Atoms for Peace, Redux

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Introduction

The October 2006 nuclear test was a confirmation that North Korea has the potential to develop usable nuclear weapons and, importantly, the means for their delivery. This presents a clear and present danger to sustained stability on the Korean peninsula. Current thinking following the *Atoms for Peace* model has failed because of disagreements over the sequencing of denuclearization vis-à-vis energy aid, which is characterized by a classic prisoner's dilemma.

International security relations are often plagued by the commitment problems, where states striving for self-preservation in the system find it difficult to cooperate.[1] Cooperation can break down due to power asymmetries,[2] but may be sustained when interactions occur over multiple spheres,[3] or are repeated.[4]

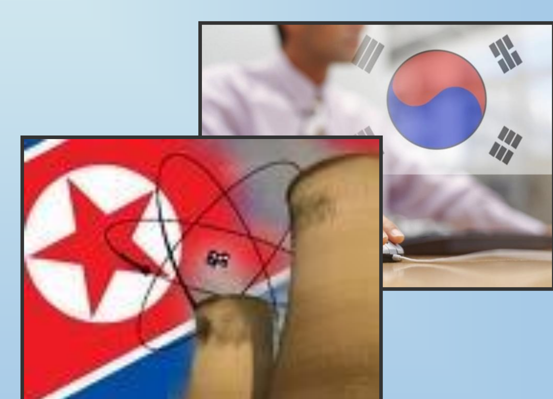
		US	
		D	ND
DPRK	NP	c, c	a, d
	P	d, a	b, b

d > c > b > a

This paper proposes an alternative approach to mutual cooperation in energy provision between interdependent states by having North Korea host reactors that deliver energy to South Korea. This can address both the fear experienced by the North that the South would threaten its energy independence were the reactors located in the South, while meeting need by the South to be assured that the North will not engage in weapons production.

Contributions:

- Develop game-theoretic model of energy codependency that is both stable in the short run and sustainable in the long run
- Model sidesteps problems of sequencing of energy aid vis-à-vis denuclearization
- Model offers possible applications for cooperative behavior between the Middle East and South Asia



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[3] Bernheim, B.D. & M.D. Whinston, "Multimarket Contract and Collusive Behavior", *RAND J of Ec* 21(1): 1–26
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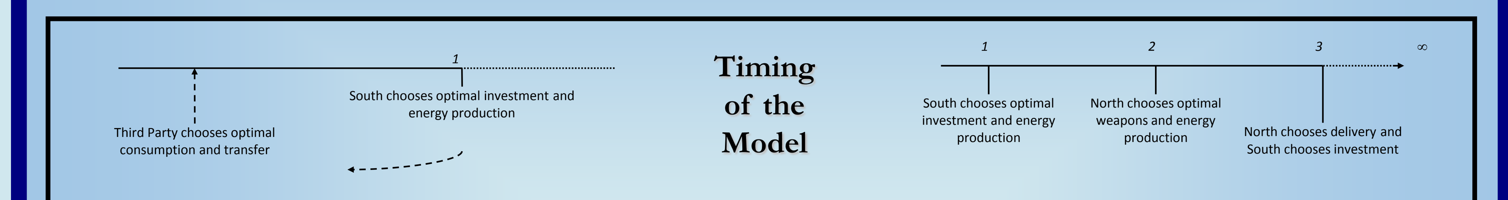
Abstract

The likelihood that North Korea possesses nuclear weapons is a clear and present danger to sustained stability on the Korean peninsula. Unfortunately, the traditional notion of "Atoms for Peace" has been a failure in the engagement of the North. In this paper we propose a novel approach to mutual cooperation in energy provision on the Korean peninsula, premised on having North Korea host reactors that deliver energy to South Korea. We establish conditions where there exists a stable, time-consistent equilibrium where the North never finds it in its interest to disrupt energy supplies to the South, and where the South is willing to pay the fixed costs of nuclear plant construction in exchange for a discounted stream of energy supply from the North. We also show that third-party income streams can augment the cooperative relationship.

