International Security, Multiple Public Good Provisions, and The Exploitation Hypothesis[*]

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Abstract

Since the 1960's Olson-Zeckhauser's (1966) analysis, and its "exploitation of the great by the small" has provided economists' core model of alliance's provision of security/defense. But with the end of the Cold War countries allocative behavior has diverged markedly from OZ's predictions for defense as a homogeneous pure public good voluntarily provided. This paper suggests a replacement for OZ, with the essential difference that "defense" rather than being aggregated into their single public good is disaggregated into more realistic categories of self-insurance and self-protection. Because allocative behavior in public good groups is essentially driven by income effects, we concentrate on these, which become complex and conflicted, giving much greater scope for goods-inferiority. The analysis is followed by numerical simulations, which conform to actual experienced allocations in NATO much better than the conventional "exploitation" model.

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1. INTRODUCTION

This paper extends existing analyses of self-insurance and self-protection that countries may implement at a multi-national level in pursuit of their security. This leads us to challenge as inadequate the conventional wisdom about how separate countries in an alliance share the economic burden of defense --- the Olson Zeckhauser (OZ) model --- and to propose a better alternative as represented by our theory. This paper shows that a disaggregated self-insurance/self-protection framework can explain recent burden sharing better than the one pure public good model of Olson and Zeckhauser.

Security benefits may spill over becoming public goods among countries (Olson and Zeckhauser, 1966) which then interact in their allocations of national incomes to international (or regional) safety and welfare. Examples of these public goods include formation of international organizations, collective military preparedness, and active international diplomacy which may reduce commonly shared probabilities of regional and international tension. The distinctions of self-insurance, self-protection, and market insurance were first made by Ehrlich and Becker (1972). But application of their models to international security where market insurance for entire countries is usually unavailable remains surprisingly sparse except for some work on terrorism such as Sandler (1992, 1997, and 2005). In particular, economists' voluntary public good (VPG) models have not been well extended to understand incentives and behaviors of sovereign agents desiring to manage risks along multiple

channels analogous to EB's self-protection and self-insurance in a multi-good, multi-country setting. The purpose of this paper is to contribute to that extension, by explicitly investigating the effect of loss in the bad state.

With multiple types of pure public goods one should expect, allocative instability and imbalance from incentives discovered by Cornes and Itaya (2010). They demonstrated that when two agents in a partnership both could provide two different (pure) public goods, then at a Nash equilibrium, it is impossible (unless both agents have identical preference functions) for both agents to share in the provision of both goods. Here we develop a realistic formulation that can avoid that Cornes-Itaya problem in a multiple public good framework. However, instead of their problem, we face another one: goods inferiority. That is, when insurance is provided as a pure public good by/among nations in an allied group, we demonstrate a strong presumption for goods-inferiority. We show that even if the sign of income effect on self protection is positive in a single-country setting, the effect of higher income on Nash Equilibria becomes negative in a two-country setting. The cause of this anomaly we denominate as a "spillover income effect". Because of this effect corner solutions are likely to occur with respect to provision of self protection. When both self insurance and self protection are inferior, big countries should provide much less security spending than small countries, but in reality this is not normally observed. We call this seemingly paradoxical outcome the "inferiority difficulty".

To address this difficulty, we also focus on effects of changes in loss-in-the-bad-state. If loss-in-the-bad-state increases, it should stimulate security spending. If such loss is positively associated with income, income growth should stimulate security spending still more – a relationship that we believe will in reality better explain security allocations among allies as losses in the bad state often change over time.

Assuming CRRA utility functions, our simulations provide numerical results of income and loss-in-the-bad-state and the resulting resource allocations that support our explanatory hypothesis. We believe that these numerical examples and the theory supporting them better explain various changes in observed security spending of NATO than does the conventional wisdom.

