Can Wang (China), Zhugang Jin (China), Wenjia Cai (China)

Incentive to freeride in international climate cooperation

Abstract

Externality theory of global warming and emission reduction leads to the tragedy of the commons, which however, cannot fully explain the different degrees of freeride incentives in real climate negotiations. A theoretical model based on dynamic game theory with rationality hypothesis is put forward, which by distinguishing the positive, negative and spillover effects of climate change investment on each negotiator's utility, allows identification and investigation of the criteria of freeride motivation. Connections between freeride incentives and the initial GDP growth are carefully evaluated and simulated with illustrative cases. The results not only confirm the hypothesis that initial GDP growth does affect the freeride motivation significantly, but also indicate the following interrelationships: High-growth countries have more incentives to freeride rather than to cooperate, which is the opposite for low-growth countries. Such self-motivated theoretical models lead to the conclusion that high-growth countries have more freeride incentives that not only accords with the real situation of climate change negotiation, but also pioneers a new perspective for the investigation of each country's potential political and economic purposes in global climate change negotiation. Delving into utility-driven behavior in climate negotiation will assist us to have a deep insight into the crux of the stagnation of climate negotiation, and help us make much more specific and feasible proposals for the negotiation promotion.

Keywords: climate negotiation, freeride, GDP growth, utility.
JEL Classification: E61, I38, O50, Q58.

Introduction

Climate change is one of the challenges faced by human beings. Though lots of progresses have been made to reach a consensus on the necessity to deal with the global threat for our common interests, there is still a huge gap in the specific responsibility and reduction targets among different negotiators, especially between the developed and developing countries. The former group, such as the United States, the European Union and Canada, emphasizes that without the participation of current huge emitters like China and India, it's neither fair nor effective for them to implement greenhouse gas reduction, whilst, developing countries fight back with reasons of CBDR (common but differentiated responsibilities) (Cullet, 2010).

Apart from the argument put forward by each negotiator on the surface, what we're really concerned about is to figure out the motivation behind each country's negotiation strategy and practical action. Although Ringius et al. (2002) once pointed out that the "public goods" feature of global warming may lead to a lack of participation motivation known as "Tragedy of Commons", the real situation is much more complicated, which can neither be explained with traditional externality theory: according to the database of the World Bank, the CAGR (Compound Average Growth Rate) of PPP (Purchasing Power Parity) adjusted for GDP from 2000 to 2011, for Europe and Central Asia is 4.36%, which is quite small compared to East Asia and the Pacific's 7.49%. However, the proportion of private investment in energy to GDP for Europe and central Asia rises by 170% over the same period, but decreases by 20% for East Asia and the Pacific. The stronger motivation of climate related investment for the Europe and Central Asia with smaller GDP growth, compared to the East Asia and the Pacific, also indicate that high-growth countries have more incentives to freeride in climate change investment issues, which cannot be illustrated with traditional public good theory. In order to reveal the underlying factors affecting their different responses to climate change, a deeper investigation into the negotiators' intrinsic motivations is necessary. For countries with rationality hypothesis, some key decisions need to be made, including the optimal response to the other countries' greater proportion of investment in tackling climate change, the incentives of cooperation or free-ride, and the connection between the incentives and its initial GDP growth. Apart from the interpretation purposes, such investigation will also assist the design and implementation of global climate change policies.

Based on optimal and rational reaction analyses, the interactions between incentives and individual properties including GDP growth are built into our theoretical model. Theoretical criteria are also proposed to test the hypothesis of freeride as well as an illustrative case provided. This paper not only distinguishes the three different effects of climate change investment (i.e. positive, negative and spillover effects) on each country's utility, but also integrates these effects into the utility-driven model, which will be introduced in detail in section 1. The illustration case together with sensitivity analyses are presented in section 2. Discussions and conclusions with policy implications are made in the final section.

1. Theoretical model

Consider a utility-maximizing individual country whose utility at time t can be expressed as constant relative risk aversion (CRRA) form:

$$Utility_t = \begin{cases} \frac{C_t^{1-\eta}}{1-\eta}, if\ \eta \neq 1 \\ \ln(C_t), if\ \eta = 1 \end{cases}, \quad (1)$$

where η is the index of relative risk aversion. C_t is the disposable consumption at time t which can be connected with GDP growth rate g_s by normalizing the initial consumption at 1:

$$C_t = exp(\int_0^t g_s ds). \quad (2)$$

In order to involve the impact of global warming on utilities, we simplify the relationship between GDP growth rate and temperature increment introduced by Dell et al. (2008, 2009) and Pindyck (2012) where g_0 refers to the steady GDP growth without the effect of temperature increment T_t at time t:

