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## The Structure of Arms Races Before and After the End of the Cold War: From Strategic Substitutes to Strategic Complements

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CENTER DISCUSSION PAPER NO. 753

THE STRUCTURE OF ARMS RACES BEFORE AND AFTER  
THE END OF THE COLD WAR:  
FROM STRATEGIC SUBSTITUTES TO STRATEGIC COMPLEMENTS

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## ABSTRACT

This paper applies the theory of collective action to the arms race. The analytical property of strategic interdependence has completely changed since the end of the cold war. In the presence of the "evil empire," the allies' strategic structure was "strategic substitutes;" the strategic structure after the cold war was "strategic complements." During the cold war, defense was a public good, and the small countries had a tendency to exploit the large. In the period after the cold war, defense has become a public bad, and the large country tends to exploit the small.

KEY WORDS: Arms Races, Collective Action, Strategic Complements, Strategic Substitutes, Country Sizes

**The Structure of Arms Races Before and After  
the End of the Cold War:  
From Strategic Substitutes to Strategic Complements**

Koichi Hamada  
(ECAAR-Japan and Yale University)

**1. Introduction**

After the fall of the Berlin wall, the "evil empire" against the free world disintegrated. There are, of course, potential local threats from countries like North Korea, Iraq, and actual fighting has been going on around Bosnia. Some of these conflicts may threaten us with the possibility of nuclear war, but the simple division of the world into the capitalist allies and the socialist bloc no longer exists.

We will study the strategic structure of the post cold-war world, by applying a simple framework of the Nash equilibrium in game theory. To understand the nature of strategic interdependence in peace and military issues, the natural methodology is game theory. In fact, game theory was developed first as a theory of economic warfare, by von Neumann and Morgenstern (1944).<sup>1</sup> I chose this topic of game theoretic approach also because I thought this type of topic might attract the younger generation of economists whose participation in the ECAAR in Japan as well as in the United States is strongly needed.

We will argue that the analytical properties of strategic interdependence have completely changed since the end of the cold war. In short, the strategic structure between the allies in presence of the "evil empire" had the nature of "free-ridership" or of "strategic substitutes"; that between nations after the cold war has the nature of "keeping up with the Joneses," or of "strategic complements."

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<sup>1</sup> I often listen to the account of Shizuo Kakutani, who is known to economists for his fixed point theorem, on the research of von Neumann and Morgenstern at the Institute for Advanced Studies at Princeton. He tells us that the theory of games was first known as the theory of economic warfare, and that his notes and research materials related to von Neumann's work were confiscated in New York when he had to go home on an exchange boat sent to repatriate U.S. and Japanese civilians stranded on the wrong side after the outbreak of the war.

Before the breaking down of the Berlin wall, the alliance against the Communist bloc played the game of public goods where most countries tried to shift the burden of defense on to other countries. They were motivated to let others spend more on mutual defense. For the alliance as a whole, the supply of public goods fell short of the optimal level. The large country, or the hegemon, had incentives to spend for the international public good. The result was characterized by the phrase: "The small exploits the large" (Olson 1965, Olson and Zeckhauser, 1966). Small countries deviate more from the appropriate supply of the public goods. In this situation, one country's increase in defense spending is countered by another's decrease. Modern game theorists call this situation the case of "strategic substitutes" in the Nash equilibrium.

After the breakdown, what the alliance stood for became vague. The strategic structure has changed (Downs ed. 1994). We aim to characterize the exact nature of this structural change. In this changed world, nations do not know which other nations will be allies or enemies tomorrow. A nation will spend more on defense if another country, particular its neighbor, spends more. Nations engage in the process of "keeping up with the Joneses." Here the extra defense spending turn into "public bad" rather than "public good" and the supply of public bad risks becoming excessive. It will be shown below that small countries expand their expenditure more than proportionally to their size. Figuratively, one could describe this situation "the large exploits the small." At least small countries spend more proportion of national income on defence expenditure. This situation is known in game theory as the case of "strategic complements."

In this paper we will address the nature of arms races or arms reduction before and after the melting ice of the Cold War. First, we will analyze how the strategic structure of interdependence changed after the fall of the Berlin wall and how the strategic structure of national incentives is related to the size of nations (Sections 2 and 3). Then, given the structure of international interdependence during and after the cold war, we will briefly discuss the problem of incentive compatibility in arm races. The question is: Is there any incentive structure for nations to reduce the abuse of their arms expenditures? In our simple framework, the answer to this question tends to be on the negative, pessimistic side (Section 4). Finally, we will conclude this short paper by summarizing the result and referring to related topics such as brinkmanship.

## 2. The Hegemon and the Supply of Public Good during the Cold War

Before the fall of the Berlin wall, the Western Allies commonly believed that their military alliance was a desirable thing and that their military expenditures had the nature of an international public good, or more precisely, a club-type public good. The same sentiment was most likely shared by countries in the socialist bloc. In other words, there was an evil empire on the opposite side of the Iron Curtain. At that time the major question was one of burden sharing of the defense expenditure: How, for example, do the Allies in NATO share the burden of defense expenditure? How are they motivated to contribute to the mutual defense? And are there not temptations to free ride by relying on other countries and, in particular, on the leader country like the United States? Similar questions could be asked for the nations within the Soviet bloc.

An early, but still influential argument, was developed by Olson (1965) and Olson & Zeckhauser (1965). Addressing the economics of military alliances, they found in the example of relative expenditures by NATO countries that a larger country spent a larger proportion of national income on military expenditure than smaller countries. The theoretical foundation of this tendency was developed as the theory of collective action (Olson, 1965).

Game theory is not explicitly treated in his book, but the concept of the Nash solution is implicitly used in his analysis. The logic goes like this. First, the military alliance creates a defense capacity that is an international public good. It is a public good in the sense that one cannot exclude a member of the alliance from consuming and enjoying the service of the collective defense (non-exclusiveness); it is a public good because if a nation enjoys the service of the alliance, the benefit to another nation will not be diminished (non-rivalry).

Of course, these statements are a little too strong. Some exclusivity can be obtained under certain circumstances, and in that case the collective defense turns into a club good. Non-exclusiveness does not apply in this case. Also, if a military power is defending one country, probably another country may find itself less secure if the force is employed on its border. Non-rivalry does not apply.

But these are subtle qualifications. The basic logic of the following public good analysis will essentially hold even if we take these qualifications into account.

Let us develop simple examples of the alliance before the end of the Cold War. They are adapted versions of the model developed in Hamada, (1995). Though they are simple examples, they illustrate the basic property of strategic interdependence.