The conventional wisdom comes from Olson and Zeckhauser (1966). Their theory led to the so-called exploitation hypothesis, whereby the large, wealthy allies shoulder the defense burdens of an entire alliance including all those of their smaller-GDP allies. If defense spending is purely public and the income effect is positive, wealthier allies can be expected to contribute more defense than less wealthy allies, provided tastes do not differ significantly among allies. Actually, some early studies of defense demand found defense to be a normal good during the Cold War, and thus, they confirmed the "exploitation hypothesis".

However, some studies have argued that the good NATO supplied was not purely public,

especially after 1967 and were skeptical about the plausibility of the exploitation hypothesis in 1970s.

See among others Murdoch and Sandler (1984), Sandler and Forbes (1980), and Sandler and Shimuzu

(2012). As shown in Table 4.1(a), recent data on military spending after the Cold War do not support the

OZ 'exploitation hypothesis.' There have been many candidates to explain why the exploitation

hypothesis failed --- non Nash-Cournot allocative behavior, Lindahl behavior, systematic differences in

recognition or evaluation of the "threat," inapplicability of a single utility function to represent the

interests of an entire government or nation etc. Among others, Sandler and Hartley (2001) developed the

joint product model.[1]

The argument of this paper depends on none of the foregoing "candidates." Nevertheless, from

calculating the effect of changes in possible loss, our numerical examples offer an alternative

explanation for historical security allocations. Specifically to explain the reduction in the security

expenditures of NATO in 1990s pursuant to the fall of the Soviet Union our model show how this would

follow from a decrease in NATO's threatened loss-in-the-bad-state. Thus, we present an alternative

model of a defense alliance which has a richer structure, and which is more satisfactory than that of

Olson/Zeckhauser (1966).

This paper consists of five sections. Section 2 formulates a basic analytical framework for two

allied countries, and derives the optimization conditions. In Section 3, investigating the income effects

on self-insurance and self-protection, the analysis explores how in a two country world an increase in the

income of one country affects its self-insurance and self-protection through the response of the other

country. Section 4 presents some numerical results to illustrate security allocations and evaluate the

plausibility of exploitation hypothesis. Here we show how our insurance/protection framework implies

behavior close to observed NATO allocations. Finally section 5 concludes.

2. ANALYTICAL FRAMEWORK

2.1 Basic assumptions

Suppose that the world consists of two countries: A and B. We consider two contingent states of

the world: a good state "1" and a bad state, "0". Ignoring all insurance and compensation possibilities

expected utility for country $i(i = A, B)$ is given as:

$$W^i = pU^1(C^{1i}) + (1 - p)U^0(C^{0i}), \tag{1}$$

where W^i is country i's expected utility, C^{1i} is i's consumption in a good state, C^{0i} is i's consumption in a

bad state, and p is the chance of a good state. Although we consider the term "1-p" as the risk of invasion

or war, it might be the risk of trade interruption, disease outbreak, or natural disaster. Utility function

U( ) is assumed to be the same whether luck is good or bad. U^1 denotes realized utility if the good event

happens, and U^0 if the bad event happens, and $U_Y \circ \P U / \P Y > 0, U_{YY} \circ \P^2 U / \P Y^2 < 0$.

We will focus on the two canonical types of Ehrlich-Becker (EB) defense; (i) EB's "self-protection;" which raises the chance of a good state, (ii) EB's "self-insurance" which reduces the loss in a bad state. Countries can provide self-insurance and self-protection mutually, as public goods for each other. The individual country's budget constraint is given as

$$C^{1i} = Y^i - m_1^i - \rho m_2^i; \, C^{0i} = Y^i - m_1^i - L^i, \tag{2}$$

where Y^i is the fixed national income of country i, m_1^i represents country i's allocation to risk improving self-protection, ρm_2^i gives the expenditure on self-insurance in good times (measured in units of C^{1i}), m_2^i represents the amount of self-insurance purchased by country i at price ρ, and L^i gives the loss for country i in a bad state.

