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Research on Sustainable Development Issue in the Vision of Game Theory

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Research on Sustainable Development Issue in the Vision of Game Theory

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Abstract : Sustainable development issues belong to external non-economical common land based concerns. From an historical viewpoint, the main responsibility for the current series of global environment problem should be taken on by developed countries. Therefore, on sustainable development issue, international society has formed a principle of "common but different" responsibility-sharing rule. By game theory model, it is found that the reason why the negotiation between developed countries and developing ones reaches a deadlock again and again is short of proper conditions or mechanism to co-operate. There are at least three prerequisites to solve sustainable development issues, none of which has been met so far.

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I. Sustainable Development Issue

Since two published reports "Our common future" and "Declare on sustainable development" formally put forward the concept of sustainable development, the worldwide discussion on sustainable development has become a source of constant discussion. However, the discussion has not yet achieved a responsible or workable breakthrough between the worlds developed and developing countries.This seemingly endless debate continues at all levels of discussion.

At present, one focus of these quarrels is that developing countries ask the developed ones to bear more of the responsibility and be more forthcoming with assistance by providing advanced technology, equipment better facilities and funds. For the most part the developed countries promises to the developing countries have been strong in words but not in action. They further compromise the developing countries by asking them to slow down their economic expansion and take more effective and strictmeasures to conserve the ecological environment and harness their own environment pollution. As a result of this ongoing debate, there appears to be no innovative mechanisms throughout these quarrels that is leading to a solution of the sustainable development issue. The following game model has been constructed to reveal the essence of and possible solutions to the issue.

Primary assumptions: ①there are only two participating countries in the game, one being a developed country and the other a developing one. ②The strategic choices for the developed country are to assist the developing country to either harness pollution or not to. ③The strategic choices of the developing country are to either take measures to harness pollution or not to.④The amount of assistant fund is h.(including economic benefit transformation from non-money assistant manners).⑤ The economic costs for harnessing pollution is c.⑥The developing country's economic loss by not seeking to reduce their pollution level is w.⑦The developed country's economic loss because of The developing country's pollution external harm is w'.(Identically, $c > w > w'$, or, without the developed country's assistance, the developing country has a strong motivation to harness pollution)

The game model can be shown as following:

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		The developing country	
		Harness pollution	Don't harness pollution
The developed country	Offer assistance	$(-h, h-c)$	$(-h-w', \underline{h-w})$
	Don't offer assistance	$(\underline{0}, -c)$	$(\underline{-w'}, \underline{-w})$

By drawing underline method in above double-variable-avail matrix, we can easily find that in this game, $s^* = (\text{Don't offer assistance}, \text{Don't harness pollution})$ is a Nash equilibrium, which means that in respect to the developed country, its optimal strategy is to choose "Don't offer assistance" strategy whether the developing country chooses "Harness pollution" strategy or "Don't harness pollution" strategy because; $0 > -h, -w' > -h-w'$. The developing country, Whether the developed country chooses the "Offer assistance" strategy or "Don't offer assistance" strategy, its optimal strategy is to choose "Don't harness pollution" strategy because $h-w > h-c, -w > -c$.

This is the primary reason why a sustainable development theory between develop and developing nations has been no good practical function since it was put forward. Because the developing country's pressing task is to develop its economy, pollution and the environmental problems is accepted as an external diseconomy. These nations have neither the funds, the incentive or the ability to tackle these problems by themselves.