Suppose there are two goods; private good, good 1, that is consumption good and public good; good 2, that is defense. The public good has the nature of non-rivalry and non-exclusiveness. Each citizen and, accordingly, nation contributes a certain amount of income to the supply of defense as an international public good for security. The hegemon has a population (normalized by the world population) of  $1 - \varepsilon$ , and the smaller country has the population of  $\varepsilon$ .

Suppose the utility of a representative individual in the two countries is respectively

$$(1) c_1^{1-\alpha} c_2^\alpha, \text{ and } c_1^*{}^{1-\alpha} c_2^*{}^\alpha,$$

where  $c_1, c_2$  are per capita consumption of private good and defense by the citizen of the hegemon, and  $c_1^*, c_2^*$  are consumption of private good and defense by the citizen of the smaller country.  $\alpha$  is the proportion of income that a nation would spend if there were no expenditure for defense by the other nation.<sup>2</sup>

Each individual of country 1 receives a unit of income that is given like manna in the form of private good 1, a part of which she consumes as good 1, and the rest of which she contributes to the alliance to provide defense. Each individual in country 2 similarly receives  $y^*$  unit of income. Thus

$$(2) c_1 + x_2 = y, \quad c_1^* + x_2^* = y^*.$$

Here  $x_2$  and  $x_2^*$  are the per-capita contributions of citizens in the two countries. The world per-capita supply of defense is assumed to be the weighted sum of these contributions:

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<sup>2</sup> We can obtain the same qualitative results without assuming specific forms of the utility function as long as the utility function is homothetic, but we rely on (1) for the sake of exposition.

$$(3) c_2 = c_2^* = (1 - \varepsilon)x_2 + \varepsilon x_2^*$$

The governments collect these contributions equally from individuals. They are assumed to play strategically given the amount of the contributions of the other country.

One can derive the reaction curve of each country in terms of its contribution to the alliance. By maximizing utility (1), given the budget constraint (2) and defense provision (3), and given the value of  $x_2$  or  $x_2^*$  of the other country, we obtain

$$(4) x_2 = \alpha y - \theta(1 - \alpha)x_2^*, \text{ and } x_2^* = \alpha y^* - \theta^{-1}(1 - \alpha)x_2,$$

where  $\theta$  is defined by  $\theta = \frac{\varepsilon}{(1 - \varepsilon)}$ . A smaller value of  $\varepsilon$  corresponds to a smaller value of  $\theta$ , that is, a higher degree of dominance of the hegemon. If the two countries have the same size  $\theta = 1$ . The resulting Nash equilibrium is given by the pair  $x_2$  and  $x_2^*$ ,

$$(5a) x_2 = [y - \theta(1 - \alpha)y^*]/(2 - \alpha),$$

$$x_2^* = [y^* - \theta^{-1}(1 - \alpha)y]/(2 - \alpha), \text{ if } \theta(1 - \alpha)^{-1} \geq \frac{y}{y^*} \geq \theta(1 - \alpha)$$

$$(5b) x_2 = \alpha y, x_2^* = 0, \text{ if } \frac{y}{y^*} \geq \theta(1 - \alpha)^{-1}$$

$$\left[ \begin{array}{l} (5c) x_2 = 0, x_2^* = \alpha y^* \text{ if } \frac{y}{y^*} \leq \theta(1 - \alpha) \\ \text{which never happens if } y^* > y \text{ and } \theta < 1. \end{array} \right]$$

The case (5b) indicates where the hegemon can become a privileged group on its own. More precisely, the hegemon has to be a privileged group because the other country does not spend on defense. Case (5c) is unlikely to occur because we assume  $\theta$  is small.

Figure 1 illustrates these reaction curves. If  $\varepsilon$ , and accordingly  $\theta$ , are small, the reaction curve of the hegemon does not diverge from the optimal provision of the defense expenditure  $x_2 = \alpha y$ . The internal Nash solution described by (i) is shown by the intersection of two reaction curves. In fact one can easily ascertain that the contract curve (or the Pareto optimal cooperative solution) lies on a curve that passes through point  $(\alpha y, \alpha y^*)$ . On the other hand, when  $\varepsilon$  and  $\theta$  are small, the reaction curve of the smaller country diverges greatly from the optimal provision  $x_2^* = \alpha y^*$ . As is indicated in the diagram, the small can exploit the large in this case involving the public good.



This type of approach was taken by Olson (1965), and by Olson and Zeckhauser (1966). The latter work includes a diagram similar to Figure 1, and the former contains the well-known remark, "there is a systematic tendency for 'exploitation' of the great by the small" (Olson, 1965, p.29). Olson and Zeckhauser support this hypothesis by examining NATO countries' defense expenditure data. Few seem to be clearly aware of the fact, however, that this exploitation property stems from the situation involving the supply of a public good and that the opposite is true in the situation with the private good (see Hamada 1995).

A similar approach can be applied if there are many small countries and a large hegemon. Suppose that a small country occupies a fraction  $\varepsilon$  of the world economy, but that there are  $n$  small countries. The hegemon's reaction function does not change except that  $\theta$  is defined as  $n\varepsilon/(1 - n\varepsilon)$ . Reaction functions of smaller countries are modified. That is,

$$(6) \quad x_2 = \alpha y - \theta(1 - \alpha)x_2^*, \quad x_2^* = \frac{\alpha}{[(1-\alpha)n+\alpha]} - y^* - \frac{1-n\varepsilon}{(1-\alpha)n\varepsilon+\alpha\varepsilon} (1 - \alpha)x_2.$$

The behavior of smaller countries will divert even further (Figure 2). The resulting Nash (internal) equilibrium is given by

$$(7) \quad x_2 = \left[ \alpha y - \frac{\theta(1-\alpha)\alpha}{(1-\alpha)n+\alpha} y^* \right] / D, \quad x_2^* = \left[ \frac{(1-n\varepsilon)(1-\alpha)\alpha y}{[(1-\alpha)n+\alpha]\varepsilon} - \frac{\alpha y^*}{(1-\alpha)n+\alpha} \right] / D,$$

where  $D$  is the determinant defined as

$$D \equiv 1 - n(1 - \alpha)^2 / [(1 - \alpha)n + \alpha]$$

which is found to be always positive.

In the terminology of modern game theory, the situation of public good is called the case of strategic substitutes. In this situation, both reaction curves are negatively sloping. If one country expands its military expenditure, the other has an incentive to reduce its own. The expenditure of one party works to substitute the expenditure of the other.