The first risk management instrument to consider is self-protection. Both m_1^A and m_1^B spent on self-protection decrease the chance of a bad event, 1-p, from what we call "baseline risk[2] of [1-p(0)]." Thus we use the collective summation technology by writing

$$p = p(M_1), \tag{3}$$

where M_1 is the sum of the self-protection of the two countries

$$M_1 = m_1^A + m_1^B. \tag{4}$$

Here, we assume that $p' > 0$ and $p'' < 0$ throughout. M_1 is an international public good.

The second risk management instrument is self-insurance. The loss for country i in the bad state is

given as

$$L^i = \overline{L}^i - F(M_2), \tag{5}$$

where $\overline{L}^i$ is the baseline loss for country i in that bad state, $F(M_2)$ is the self-insurance benefit, and

M_2 is the sum of the self-insurance outlays. M_2 is also an international public good.

$$M_2 = m_2^A + m_2^B. \tag{6}$$

Self-insurance differs from standard market insurance in that self-insurance benefit function

$F(M_2)$ should show diminishing returns or increasing costs. $1 > F' > 0$, $F'' \leq 0$. EB make this assumption

also, and refer glancingly to the role of human capital in providing for self-insurance as a source of

diminishing returns. National self-insurance may often involve actions like stockpiling or standby

production maintenance and these surely will show diminishing returns[3]. Declining "productivity" of

"M_2" thus is the first source of a distinction between sovereign self-insurance vs. lesser scale

decentralized market insurance.

A second major difference between self-insurance as provided by an entire country and ordinary

market insurance is that when a whole nation provides insurance to itself, fair pricing would seem to be

the standard case and not an outlier just referenced for comparison. Moreover, it is plausible to assume

that the nation as a price maker, not as a price taker, incorporates this actuarially fair condition in its

optimization.

2.2. Optimization of each country

In our formulation of a two country model the expected utility may be rewritten as

$$W = p(M_1)U^1[Y - m_1 - \frac{1 - p(M_1)}{p(M_1)}m_2] + (1 - p(M_1))U^0[Y - m_1 - \{\bar{L} - F(M_2)\}]. \tag{1'}$$

Expected utility (1)' is maximized with respect to m_1^i and m_2^i subject to (2), (3), (4), (5), and (6)

for each country. This gives (7) as the first order condition (FOC) for self-insurance, and (8) as the FOC

for self-protection.

$$FOC_{\{M_2, C^i\}}: \quad -p\pi U_Y^{1i} + (1 - p)U_Y^{0i}F'(M_2) = 0, \tag{7}$$

$$FOC_{\{M_1, C^i\}}: \quad [p'(U^{1i} - U^{0i})] - [pU_Y^{1i} + (1-p)U_Y^{0i}] - \left[\left(\frac{d\pi}{dM_2}\right)m_2^i U_Y^{1i}\right] = 0. \tag{8}$$

To begin with, we consider the FOC for self-insurance. Eq. (7) shows the expected marginal

utility cost of providing m_2 i.e. $[p\rho U_Y^{1i}]$, equal to the expected marginal utility benefit of providing m_2,

i.e. $(1 - p)U_Y^{0i}F'$, evaluated at the solution value of M_2. If this necessary condition is rewritten as in (9)

then its actuarial meaning becomes clear. The RHS there gives the probability weighted marginal

insurance/benefit receipt under adversity for the last, probability-weighted dollar of premium paid in

good times

$$U_Y^1/U_Y^0 = [(1 - p)/p\pi]F'(M_2). \tag{9}$$

If self-insurance is actuarially fair (henceforth simply "fair") as we believe should be the paradigm

for an entire country then the concept must be defined as in eq. (10).

$$p = (1 - p)/p. \tag{10}$$

Inserting eq. (10) into (7), then the optimum simplifies to

$$U_Y^{1i}/U_Y^{0i} = F'(M_2). \tag{11}$$

In contrast to the linear market insurance case no equivalence is implied between U_Y^{1i} and U_Y^{0i}, with

significant implications, we shall see for the inferiority vs. normality of insurance.