$$g_t = g_0 - \gamma T_t. \quad (3)$$

γ is the marginal effect of temperature increment on GDP growth. Given temperature increment T_H at year H, T_t follows the trajectory which has been proposed by Weitzman (2009) and applied by Pindyck (2011, 2012):

$$T_t = 2T_H \times [1 - (\frac{1}{2})^{t/H}]. \quad (4)$$

Besides the trajectory of the time dimension, the increment of temperature at horizon year (i.e. T_H) is uncertain with a probability density function f_T. One of the intuitive expressions is Gamma distribution with three parameters (i.e., r_T, λ_T, θ_T) calibrated based on related researches (Pindyck, 2012):

$$f_T(x; r_T, \lambda_T, \theta_T) = \frac{\lambda_T^{r_T}}{\Gamma(r_T)}(x-\theta_T)^{r_T-1} e^{-\lambda_T(x-\theta_T)}, x \geq \theta_T, \quad (5)$$

where $\Gamma(r_T) = \int_0^{+\infty} x^{r_T-1} e^{-x} dx$.

For the marginal effect of temperature increment on GDP growth (i.e., γ) which can be calibrated based on the loss function $L(T) = e^{-\beta(T)^2}$ that IPCC and other Integrated Assessment Models (IAMs) have estimated[1], it's of vital importance to involve uncertainty into our model to describe the distribution of γ.

[1] From equations (2)-(4), we can find that C_t at time H can be expressed as: $C_H = exp(\int_0^H g_0 - 2\gamma T_H[1-(\frac{1}{2})^{t/H}]dt) = exp(g_0 H - 2\gamma H T_H[1 + \frac{1}{2ln(0.5)}])$. From the perspective of loss function, C_H also satisfies: $C_H = L(T_H) \times e^{\int_0^H g_0 dt} = e^{-\beta(T_H)^2 + g_0 H}$ With the two equations, the marginal effect γ can be re-expressed as: $\gamma = \frac{T_H}{H \times [2 + \frac{1}{ln(0.5)}]} \times \beta$.

Following the instruction proposed by Pindyck (2012), we also fit a displaced gamma distribution to γ with three parameters (i.e. r_γ, λ_γ, θ_γ) to simplify our model.

In fact, the climate change technology and construction investment (CCTCI) to decelerate global warming has three different impacts on a utility.

Negative effects: CCTCI will reduce the proportion of consumption which determines the utility. In order to smooth the risk of a crowding-out effect as additional CCTCI may replace the customary investment, we assume that the CCTCI comes from the part of consumption rather than the traditional investment, which means CCTCI may not disturb the fundamental process of GDP growth. We adopt inv_i to denote the percentages of CCTCI to GDP for country i and the disposable amount of consumption should be modified:

$$C_i^* = C_i \times (1\text{-}inv_i). \quad (6)$$

Positive effects: CCTCI can accelerate the GDP growth potentially. As CCTCI is usually carried out as an extra investment in technology, extra construction and equipment consumption for adaption, it will boost the GDP growth rate. Such positive effects have been confirmed by European Union's experience (Jaeger et al., 2011). In order to reflect the acceleration effect, we use ξ_i to indicate the marginal effect of inv_i to GDP growth for country i. Then equation (3) should be modified:

$$g_{i,t}^* = g_{0\_i} \times (1 + \xi_i \times inv_i) - \gamma_i T_t. \quad (7)$$

Spillover effects: Individual CCTCI can affect the upper boundary of temperature increment (UBTI) gradually. Every country meets the same UBTI for the public goods feature of temperature increment. However, UBTI is determined by accumulated individual country's investments meeting the following relationship Φ:

$$T_{UP} = \Phi_0(inv_{world}) = \Phi_0(\sum_i w_i \times inv_i) = \Phi(inv_i), \quad (8)$$

where w_i is weighting factor, which represents the percentage of each individual's GDP to the world's. T_{UP}indicates that the temperature increment at horizon year H will be controlled below T_{UP} if global CCTCI meets the amount of inv_{world}. Extra information about the upper boundary of temperature increment will change the probability density of temperature increment and affect utilities eventually with Bayesian updating, which means equation (5) should be updated:

$$\tilde{f}_T(x; r, \lambda, \theta) = \frac{f_T(x; r, \lambda, \theta)}{\int_\theta^{T_{UP}} f_T(x; r, \lambda, \theta) dx}, \theta \leq x \leq T_{UP}. \quad (9)$$

