North
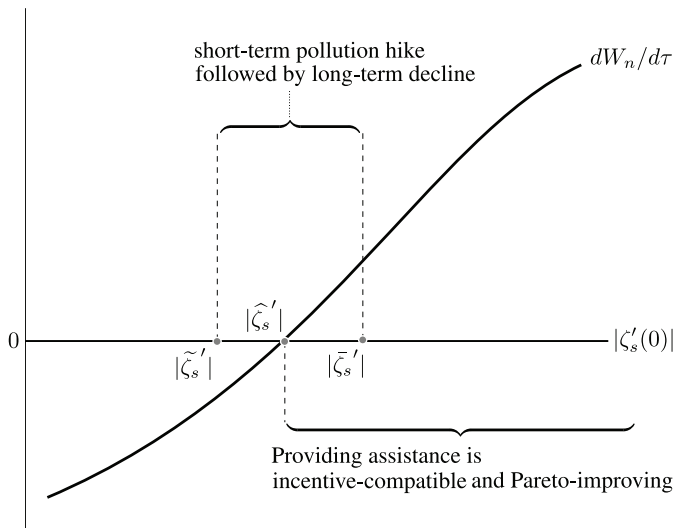
Robustness: numerical analysis

Numerical model

- More general utility function:

$$W_i = \sum_{t=0}^{T} \beta^t U(C_{i,t}), \quad U(C) := \frac{C^{1-\varepsilon} - 1}{1 - \varepsilon} \qquad (12)$$

- Longer time horizon: $T = 120$
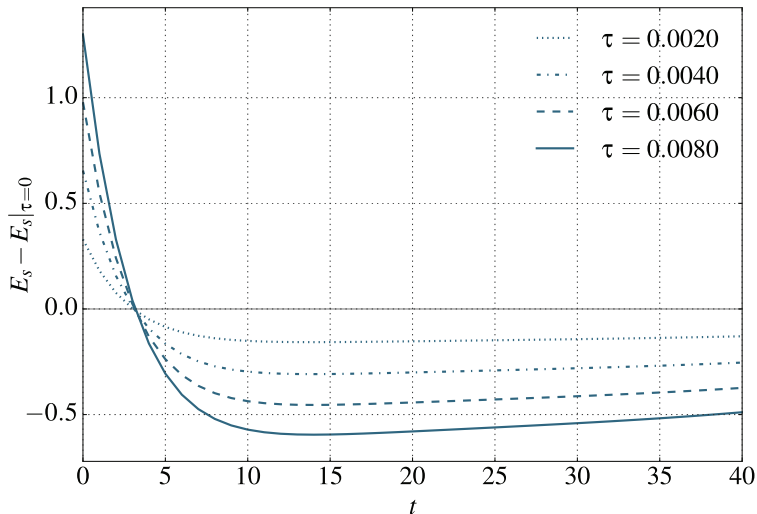- Linearly approximated value function is not necessary