Next we investigate the FOC for self-protection (8). Inserting the condition for actuarial fairness

(10) directly gives:

$$[p'(U^{1i} - U^{0i})] - [pU_Y^{1i} + (1-p)U_Y^{0i}] + [(p'/p)m_2 U_Y^{1i}] = 0. \tag{12}$$

We can characterize this optimality condition on the provision of self protection saying that there are

"direct" marginal benefits in the form of the gain in utility $p'(U^{1i} - U^{0i})$, "direct" marginal costs $[pU_Y^{1i}$

$+(1-p) U_Y^{0i}]$ and "indirect" benefits, $p'm_2 U_Y^{1i}/p$, comprised of, an unambiguous gain from the decrease

in insurance premiums paid for *the same* m_2 coverage received. These indirect benefits stem from the

lower price implied by lower risk (1-p).

2.3 Cornes-Itaya problem

If we consider multi-types of pure public goods, a source of instability and imbalance may

follow from incentives discovered by Cornes and Itaya (2010). They demonstrate that when two agents

in a partnership or alliance both could provide two different (pure) public goods, then at a Nash

equilibrium, it is impossible (unless both agents have identical preference functions) for both agents to

share in the provision of both goods at an interior solution. On the other hand, if countries are identical,

the problem --- and the amount of each good supplied by each country --- becomes indeterminate. This is

the Cornes-Itaya problem. If the Cornes-Itaya formulation is extended to allow variable costs associated

with public good provision, this immediately eliminates the indeterminacy associated with interior

equilibria.

Observe that unlike the standard constant-average-cost formulation (conventional in the

voluntary public good model of groups, including Cornes-Itaya) in our formulation of a two country

model --- i.e. in $W = p(M_1)U^1[Y - m_1 - \dfrac{1 - p(M_1)}{p(M_1)}m_2] + (1 - p(M_1))U^0[Y - m_1 - \{\overline{L} - F(M_2)\}]$--- the cost of

insurance is a non-linear function of m_1, m_2. And this non-linear "technology" for transforming C^{1A} into

M_1, M_2 using m_1^A, m_2^A for country A (same for country B with superscript "B"), implies that m_2^A appears

in the first order condition (12) along with C^{1A}, M_1, M_2, so that we may determine m_1^i, m_2^i (i=A,B) in a

two-pure-public-good model. That is, we can have an interior solution for both types of pure public

goods even if both countries are not identical. The present formulation, suggested by the alliance

application, is a specific example which inherently has variable costs and thereby removes

indeterminacy.

3. INCOME EFFECTS ON PUBLIC GOODS

3.1 Income effects ignoring the spillover effect from the other country

We first investigate the inferiority vs. normality of self-insurance in a one country setting where

the spillover effect from the other country is ignored. Total differentiation of FOC (7) gives:

$$\P m_2^i / \P Y \circ M_Y = [p\rho U_{YY}^{1i} - (1 - p)U_{YY}^{0i}F']/D, \tag{13}$$

where D represents the second order condition (SOC).

$$SOC_{\{M_2,C^i\}}: \ D = p\pi U_{YY}^{1i} - (1-p)F'U_{YY}^{0i} + (1-p)U_Y^{0i}F'' < 0. \tag{14}$$

From the SOC we know therefore

$$p\rho U_{YY}^{1i} - (1 - p)U_{YY}^{0i}F' < -(1 - p)U_Y^{0i}F'' \text{ and } -(1-p)U_Y^{0i}F'' \geq 0. \tag{15a}$$

Hence the sign of the numerator in Eq. (13) is ambiguous and m_2 as self-insurance *may* be inferior

depending on the pricing of insurance.