Hence the optimal CCTCI for country I can be worked out by maximizing the following discounted present expected utility U_i with discounting rate δ_i:

$$U_i = \overbrace{\int_0^{+\infty}\int_{\theta_{\gamma\_i}}^{+\infty}\int_{\theta_T}^{T_{UP}} Utility^*_{i,t} \times e^{-\delta_i t} \times \tilde{f}_T(T;r_T,\lambda_T,\theta_T)\times f_{\gamma\_i}(\gamma;r_{\gamma\_i},\lambda_{\gamma\_i},\theta_{\gamma\_i})dTd\gamma dt}^{\Psi_i(inv_i,inv_j,g_{0,i})}, \quad (10)$$

where T_{UP} and Bayesian-updated probability density function $\tilde{f}_T$ refer to Equations (8) and (9) respectively. The adjusted utility at time t (i.e. $Utility^*_{i,t}$) is also calibrated as Equation (11) shows.

$$Utility^*_{i,t} = \frac{\left\{(1\text{-}inv_i)\times exp(\int_0^t g_{0,i}\times(1+\xi_i\times inv_i)\text{-}2T\times\gamma_i\times[1-(\frac{1}{2})^{s/H}]ds)\right\}^{1-\eta_i}}{1-\eta_i}. \quad (11)$$

Obviously, if we use $OptInv_i$ to indicate the optimal CCTCI for country i considering the other countries' investments inv_j, $OptInv_i$ may be related to itself GDP growth rate $g_{0,i}$ as equations (10) and (11) show, which means we can work out $OptInv_i$ by maximizing U_i:

$$\underset{inv_i}{Max}\,\Psi_i(inv_i,inv_j,g_{0,i}) \Rightarrow OptInv_i = \Theta_i(g_{0,i},inv_j). \quad (12)$$

Then one of the most interesting questions is, will country i's $OptInv_i$ increase or decrease if the other countries' investment inv_j increases? If criterion $K = \frac{\partial(OptInv_i)}{\partial(inv_j)}$ is positive, it means country i has incentives to cooperate to deal with global warming initiatively considering the others' more investment; if $K < 0$, it means country i has more incentives to freeride rather than to cooperate. As $OptInv_i$ is dependent on its own initial GDP growth $g_{0,i}$, the testing criterion K is also closely related to itself GDP growth rate, then will countries with higher GDP growth show up more incentives to freeride or cooperate? This theoretical model provides us a new perspective to investigate the climate negotiators' motivation. Illustrative cases together with simulations and sensitivity analyses are further discussed in section 2.

2. Illustrative case and simulation

According to the theoretical model, an illustrative case is carried out together with simulation. In order to make the results more clear and simple, we involve two individual countries, A and B[1]. Given B's CCTCI varies from 1 to 2 percent of its GDP, we work out country A's optimal CCTCI respectively. In order to distinguish the influences of A's initial GDP growth on its freeride or cooperate incentives, three groups of country A with different initial GDP growth assumptions (i.e. A1, A2 and A3) are involved firstly. Table 1 lists all the primary parameter settings.

Table 1. Primary parameter settings for illustrative case

Group	Parameters	Values
Common	($r_{\gamma A}$, $\lambda_{\gamma A}$, $\theta_{\gamma A}$)	(11.141, 22329, -2.8505e-4)
	(r_T, λ_T, θ_T)	(3.8, 0.92, -1.13)
	(η_A, δ_A, ξ_A, H, w_A, w_B)	(2, 0, 1, 100, 13.26%, 19.02%)
A1	$g_{0,A}$	2%
A2	$g_{0,A}$	3.5%
A3	$g_{0,A}$	5%

Notes: r_T, λ_T, θ_T are consistent with other researches including Pindyck (2012); $\xi_A = 1$ refers to the assumption that we treat the CCTCI the same as traditional investment with the same multiplier effect.

Figure 1 shows the relative change process of country A's utility for three different GDP growth groups. B1 and B2 refer to the 1% and 2% GDP investment backgrounds for country B. Solid lines with plus signs represent the relative utility change processes when country B's investment is limited to 2%, and solid lines without plus signs are for 1% investment situation. Groups a, b, c represent A1, A2 and A3 groups, respectively. For A1 group, both relative utility change processes are in the shape of inverted U, which means there exists optimal CCTCI for country A. The optimal CCTCI for country A when country B invests 1% GDP is approximately equal to 1.053%. Similarly, $OptInv_{A,B=2\%|g_{0,A}=2\%}$ is equal to 1.278%. It's obvious that country A will initiatively cooperate when A's initial GDP growth is 2% because $OptInv_{A,B=2\%|g_{0,A}=2\%} > OptInv_{A,B=1\%|g_{0,A}=2\%}$. However, if country A's GDP growth becomes higher, the difference between $OptInv_{A,B=2\%}$ and $OptInv_{A,B=1\%}$ shrinks and even becomes negative. This means, high-growth countries have greater intrinsic incentives to freeride rather than cooperate when the other countries invest more.