Model



Model with Third Party

3rd Party

$$\max_{\tau_t, C_t} \sum_{t=0}^{\infty} \delta_X^t U_X\left[C_t, \varepsilon(\tau_t)\right] \quad s.t. \quad P_C C + P_{E_N}\tau \le Y_X$$

$$\varepsilon(\tau_t)\begin{cases} \tilde{\varepsilon}\cdot\tau_t & \text{if } \tau_t > 0 \text{ and } I_t > 0 \\ 0 & \text{otherwise} \end{cases}$$

(Externality benefits)

$$\sum_{t=0}^{\infty} \delta^t P_{E_N,t}\left[(1-\alpha)E_{N,t}(K_t)+\tau\right] \ge \sum_{t=0}^{\infty} \delta^t P_{E_N,t} E_{N,t}(K_1)$$

(Modified delivery strategy)

Solution concepts:

- Subgame perfect (pure) Nash equilibrium
- Linked games

Baseline Model

South

$$\max_{\hat{E}_S, I} U_S(I, E_S) \quad s.t. \quad E_S = \hat{E}_S + \alpha E_N$$

$$I_t = \begin{cases} \hat{I}_t & \text{if } \alpha_{t-1} > 0 \\ 0 & \text{otherwise} \end{cases}$$

(Investment strategy)

North

$$\max_{\hat{E}_N, W} U_N(W, E_N) \quad s.t. \quad D\cdot P_{E_N} E_N + P_W W \le Y_N(K),$$

$$D = \begin{cases} 1-\alpha & \text{with delivery} \\ 1 & \text{otherwise} \end{cases}$$

$$\sum_{t=0}^{\infty} \delta^t (1-\alpha) P_{E_N,t} E_{N,t}(K_t) \ge \sum_{t=0}^{\infty} \delta^t P_{E_N,t} E_{N,t}(K_1)$$

(Delivery strategy)

Results

Assumption 1. (a) Investment in each period is the fixed, positive amount invested in the first period; (b) Energy prices in the North are constant; (c) Energy production displays constant returns to scale in capital.

Proposition 1 (Atoms for peace redux). *Given* **Assumption 1** *and some functional form restrictions, if*

$$\frac{\beta}{1-\beta} < \frac{P_W}{(1-\delta)P_{E_N}}, \tag{1}$$

then the optimal investment by the South in the North is nonzero and given by

$$\hat{I}^* = \frac{\chi}{P_I}\left(Y_S + \frac{\delta}{1-\delta}\frac{P_{E_S}}{P_{E_N}}Y_N\right) > 0. \tag{2}$$

The optimal amount of investment by the South, which depends on, among other things, the elasticity of substitution between investment and indigenous energy production (χ), the ratio of Southern income to the price of investment (Y_S/P_I), and the relative price of Southern to Northern energy production (P_{E_S}/P_{E_N}).

Proposition 2 (Comparative Statics). *The optimal investment by the South in the North given in (2) is decreasing in the cost of energy in the North, P_{E_N}, and the cost of investment, P_I, while increasing in the cost of energy in the South, P_{E_S}, the elasticity of substitution between investment and indigenous energy production, χ, and relative cost of energy, (P_{E_S}/P_{E_N}).*

Assumption 2. The Third Party fully discounts the future.

Proposition 3 (Three-party atoms for peace redux). *Given* **Assumptions 1** *and* **2** *and some functional form restrictions, if*

$$\frac{\beta}{1-\beta} < \frac{P_W}{(1-\tau)(1-\delta)P_{E_N}}, \quad \text{and} \quad \tilde{\varepsilon} > \frac{Y_X/P_C - 1}{Y_X/P_{E_N} - 2}, \tag{3}$$

then the optimal investment by the South in the North is nonzero and given by

$$\hat{I}^{*'} = \frac{\chi}{P_I}\left(Y_S + \frac{\delta+\tau(1-\delta)}{(1-\tau)(1-\delta)}\frac{P_{E_S}}{P_{E_N}}Y_N\right) > 0. \tag{4}$$

The North now considers investment, energy production, *and* the transfer in making its decision to deliver energy or not. Optimal investment by the South is now affected by the size of the transfer.