II. Innovative Mechanisms that Move Towards Solving the Sustainable Development Issues

Continue to assume that there are still only two participating countries, one being developed country and the other developing country. Assume further that an agreement between both countries has been signed that every year the developed country must assist the developing country by providing a reasonable amount of funds to assist environmental concerns. Assume: ①The strategic choices for the developed country are to verify pollution-harnessed conditions in the developing country or not to. ②The strategic choices for the developing country are to take measures to harness pollution or not to. ③The amount of assistant fund is h. (Including economic benefits transfers from non-monetary assistant).④The developed country's verifying cost is h'. ⑤Economic cost for harnessing pollution is c.⑥The developing country's economic loss because of their leaving pollution as is w.⑦The developed country's economicloss because of The developing country's pollution external harm is w'.(Identically, $c > w > w'$, or, without the developed country's assistance, the developing country has a strong motivation to harness pollution). ⑧fines incurred because of not harnessing pollution are z.Generally, $z > h'$ (therefore the developed country is motivated to verify the developing country), and $c < w + z$ (otherwise even if the developed country is likely to verify the developing country, the developing country still tends to choose the strategy of "don't harness pollution"). Therefore, the new game model is changed as following:

		The developing country	
		Harness pollution	Don't harness pollution
The developed country	Verify	$(-h-h', \underline{h-c})$	$(\underline{z-h'-h-w'}, h-w-z)$
	Don't verify	$(\underline{-h}, h-c)$	$(-h-w', \underline{h-w})$

By drawing the underline method in above double-variable-avail matrix, we find that there exists no Nash equilibrium in this game. The detailed process is: To the developed country, if the developing country chooses "Harness pollution" strategy, it would most likely choose a "don't verify" strategy because of $-h > -h - h'$, while if the developing country chooses "don't Harness pollution" strategy, it would like to choose a "verifying" strategy because of $z - h' - h - w' > -h - w'$. From the perspective of the developing country, if the developed country chooses a verifying strategy, it would most likely choose a harnessing pollution strategy. If the developed country chooses a "don't verify" strategy, it would most likely choose a "don't harness pollution" strategy. Therefore, by imposing added conditions and a verifying mechanism, the sustainable development game is wheeled to beneficial angle.

III. Further Discussion on the Variants' Effect on the Game Result

Suppose that verifying probability of the developed country is p, then the no verifying probability is $1-p$. Similarly, suppose that the probability for the developing country is to choose a "harness pollution" strategy q, then the probability for the developing country to choose a "don't harness pollution" strategy is $1-q$. Therefore the developed country's mixed strategy is $p_1 = (p, 1-p)$, while the developing country's mixed strategy is $p_2 = (q, 1-q)$. Therefore the developed country's strategy space is $S_1 = (verify, \text{don't verify})$ and the developing country's strategy space is $S_2 = (\text{harness pollution}, \text{don't harness pollution})$

The developed country		
strategy	verify	don't verify
probability	p	$1-p$

The developing country		
strategy	harness pollution	don't harness pollution
probability	q	$1-q$

So, the developed country's prospective revenue function is:

$$v_1(p_1, p_2) = pq(-h-h') + p(1-q)(z-h'-h-w') + (1-p)q(-h) + (1-p)(1-q)(-h-w')$$

Similarly, the developing country's prospective revenue function is:

$$v_2(p_1, p_2) = pq(h-c) + p(1-q)(h-w-z) + (1-p)q(h-c) + (1-p)(1-q)(h-w).$$

The next step is to pursue mixed Nash equilibrium (p_1^*, p_2^*), which is optimized key.

$$\max_{p_1 \in P_1} v_1(p_1, p_2^*) = \max_{0 \le p \le 1} [pq^*(-h-h') + p(1-q^*)(z-h'-h-w') + (1-p)q^*(-h) + (1-p)(1-q^*)(-h-w')]$$

$$\max_{p_2 \in P_2} v_2(p_1^*, p_2) \quad \max_{0 \le q \le 1}[p^* q(h-c) + p^*(1-q)(h-w-z) + (1-p^*)q(h-c) + (1-p^*)(1-q)(h-w)]$$

$$\frac{\delta v_1}{\delta p} = q^*(-h-h') + (1-q^*)(z-h'-h-w') + q^* h - (1-q^*)(-h-w') = 0$$

$$\begin{cases} \frac{\delta v_2}{\delta q} = p^*(h-c) - p^*(h-w-z) + (1-p^*)(h-c) - (1-p^*)(h-w) = 0 \end{cases}$$

$$p^* = \frac{c-w}{z}$$

$$\begin{cases} q^* = 1 - \frac{h'}{z} \end{cases}$$

In conclusion, the mixed Nash equilibrium for verifying and monitoring game is $p^* = (p_1^*, p_2^*)$. In this formula, $p^* = (\frac{c-w}{z}, 1-\frac{c-w}{z})$, $p_2^* = (1-\frac{h}{z}, \frac{h}{z})$.