Table 1 shows the simplified pay-off matrix of the game just described for a symmetric world. Two equal sized countries are in a military alliance and jointly cope with a common enemy. If both countries take substantial responsibility for military spending, the outcome (2, 2) will be realized. However, a country can take a free ride strategy that it will save its military expenditure once the other country provides sufficient defense spending. If both take

this free ride attitude, then the alliance will end up with less than optimal military expenditures. Accordingly, as in Figure 1 the reaction curve of country 1, which is the focus of country 1's optimum response given the other country's strategy has a downward slope. That is, if the other country spends more, then this country will spend less.

Moreover, if we introduce a big country and a small country, the former is much more motivated to defend the region. If we consider the free world where the United States occupies a large space relative to other countries, then the United States will have an intrinsic interest to defend all the territory of the free world. A large country is more concerned with its territory. To protect its well being, the large country is motivated to share a substantial or even the total burden of defense expenditure. (If it is motivated to share the total burden, we call it a privileged group.) On the other hand, as long as the large country, the hegemon, spends a large amount on defense, small countries do not much improve their welfare if they spend on defense. The reason is that the defense as an international public good is the result of the sum of activities of the allied countries.<sup>3</sup>

From this angle, Olson and Zeckhauser calculated the relative contributions in NATO's defense expenditure and observed the tendency for a larger country to pay more than a proportionate share of the burden of military expenditures.

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<sup>3</sup> The reaction curve of a small country comes down and a large country has to bear a substantial or a total volume of defense expenditure.

### 3. Competition for Defense Expenditures After the Fall of the Berlin Wall

From the time the ice of the Cold War began to melt, the strategic structure of military interdependence has changed. There is no strong absolute enemy or "evil empire". On the other hand, one nation does not know which other country may become its potential enemy. Yesterday's friend may be tomorrow's enemy. And if one country starts increasing its military expenditures, other countries are compelled to match that spending. In this sense the strategic structure has changed. In this situation, even though they know reducing armaments is mutually beneficial, each country worries about the spending by its neighbor and expands its military expenditures. Hypothetically, if Iran's military expenditure increases, so does Iraq's. For the world as a whole, a competitive arms race will develop. In this case, the exploitation of the large by the small does not apply. Rather, small countries tend to spend a larger proportion of their income on defense.

Thus, let us consider the case that the expansion of defense expenditure by a neighboring nation is detrimental to the country. Let us assume the same utility functions (1), consumption constraints (2) as in the last section. However, in this section we will assume that the level of security depends on the difference between one's defense expenditure (adjusted by the country size) and a part of the other country's expenditure (adjusted by its country size):

$$(4A^*) \quad c_2 = (1 - \varepsilon) x_2 - \varepsilon\beta x_2^*, \text{ and } c_2 = (1 - \varepsilon)\beta x_2 + \varepsilon x_2^*$$

where  $0 < \beta < 1$  indicates the degree of neighborhood effect.

In the same way as in the previous section, one can derive the reaction curves in the following form:

$$(4A) \quad x_2 = \alpha y + \theta(1 - \alpha)\beta x_2^*, \text{ and } x_2^* = \alpha y^* + \theta^{-1}(1 - \alpha)\beta x_2$$

where  $\theta$  is again equal to  $\varepsilon/(1 - \varepsilon)$ .

Here one can see the reaction curves are positively sloped (Figure 2). In this simple model, the contract curve passes through the origin. The intersection of the reaction curves gives the Nash solution where defense expenditure of nations far exceeds the desirable one. The Nash equilibrium is always internal and given by

$$(5A) \quad x_2 = \alpha[y + \theta(1 - \alpha)\beta y^*]/D, \quad x_2^* = \alpha[y^* - \theta^{-1}(1 - \alpha)y]/D,$$

$$D = 1 - (1 - \alpha)^2\beta^2$$

if  $\theta$  is small,  $x_2^*$  will become large. Thus a smaller country will spend a larger proportion of its income on defense. We can thus paraphrase Olson's familiar dictum as "the large exploit the small." Small countries correspond to a lower value of  $\theta$  for the reaction function determining  $x_2^*$ , and relatively small countries tend to spend more than proportionately on defense. This section shows that competitive arms build-ups will follow once each country looks on its neighbors as potential enemies.

It may be possible to argue that many Asian countries are expanding their armaments according to the strategic complements structure. Also after the disappearance of the communist bloc's threat, the nature of strategic interdependence has changed to emphasize the strategic complements nature within a bloc. In fact Olson and Zeckhauser noticed in their classical article that if alliance countries are mutually, even partially, hostile toward each other then the alliance will be strong. If they spend to defend themselves against their neighbor, then they automatically spend for defending the alliance. But what they considered as an auxiliary element now becomes in the changed framework the main element that leads strategic confrontations.

The pay-off table in the post cold-war world can be depicted as Table 2. If two countries reduce arms, everything will be fine. If one of them reduces its armed forces but the other expands them, this could increase the prospects that the arms reducing country will be invaded by the other. Basic conflicts between hostile governments take this form. In fact, even during the cold war this was the basic structure between the western allies and the communist/socialist bloc countries. Within each alliance there are problems of free-riding as analyzed by Olson and Zeckhauser, but between the alliances or blocs this structure of strategic complements existed.<sup>4</sup>

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<sup>4</sup> Under the American Constitution (The Second Amendment), the right to bear arms is recognized. This article made much sense when it was established, because Americans had to fight against the colonizing enemies. The right to resist against the enemies by federation was the situation of strategic substitutes. When this article is invoked to resist gun control, however, the situations in American cities are those of strategic complements. In this current situation, bearing arms to protect other (or public officials?) will result in an unfavorable equilibrium in the prisoners' dilemma.

From our analysis, we obtain two testable hypotheses:

- (i) Within a military alliance, and particularly before the breakdown of the cold war, large countries spend more than proportionately (with respect to their size) on defense.*
- (ii) Without the military alliance, smaller countries spend more than proportionately (with respect to their size) on defense.*

Also one can take account of various topological factors: geographical, ethnic, religious and cultural distance between countries. One can examine the distance of the relationship in terms of circular matrices. One can modify the formulation to take account of political systems such as dictatorship, democracy or post socialist states, and the degree of international transactions like trade and investment, and most importantly the current situation of the nation and its preconditions given by its history.

Figure 3 depicts the ratios of military expenditure to GDP and how NATO nations ranked by population in 1993. Here one can detect a weak positive relationship long discussed since Olsons and Zeckhauser. This is the prediction from the theory of collective action, the case of strategic substitutes. Figure 4A and 4B (excluding China) show the same relationship for Asian countries where no strong military alliances exist between countries. This figure indicates a surprisingly strong negative relationship --- just as predicted by the strategic complements model discussed in this section.