Results

- Model's important features survive:
  - key role played by human capital protection
  - strategic complementarity
  - consistent welfare implications
- Our message is more general than it may appear first
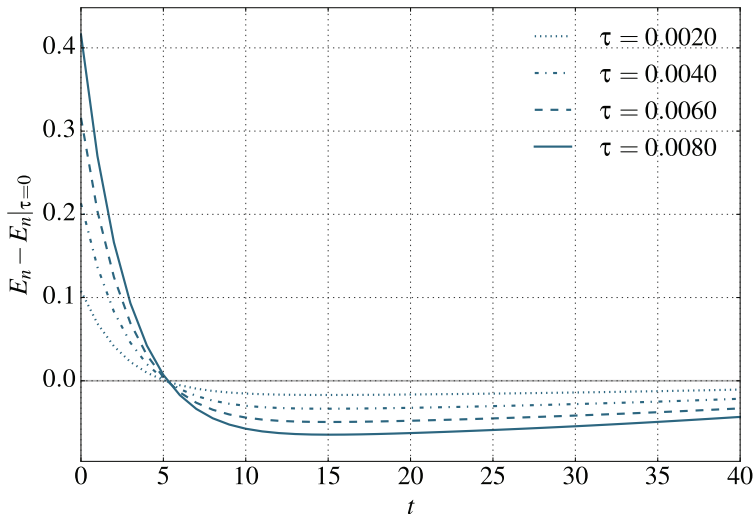
South's emission (ineffective protection)
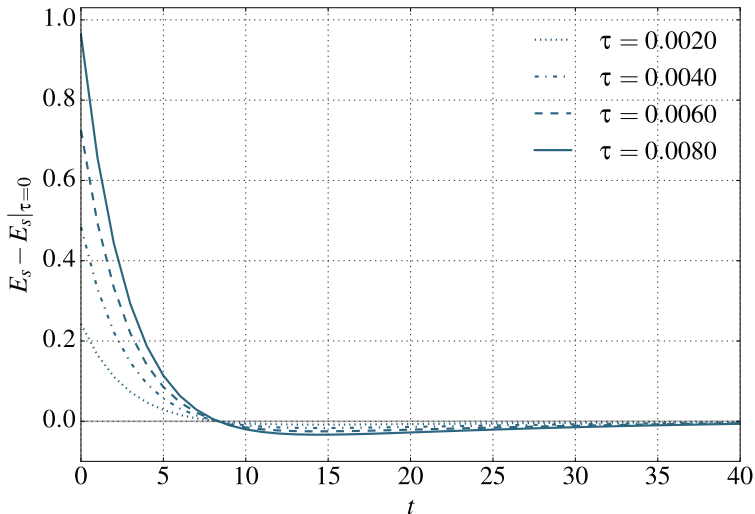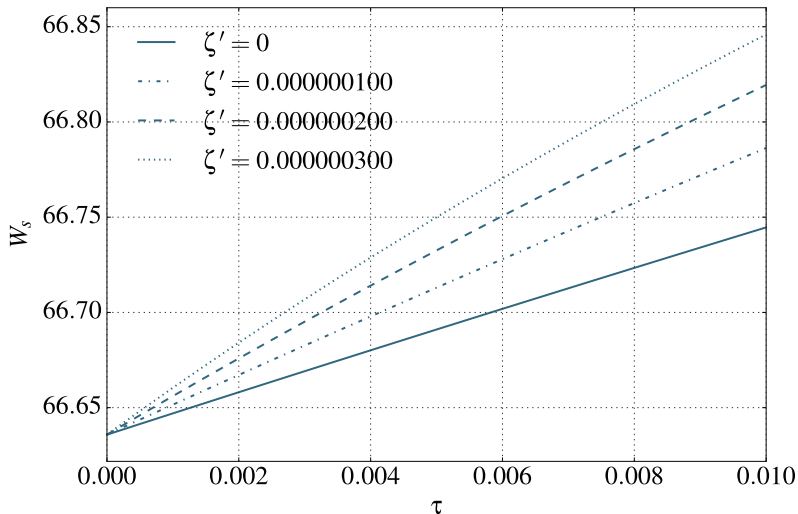
South's emission (effective protection)
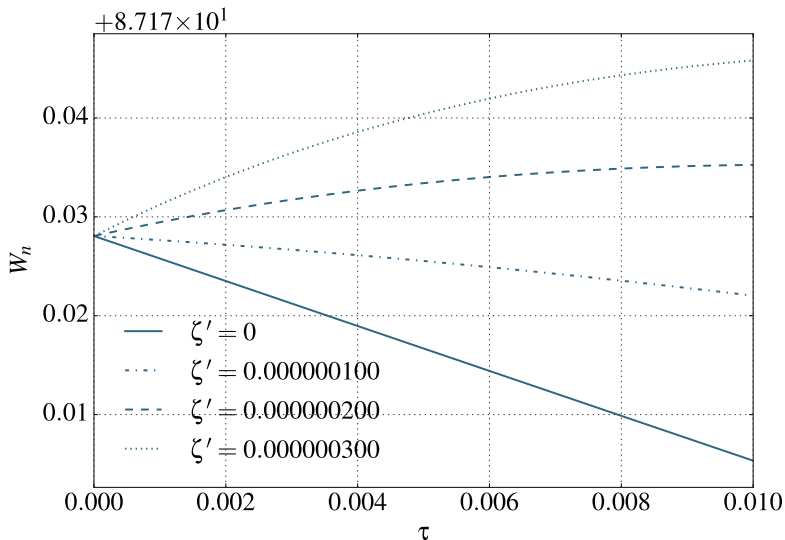
Nouth's emission (ineffective protection)
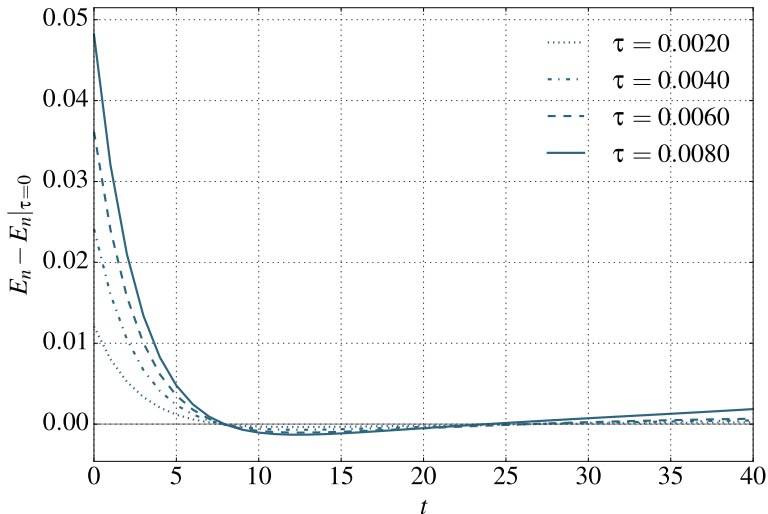
Nouth's emission (effective protection)

Welfare implication (South)

Welfare implication (North)

Conclusions

Strategic and dynamic environment

- Capital-destruction externality implies the dynamic complementarity effect
- Best responses can be strategic complement
- Possibility of mutually beneficial cooperation

Adaptation assistance

- Facilitates mitigation in the future if the assistance is targeted at human capital protection
- Pollution might increase in the short run, but can decline in the long run
- North's unilateral commitment to providing assistance to South has an economic rationale