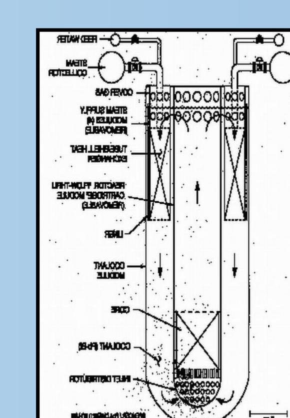
Proposition 4 (Comparative Statics). *The optimal investment by the South in the North given in (4) is increasing in the size of the transfer, τ.*

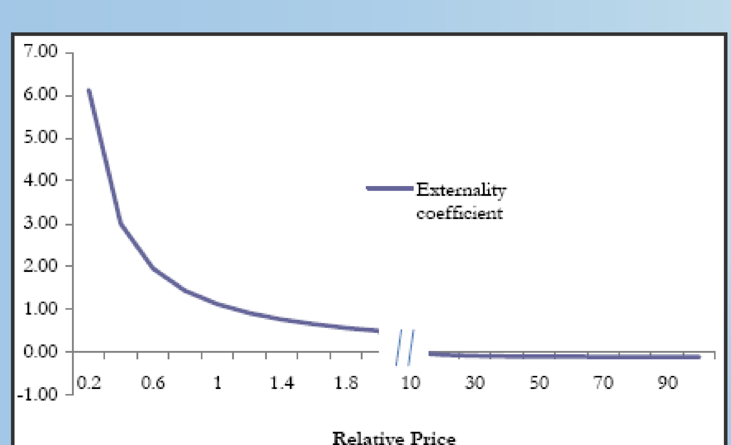
Discussion

The baseline result in **Proposition 1** requires that condition (1) be satisfied. What does this condition mean? Essentially, it requires that the present value of the relative price of weapons to energy be sufficiently large. To see this, suppose that the North places an equal weight on weapons and energy production (β = 0.5). Then the condition simplifies to

$$\frac{P_W}{P_{E_N}} > 1-\delta$$

which, for reasonable values of δ, requires that the price of weapons be so much larger than that of energy so as to discourage the allocation resources to its production altogether. This result suggests that the South (or another entity) can actually induce its own continued participation in the game by somehow subsidizing energy production in the North. Another way to interpret this condition is that the relative price of weapons has to be raised. How can this be done? Recent advances in the design of compact liquid metal reactor technology offer the promise of largely exploitation-proof reactors.[5] Such "protected" reactor designs implicitly raise the cost of acquiring unprocessed nuclear material for the purposes of enrichment, and has the additional benefit of allaying concerns over the potential abuse of civilian reactors.





Threshold values of the externality coefficient

The baseline result in **Proposition 3** requires that condition (3) be satisfied. (3a) means that (1) is now moderated by the term (1 – τ), and (3b) requires that the externality multiplier be sufficiently large. The threshold size of the externality coefficient is decreasing in the relative price, as illustrated in the example below.

Example 1. Let Y_X = 10 and P_{E_N} = 1, and let $P_C \in$ [0.2, 200]. The threshold levels of the externality coefficient are then summarized in the table and plotted on the graph. The externality coefficient is clearly decreasing in relative price. Moreover, when relative prices are at least double, the externality coefficient responds positively to the income of the Third Party. This means that (economically) larger Third Parties, such as the United States and Japan, will be more likely to effect the transfer when the relative price of consumption is small.

Y_X	P_C	P_{E_N}	P_C/P_{E_N}	$\tilde{\varepsilon}$
10	0.2	1	0.2	6.125
10	1	1	1	1.125
10	2	1	2	0.500
10	10	1	10	0.000
10	20	1	20	-0.063
10	200	1	200	-0.119

In Practice

Investing in nuclear power in the North provides the South with low-cost energy. Should the North fail to deliver, it can simply stop its flow of investments and return to its *status quo* sources of energy. The North will also be able to stay true to its ideology and not be too beholden to foreign governments. Since the power plants are in the North, it actually has a nontrivial amount of leverage to hold the South in check.

Timing issues are minimized since the North does not possess an adequate power grid that would allow cooptation of the nuclear reactor(s) and running them without Southern involvement. There is also little in the transfer for the North to exploit, since the South is not supplying material that could be weaponized, nor are they providing knowledge that the North does not already have.

Our proposal does not directly address the North's existing uranium enrichment program. Adding a contingency for verifiable dismantling of this program may make the proposal more politically palatable. The cooperative framework proposed can nonetheless lay the foundation for greater trust and the ultimate denuclearization of the peninsula.

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