Incidentally, the strategic structure of international policy coordination and monetary interdependence has two structurally different relationships. Under a fixed exchange rate system, monetary interdependence assumes the nature of strategic substitutes. If one country provides more money, then the other countries, trying to reduce the inflationary pressure, reduce their money supply. Therefore, an expansion in one country is offset or substituted by a reduction in the others.

On the other hand, under one flexible exchange rates an expansion of the monetary policy by country may be transmitted to others as a contradictory shock. Therefore, it triggers an expansionary monetary policy in other countries. Expansion is matched by expansion, which is a strategic complements situation.

#### 4. Revelation of Information and the Structure of Interdependence

The difference between strategic substitutes and strategic complements has recently attracted the attention of economists and game theorists. The difference can decide in many cases the direction of comparatively static results in the Nash equilibrium.

First, we can change the game slightly, and make it a succession of two players, a first mover and a second. Then it is shown (Gal-Or, 1985) that the first mover has an advantage under strategic substitutes and the second mover has an advantage under strategic complements. In our military context, in the case of the free-rider game under the cold war regime, the United States would be able to profit from its leadership. Its credible commitment would win favorable responses from others. Under the situation of strategic complements, as has prevailed since the Berlin Wall, a waiting strategy is beneficial. Why don't we wait for the other country? The logic is: After watching your potential enemy's arms build-up, you will start boosting your armaments to make them a little stronger than your potential opponent's. Thus the waiting strategy will work.

Under the strategic substitutes case, the United States can easily assume the leadership role because of its size. Its first move can be taken as a definite signal. Under the strategic complements case, no country, not even the United States, will have incentives to take the initiative. The situation will thus become more ambiguous, and possibly unstable.

The second interesting implication of the distinction between strategic substitutes and complements concerns the revelation game of information. Suppose it is not easy to know the cost and benefit data of the opponent in arms races. Okuno, Postlewaite and Suzumura (1990) considered the following situation. Suppose the home country cannot detect the foreign country's cost benefit data concerning the level of military technology. On the other hand, the foreign country is capable of knowing the home country's cost benefit structure and accordingly its reaction curve. For simplicity, let us assume that only the home country does not know whether the foreign country has a low cost of producing arms (but possesses the nuclear technology, for example) or a high cost of producing arms (does not possess nuclear technology).

Under this asymmetric information structure, the foreign country has the choice of whether to announce its cost structure, or to keep it secret. In other words, the foreign country can reveal or conceal whether it has a low cost and accordingly is capable of behaving in an aggressive fashion or it has a high cost. Then the game consists of two stages: the first stage of information revelation, and the second stage of arms build-up.

For example, the question is as follows: For a European NATO member country, is there an incentive to tell the other members of the NATO, particularly the United States, whether or not it has the technology to produce weapons cheaply?

Okuno et. al. (1990) give a clue to this question. Suppose, in accordance with them that after the announcement, the low cost structure of military armaments by country 1 can be verified by country 1, but that the high cost structure cannot be verified. Presumably, a high productivity of producing defense equipments such as nuclear weapons can be easily verified. But if it is kept secret, it is not easy from the first country to detect whether the second country has high productivity in producing arms. Let us remember the initial premise that the cost structure of the home country is known to the foreign country.

Let us start from the case of the strategic substitutes. That is, the case of a military alliance. Figure 5 illustrates the incentive for information revelation. The reaction curve of the foreign country is either  $R^*R_L^*$  or  $R^*R_H^*$ , depending on whether it has a low or a high cost structure. Without revelation and some simplifying assumptions of linearity, the home country takes the average and  $R^*R^*$  becomes the foreign country's reaction curve. Therefore the home country takes strategy X and the foreign country takes the strategy on  $R^*R_H^*$  or  $R^*R_L^*$  depending on its cost structure. The resulting equilibrium is either  $P_L$  or  $P_H$ . If the foreign country reveals its cost structure truthfully, the home country knows the position of the true reaction curve of the foreign country and achieves Q or S.

In this situation, it is not profitable for the foreign country to reveal that it has low costs, because the home country will reduce military expenditures and thus shift the burden to the foreign country. Then the equilibrium shift from  $P_L$  to Q. Even though the low cost structure can be verifiable by our assumption, this revelation is not supported by the incentive mechanism, because the

foreign country loses its free-riding position. On the other hand, it is profitable for the foreign country to announce that it has high costs because by that revelation the foreign country would enjoy more of the free rider status. If the announcement is believed, the equilibrium moves from P to S. Unfortunately, the foreign country gains by pretending that it has high costs even though it has low costs, because in the latter the equilibrium would shift from  $P_L$  to  $P_S$ . The revelation of the high costs thus creates the credibility problem and does not work either. In the real world example, if a European country says that it does not have high productive capacity for defense, it is not verifiable under our assumption. It might be interpreted as a pretext for further free riding, and accordingly might not be believed.

Similarly, Figure 6 illustrates the incentive for information revelation in the case of strategic complements. The reaction curve of the foreign country is either  $R^*R_L^*$  or  $R^*R_H^*$ . Without revelation, the home country takes the average and takes  $R^*R^*$  as the foreign country's reaction curve. Therefore the home country adopts strategy X and the foreign country chooses the strategy on  $R^*R_L^*$  or  $R^*R_H^*$  depending on its cost structure. The resulting equilibrium is either  $P_L$  or  $P_H$ . If the foreign country reveals its cost structure truthfully, the home country knows the position of the true reaction curve of the foreign country and achieves Q or S.

In this situation, it is not profitable for the foreign country to reveal that it has low costs, because the home country will build up its own armaments and the equilibrium will then shift from  $P_L$  to Q. Even though the low cost structure is verifiable by our assumption, such a revelation is not supported by the incentives for the country that has the choice to announce or not. On the other hand, it is profitable for the foreign country to reveal that it has high costs. Unfortunately, the foreign country gains by pretending that it has high costs even though they are low, because the equilibrium shifts from  $P_L$  to R. Revelation of high costs thus creates a credibility problem and does not work either. For example, if North Korea says that it does not have nuclear weapons, and if it not verifiable under our assumption, then South Korea will have difficulty to trust it.

Thus, whether the case concerns strategic substitutes or complements, there are incentives to pretend to having high costs -- and not revealing the full truth. Pretending to be a high cost country helps free riding (the case of substitutes), or inducing the



rival country to relax its guard (the case of complements). An incentive compatible system is not constructed in this particular model. All the discussions will be different if we change the assumption that only a low cost structure is verifiable. The presence of any surveillance or inspection method that can verify the absence of certain types of weapons would help towards achieving relative arms reductions in the world.