Specifically, if the numerator is positive, given the SOC, the sign of Eq. (13) is negative, and m_2

becomes inferior[4]. Absolute risk aversion R is defined as

$$R = -U_{YY}/U_Y \text{ or } -U_{YY} = RU_Y. \tag{15b}$$

If risk aversion is increasing ($R_1 > R_0$), then D < 0, and hence the sign of (13) is positive. On the other

hand, the sign of (13) becomes negative if risk aversion is decreasing. Thus, if risk aversion is increasing

(decreasing), m_2 is normal (inferior). And if relative risk aversion is constant, absolute risk aversion will

be decreasing and hence m_2 becomes inferior. Self insurance will prove inferior even if it is fairly priced

and optimally provided since even optimal and fair self-insurance will not in general equalize incomes or

marginal utilities across contingencies. The differential in incomes across contingencies is attributable

to the declining productivity of self-insurance, as shown in (11), which contrasts with the complete

coverage and equalization of incomes that results from fairly priced and optimally provided market

insurance. Thus, the dilemmas implicit in goods-inferiority as they apply to group allocation become

more salient and serious when a group is composed of "self-insurers".

As to the income effect on self-protection, the possibility that it is a normal good cannot be

completely excluded simply by assuming that absolute risk aversion decreases with wealth. Taking total

differentiation of FOC (8) gives:

$$\frac{\partial m_1}{\partial Y} = -\frac{p'(U_Y^1 - U_Y^0) - [pU_{YY}^1 + (1-p)U_{YY}^0] + U_{YY}^1 p' \frac{m_2}{p}}{E},\tag{16a}$$

where E represents the second order condition (SOC).

$$E = p''(U^1 - U^0) - 2p'(U_Y^1 - U_Y^0) + [pU_{YY}^1 + (1-p)U_{YY}^0]$$
$$-U_{YY}^1 \frac{p'm_2}{p}(-1 + \frac{m_2 p'}{p^2}) + U_Y^1 \frac{m_2}{p^2}(pp'' - p'p') < 0.\tag{16b}$$

Unlike self insurance, we cannot completely exclude the possibility of a normal case simply by

assuming that absolute risk aversion decreases with wealth. Here if absolute risk aversion is increasing/decreasing and (1-p) is initially low/high, m_1 will be normal, while if absolute risk aversion is decreasing/increasing and (1-p) is low/high, m_1 becomes inferior.

3.2 Spillover income effect in a two country model

So far we have ignored spillover effects from the other country. Ihori, McGuire, and Nakagawa (2011) investigate income effects in a two country framework general equilibrium. Those analytical results become complicated and ambiguous. Thus, in order to explain recent burden sharing within NATO in this paper we present further analysis of these phenomena by means of examples/simulations. Nevertheless, the analysis we believe is quite general.

We begin with an intuitive explanation of the spillover-income effect from the partner country. Suppose self-protection m_1 is normal but self-insurance m_2 is inferior for each country considered separately. Then if country A's wealth rises (or economic growth occurs), we would expect m_1^A to increase, and m_2^A to decline. However, in a two-country model, we need to consider response of the other country B. Now, a decline in m_2^A stimulates country B's provision of m_2^B, which then stimulates m_1^A.

The intuition is as follows: when one country A (home) reduces its provision of security m_2^A it creates a negative externality for its partner country B (foreign), and hence the partner's effective (or

full) income $Y^B + m_1^A + \rho m_2^A$ declines. But when the public good is inferior, the partner will react to a

decrease in its full income by increasing its provision of that public good m_2^B. This generates a positive

externality for home A by reducing the marginal benefit of raising m_2^A, which then will react by reducing

its provision m_2^A further. Now, this will reduce both the marginal benefit of raising m_1^A and the marginal

cost of raising m_1^A since consumption in the bad state has become higher due to the increase in m_2^B. If

the former effect is larger than the latter effect, m_1^A declines. Hence, if its income rises country A may

reduce m_1^A in the two-country framework even if m_1^A is normal in a one country setting.

    Schematically:

$$\Delta Y^A > 0 \Rightarrow \begin{matrix} \Delta m_1^A > 0 \\ \Delta m_2^A < 0 \end{matrix} \overset{\Rightarrow}{} \begin{matrix} \Delta(Y^B + m_1^A + \pi m_2^A) < 0 \\ \Delta m_2^B > 0 \end{matrix} \Rightarrow \Delta m_1^A < 0 \text{ if the decline of marginal benefit is large}$$

We call this negative spillover effect "the spillover income effect". Thus, there could be a corner Nash

equilibrium at which only one of the two countries, (here country B), provides the public good of self-

protection than it would absent an alliance partner in a one country model. Our simulation result in

Appendix confirms this conjecture.