The above formula mean that if $q < 1-\frac{h'}{z}$, the developed country will choose "verify" strategy, on the contrary, if $q > 1-\frac{h'}{z}$, the developed country will choose"don't verify" strategy, and only when $q^* = 1-\frac{h'}{z}$, will the developed country choose mixed strategy, choosing either "verify" strategy or "don't verify" strategy(for there is no revenue difference between both strategies). Similarly, if $p < \frac{c-w}{z}$, the developing country will choose "don't harness pollution" strategy, on the contrary, if $p > \frac{c-w}{z}$, the developing country will choose "harness pollution" strategy, and only if $p = \frac{c-w}{z}$, will the developing country choose mixed strategy, choosing either "don't harness pollution" strategy or "harness pollution" strategy(for there is no revenue difference between both strategies).

for harnessing pollution c and the developing country's economic loss w are fixed, the higher the fine z which because of not harnessing pollution and being verified, the smaller the verifying probability of the developed country p^*, while the lower the fine z, the bigger the verifying probability of the developed country p^*, because the developed country may consider that the higher the fine z which is caused because of not harnessing pollution and being verified, the more the developing country dare not take risk. If the fine z which is caused because of not harnessing pollution and being verified is fixed, the bigger economic cost for harnessing pollution c and the smaller the developing country's economic loss w, the bigger the verifying probability of the developed country p^*, because the developed country may consider that on this situation the probability q^* for the developing country to choose "harness pollution" strategy becomes smaller, while the lower economic cost for harnessing pollution c and the bigger the developing country's economic loss w, the smaller the verifying probability of the developed count

From above, it is clear that the mixed Nash equilibrium for verifying and monitoring game is linked with economic cost for harnessing pollution c.The developing country's economic loss w, fines z, and the developed country's verifying cost h'. For the developing country, if the amount of fines z is the result of not harnessing pollution and being verified is fixed, the lower the developed country's verifying cost h', the bigger the probability q^* for the developing country to choose "harness pollution" strategy , and the higher the developed country's verifying cost h', the smaller the probability q^* for the developing country to choose "harness pollution" strategy, because the developing country considers that the developed country's verifying probability is variable in the opposite direction to its verifying cost. If the developed country's verifying cost h' is fixed, the higher the fine z which is caused because of not harnessing pollution and being verified, the bigger will be the probability q^* for the developing country to choose "harness pollution" strategy, while the lower the fine z which is caused because of not harnessing pollution and being verified, the smaller the probability q^* for the developing country to choose "harness pollution" strategy, because the developing country may consider that the higher the fine z, the bigger the risk that it takes because of not harnessing pollution.For the developed country, if economic cost p, because the developed country may consider that on this situation the probability q^* for the developing country to choose "harness pollution" strategy becomes bigger.

IV. Research conclusion

Sustainable development issues belong to external non-economical common land decisions. To resolve this problem, at least three prerequisites to solve sustainable development issues must be met. First, the developed country must assist the developing country. Second, there must be a kind of verifying mechanism as an incentive for the developed country to provide money and technology. Third, the fine z which is caused by not harnessing pollution and being verified must be set big enough. Whether the developing country may take action to maintain the world's sustainable development is correlated with economic cost for harnessing pollution c, the developing country's economic loss w because of pollution, the fine z happens because of not harnessing pollution and being verified, the developed country's verifying cost h', and so on. This is especially if it is strongly correlated with the fine z which happens because of not harnessing pollution and being verified. The higher the fine z, the more strongly the developing country is pushed to solve its own pollution problem.

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