Finally, a highly relevant factor for defense analysis is the "game of brinkmanship." Brinkmanship is also called the game of chicken, which is a challenge to see which player will give in first. For example, two opponents drive cars towards each other at a high speed from opposite ends of a road to see who will turn away first to avoid a crash. If neither driver concedes, then a catastrophe results. If one party "chickens out," then the other driver will win. In international politics, the best cited example of brinkmanship is the Cuban missile crisis staged by John F. Kennedy and Nikita Khrushchev. Another example is the Mayaguez Incident which occurred during the U.S. war with Vietnam (Nalebuff, 1991). After many frustrating incidents in Vietnam, a U.S. ship, the Mayaguez, was captured by Cambodia, but a U.S. military force immediately intervened and rescued it. Even an often believed liberal newspaper like the New York Times wrote that the confidence in the U.S. military authority that had been lost in Vietnam was recovered. A non-military example was the recent Japan-U.S. trade conflict concerning the import of American automobiles to Japan.

In a brinkmanship game, it is always safe for each player to adopt a compromising attitude to avoid a crisis. However, sometimes a nation has to signal its commitment to its principles or to a hard line strategy. If one player concedes, then the other will continue to take advantage. In the trade conflict game, for example, Japan --- in spite of reportedly having their conversation bugged --- tried to keep a strong attitude for a possible appeal to the WTO. This is a continuing game, and reputation is important. If you sometimes act with a firm commitment, your opponent might become conciliatory. Of course, if the other party also takes an uncompromising attitude, both parties will end up with the worst situation, for example, the breakdown of relationships if it is a trade negotiation game, and possible nuclear destruction if it is a strategic game.

When one player takes an uncompromising attitude, there is a dynamic trade-off between the long-term benefits of reputation building and the short run opportunity cost probability of

catastrophe. Nalebuff (1986) shows through a dynamic benefit cost analysis that the tactics of playing gently at first, and then playing tough later does not pay. Where there is uncertainty, showing a strong attitude may help build the credibility of commitment towards the opposite party.

## 5. Conclusions

We would like to conclude this short paper by emphasizing the fact that the strategic structure of world military interdependence has changed from the alliance structure to the competitive arms building since the fall of the Berlin wall. The strategic structure changed from one of strategic substitutes to strategic complements. Of course, in those areas, where neighboring disputes or actual warfare are going on, such as Iraq, Iran, Israel, North Korea and Bosnia, the above theory would be too abstract. In those areas there would only be limited applications of the pure theory we have just developed.

However, the tendency for small countries to spend more in a "keeping up with the Joneses" game is worth noting. This is in contrast to the tendency that a large country in an alliance spends more because others are tempted to enjoy free-rides positions in a military alliance. The corresponding theoretical difference between strategic substitutes and the strategic complements is also important because the incentive to disclose military strength is affected by the distinction of substitutes and complements.

Finally, the crucially important problem for peace research is to design a system that gives fewer incentives to spend on military arms and accordingly to reduce the risk of war. One way would be to improve the pay-off structure. Another would be to change the rules of the game itself in such a way that the equilibrium from the game will be more peaceful. In addition, nations could be persuaded to play under new rules of the game.<sup>5</sup> In the theory of public goods and collective action, this problem of how to design a proper game to avoid the tragedy of commons or the prisoners' dilemma is

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<sup>5</sup> If you play a game of poker you have to determine under what conditions you play, say a five card draw or seven card stud. However, for some people a certain way of playing a game is intrinsically more advantageous than another way.

relatively less developed (c.f. Sandler 1992). In game theory the theory of mechanism design has been developed, but most of its refined applications are directed to the optimal auction design and similar problems. There exists a considerable distance before it can be applied to institution building and to the problem of arms reduction.

We need a theory that indicates not only what rules and regimes are desirable but how actual rules and regimes emerge. If we can succeed in designing an incentive-compatible system that would reduce the calamity of wars and, at the same time, help to find an incentive compatible way to induce each nation to participate in the arms-reduction schemes, it would mean substantial improvement in human conditions on the globe.

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TABLE 1

Before the Berlin Wall

	Risk from the Evil Empire	
	Responsibility	Free Ride
Responsibility	(2, 2)	(1, 3)
Free Ride	(3, 1)	(1, 1)

TABLE 2

After the Berlin Wall

	Armament	Reduction
Armament	(1, 1)	(3, 0)
Reduction	(0, 3)	(2, 2)