[1] Individuals A and B refer to the specific countries in the real world. In order to avoid political issues, the specific country names are anonymous which at the same time will not affect our research procedures and results. More information about the specific country names that A and B represent can be offered upon request if any reader is interested in.

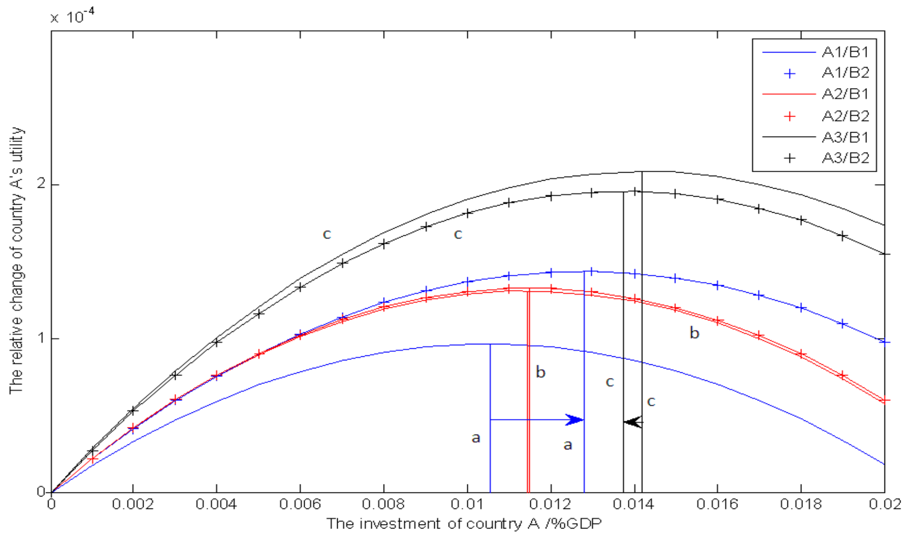

Fig. 1. The relative change process of country A's utility for different scenarios

Furthermore, Figure 2 shows the relationship between the gap and country A's GDP growth more continuously. The difference of optimal investment for country A decreases along with the increase in its GDP growth, which is consistent with the results of Figure 1. On the other hand, simulation results also indicate that countries with higher GDP growth in climate negotiation have stronger incentives to freeride, and prefer to reduce the investment when the other countries invest more. And countries with lower GDP growth have incentives to cooperate and invest more in climate change while the others increase CCTCI. In other words, for high-growth countries, the criterion $K = \frac{\partial(OptInv_i)}{\partial(inv_j)}$ is positive, and for low-growth countries, the criterion $K = \frac{\partial(OptInv_i)}{\partial(inv_j)}$ is negative. Such change process together with Figure 2 even indicates the slope of criterion K:

$$\frac{\partial K}{\partial(inv_i)} = \frac{\partial^2(OptInv_i)}{\partial(inv_j)\partial(inv_i)} < 0.$$

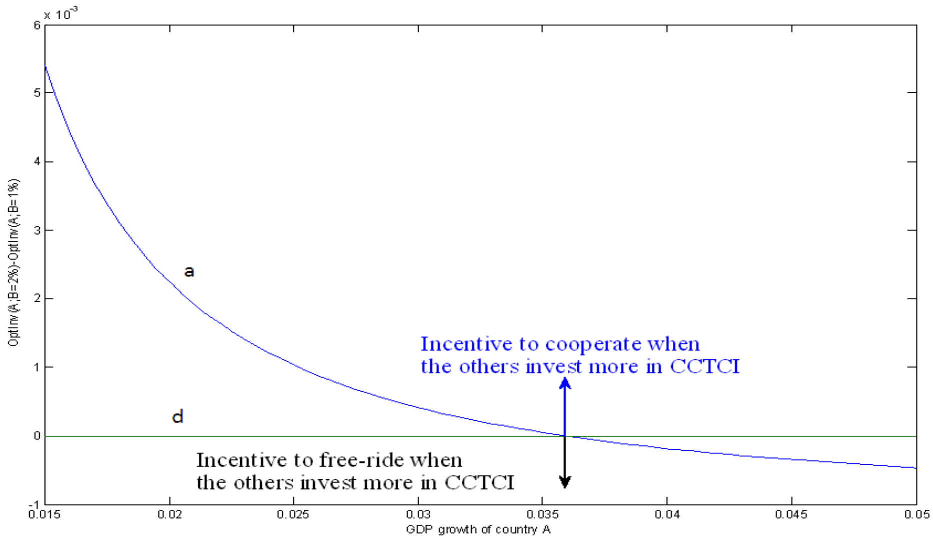

Fig. 2. Relationship between country A's GDP growth and the difference of A's optimal investments