FIGURE 1  
Strategic Substitutes

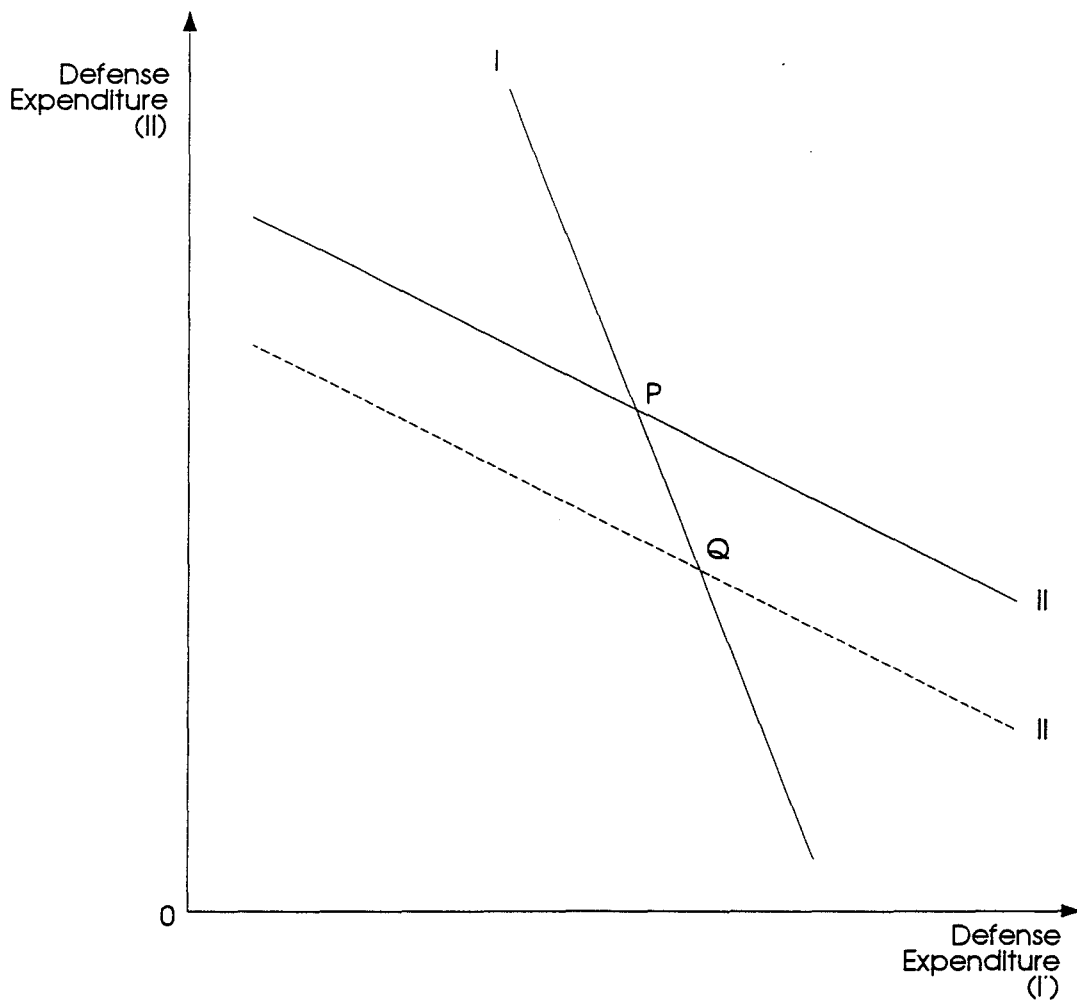


FIGURE 2  
Strategic Complements

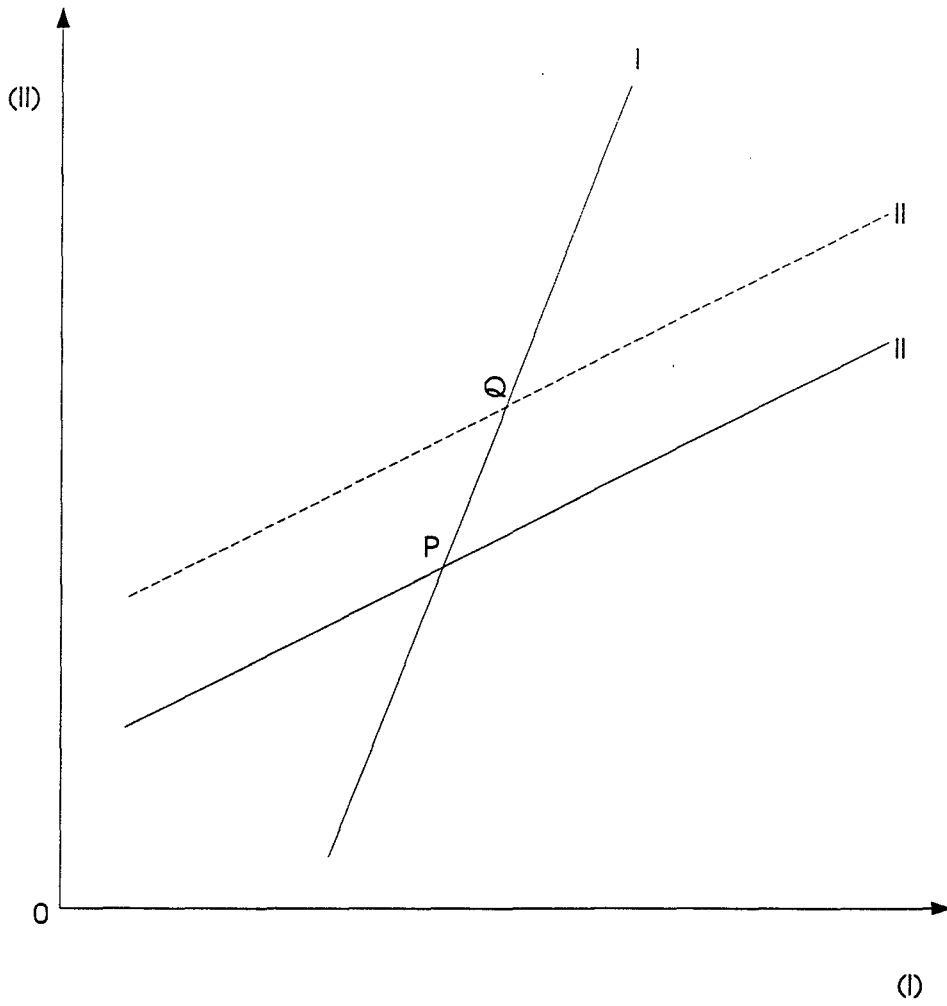


FIGURE 3

NATO Countries

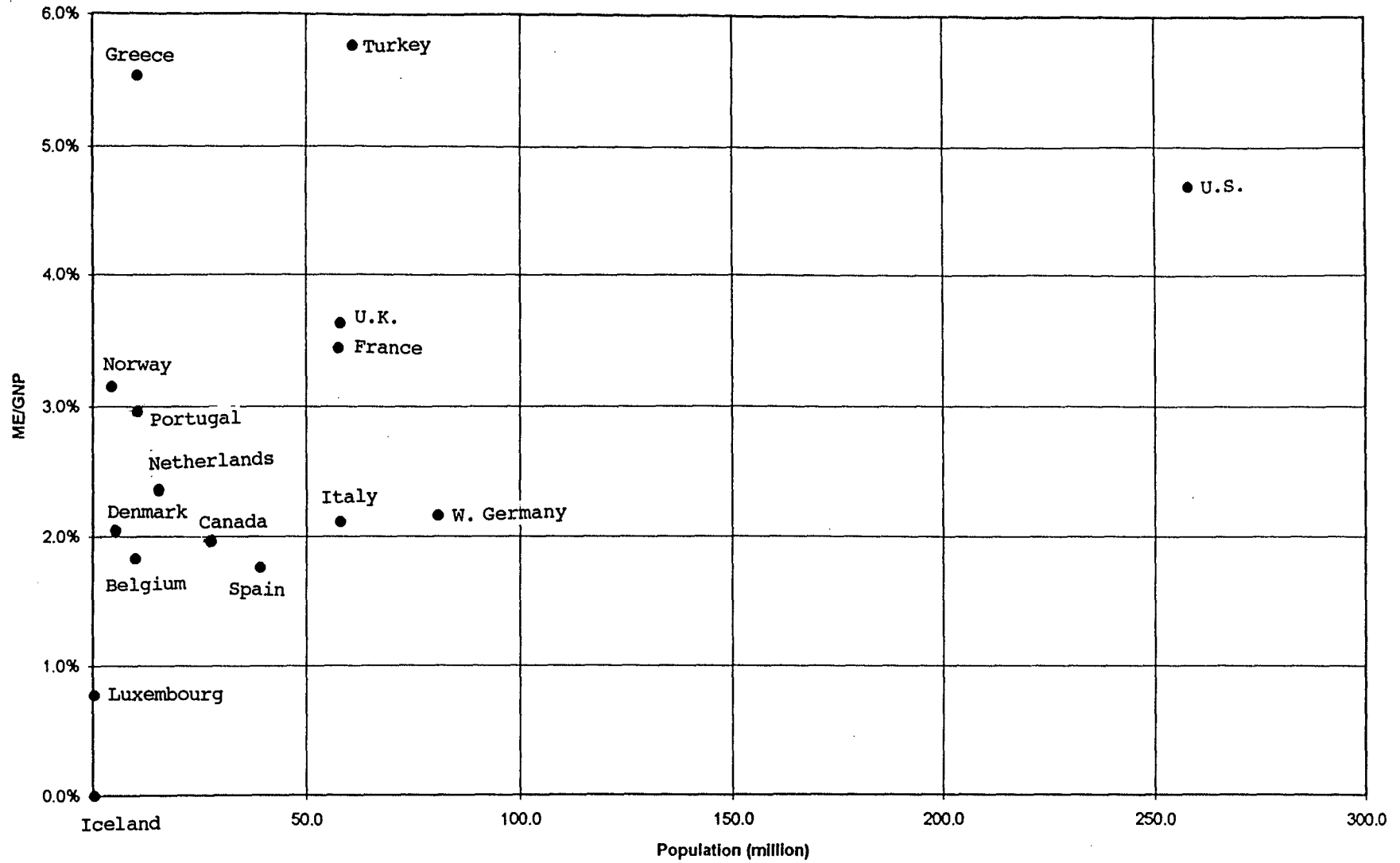




FIGURE 4A

Far East Countries

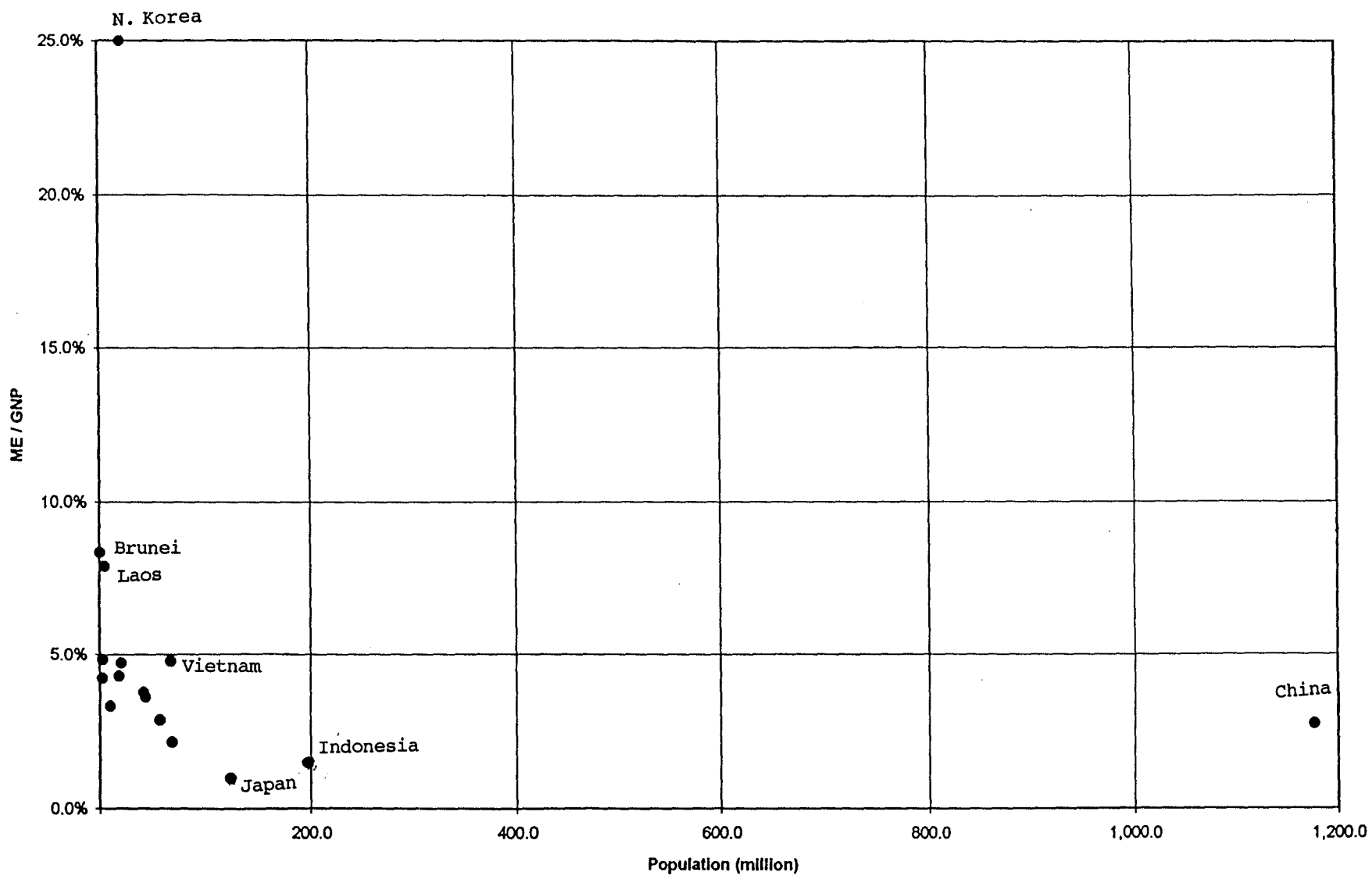


FIGURE 4B

Far East Countries (excluding China and N. Korea)