In order to make the results of simulation more reliable, sensitivity analyses are carried out as Table 2 shows. Generally, the sensitivity analyses results support the reliability of our results mentioned above.

Table 2. Sensitivity analyses results

	Base model	$r_{\gamma A}, \lambda_{\gamma A}, \theta_{\gamma A}$		η_A		ξ_A		δ_A
		More risky	Less risky	Higher	Lower	Higher	Lower	Higher
$\frac{\partial K}{\partial(inv_i)} < 0$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Conclusion and policy implication

By involving the positive, negative and spillover effects of individual CCTCI into our utility maximizing model, we put forward a new theoretical approach to test the hypothesis of freeride incentives for high-growth countries in climate negotiation.

Additionally, an illustrative case based on reality is carried out and we find that countries with higher GDP growth trend to invest less (i.e. free-ride) when the other countries invest more in CCTCI. Such simulation results accord with the current situation in climate negotiation. Developing countries with high-growth in the future, such as China, India, Union of South Africa, are trying to persuade the developed countries to take more responsibilities using the reasoning of CBDR, which can be interpreted as a preference for less optimal investing for the developing countries on the condition that the developed invest more.

On the other hand, our simulation results also show that developed countries with low-growth in the future prefer to invest a bit more on the condition that the other developing will participate in emission reduction, which also agrees with the reality. Developed countries or regions, such as United States and Canada and especially the EU with its experience of ETS (Emission Trading System) and clean technology, tend to persuade other countries to participate into emission reduction program. The developed countries' attitudes can also be interpreted as their willingness to invest more on the condition that the developing countries make reduction promises.

Generally, apart from CBDR and other climate negotiation criteria, our utility based model with case simulations not only proposes a new approach to reexamine each country's intrinsic motivations and negotiation strategies in climate change negotiation, but also reveal the intrinsic relationship that high-growth countries have more incentives to freeride rather than to cooperate in climate negotiation, which is of great importance for our understanding and promotion of climate negotiations. In order to deal with the stagnation of climate negotiations, we should pay more attention to the design and implementation of specific mechanisms to switch the freeride incentives of high-growth countries.

Acknowledgements

The research was financially supported by National Natural Science Foundation of China project (No. 71273153).

References

1. Cullet, P. (2010). Common but Differentiated Responsibilities, *Research Handbook on International Environmental Law*, p. 161.
2. Dell, M., Jones, B.F. & Olken, B.A. (2008). Climate Change and Economic Growth: Evidence from the Last Half Century, National Bureau of Economic Research, Working Paper 14132.
3. Dell, M., Jones, B.F. & Olken, B.A. (2009). Temperature and Income: Reconciling New Cross-Sectional and Panel Estimates, *The American Economic Review*, 99 (2), pp. 198-204.
4. Jaeger, C.C., Paroussos, L., Mangalagiu, D., Kupers, R., Mandel, A., Tàbara, J. D., Botta, N., Fürst, S., Henning, E. & Ionescu, C. (2011). A New Growth Path for Europe. Generating Prosperity and Jobs in the Low-Carbon Economy. Synthesis Report PIK, University of Oxford, ICCS, Université Paris, 1.
5. Pindyck, R.S. (2011). Fat tails, thin tails, and climate change policy, *Review of Environmental Economics and Policy*, 5 (2), pp. 258-274.
6. Pindyck, R.S. (2012). Uncertain outcomes and climate change policy, *Journal of Environmental Economics and Management*, 63 (3), pp. 289-303.
7. Ringius, L., Torvanger, A. & Underdal, A. (2002). Burden sharing and fairness principles in international climate policy.*International Environmental Agreements: Politics, Law and Economics*, 2 (1), pp. 1-22.
8. Weitzman, M.L. (2009). Additive damages, fat-tailed climate dynamics, and uncertain discounting, *Economics: The Open-Access, Open-Assessment E-Journal*, 3, pp. 2009-2039.