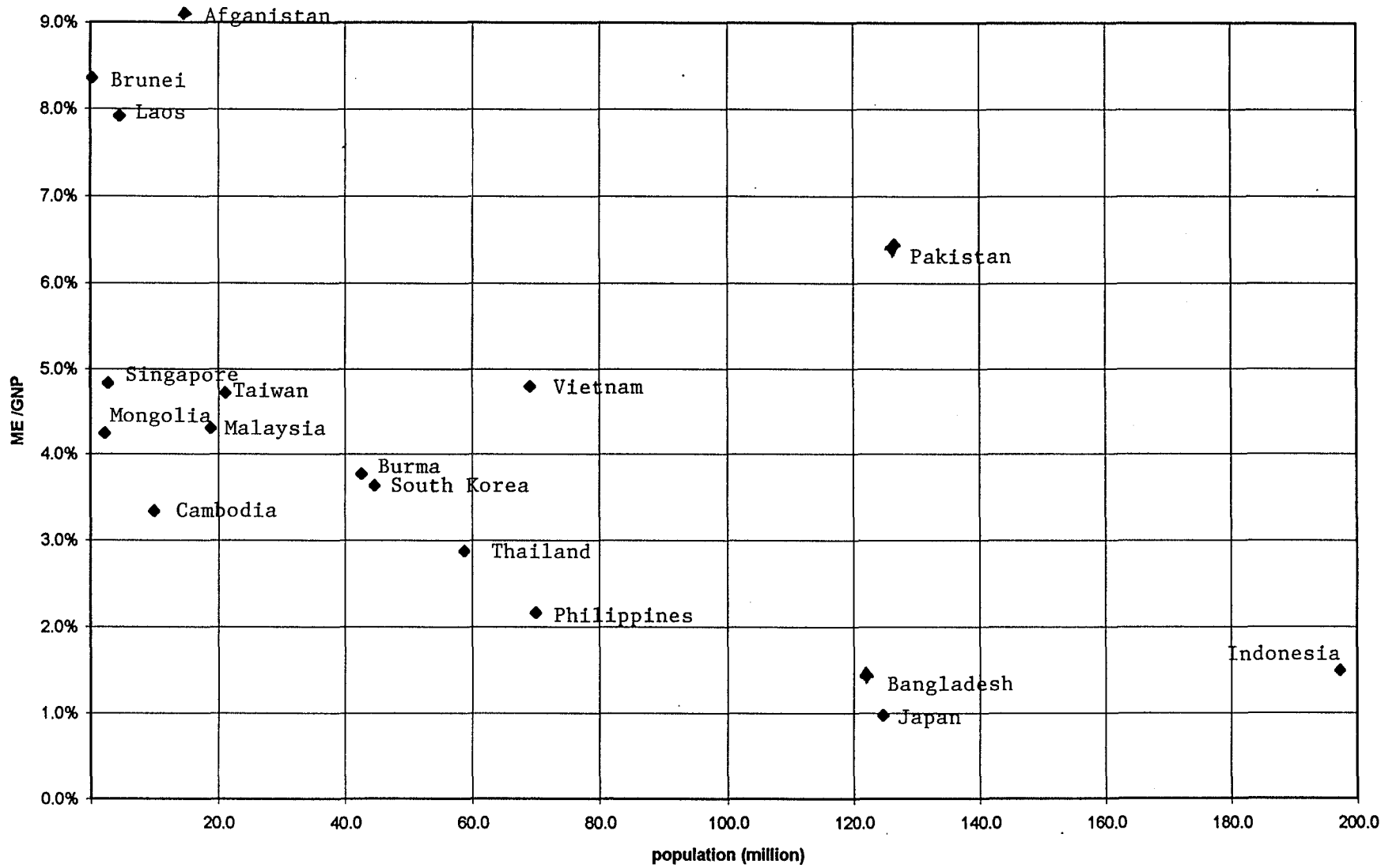


FIGURE 5

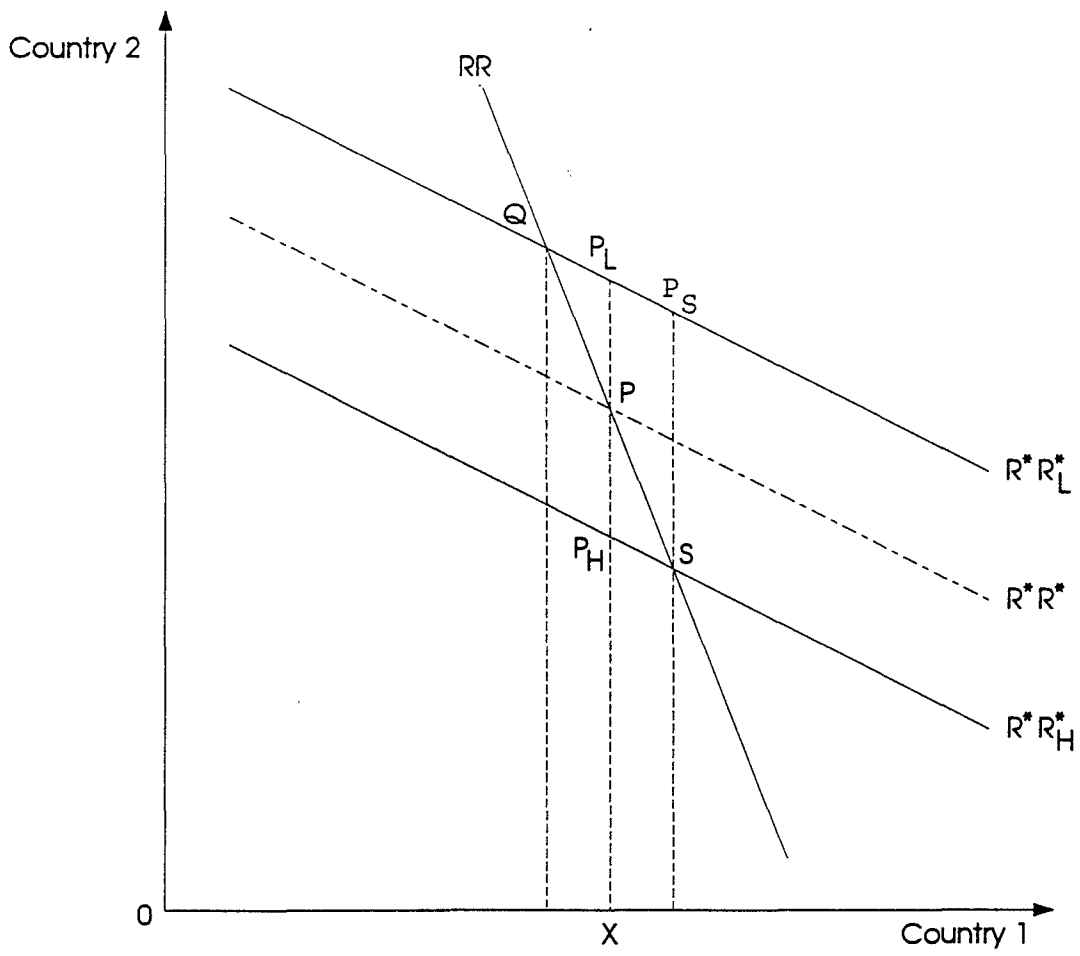


FIGURE 6