    When each country can provide both types of public good[5], as explained above both types of

security can become inferior if absolute risk aversion declines with wealth. And as recognized, for

example, in Kerschbamer and Puppe (1998) or in Ihori and McGuire (2007, 2010), when a public good

is inferior, the Nash equilibrium solution for two countries easily becomes unstable implying a corner

solution where only one country provides the public good. However actual data on military spending

do not seem to support such inferiority. We call this seemingly paradoxical outcome the inferiority

difficulty.

3.3 Changes in Loss in the Bad State

Now if loss-in-the-bad-state increases, it raises security spending, and if the loss is positively

associated with income, then income growth would also likely raise security spending. Thus, if we

include changes in both income and loss-in-the-bad-state, we should have a better, more realistic,

explanation of security spending among allies.

First of all, an increase in $\overline{L}$ itself would raise the demand for self-insurance. It is easy to show

that

$$\frac{\partial m_2}{\partial \overline{L}} = \frac{(1-p)U_{YY}^0 F'}{D} > 0. \tag{17}$$

Second, if $\overline{L}$ increases with national income ($\overline{L} = aY$), it could happen that the overall income effect

from both changes in $\overline{L}$ and Y combined may become positive even though m_2 is an inferior good.

$$\frac{\partial m_2}{\partial Y} = \frac{p\pi U_{YY}^1 - (1-\alpha)(1-p)U_{YY}^0 F'}{D} = \frac{p\pi U_{YY}^1}{D} + \frac{-(1-\alpha)(1-p)U_{YY}^0 F'}{D}. \tag{18}$$

The first term on the RHS of Eq.(18) represents the effect of income on the provision of self-insurance,

which is positive since D < 0. The second term on the RHS denotes the effect of income change upon the

associated loss-in-the-bad-state --- which in turn changes the provision of self-insurance, and is negative.

Here if a is high, the second term on the RHS of Eq.(18) becomes small. This means that the effect of

increasing income on the marginal provision of m_2 is cancelled and reversed by the effect of increasing

loss. Thus, increasing income with its associated loss may raise self-insurance, overwhelming the

negative income effect.

4. NUMERICAL RESULTS[6]

 (TABLE 4.1)

4.1 Exploitation hypothesis and burden sharing in NATO

Olson (1965) and Olson and Zeckhauser (1966) pointed out the so-called exploitation

hypothesis, whereby large wealthy allies shoulder the defense burdens of smaller allies. Olson and

Zeckhauser confirmed their 'exploitation hypothesis' based on 1964 defense budgets. If the income

effect is positive, we may theoretically confirm the 'exploitation hypothesis'. Indeed, Oneal and Diehl

(1994) --- using pooled regression analysis for 1950-1986 --- argued that Olson's original emphasis on

the public nature of the good supplied by the alliance was valid. But while the OZ hypothesis seems to

have support in earlier periods of the Cold War, recent changes in military spending do not seem to comport with the "exploitation hypothesis."

Murdoch and Sandler pointed out that between United States (US) and western European countries the difference in military expenditure-as-a-ratio-of-GDP decreased from 1960 to 1979 (Murdoch and Sandler 1984, p.84). Tables 4.1 (a) and (b) respectively show 5-year average military expenditures and national GDP's of 14 countries that were members of NATO during 1975-2009 (excluding Iceland). In the second half of 1970s, the proportionate military expenditure of the US is not significantly large compared to smaller countries, e.g. in 1975-1979 the military expenditure of the US was 5.0% , while that of Germany was 3.4 % of GDP. In 1980s, the US increased its proportionate military expenditure, while smaller countries decreased theirs. In 1990s with the end of Cold War, most of the countries in the NATO decreased their military expenditures. The magnitude of decline was largest for the US and less so in the smaller countries. Thus, for the US average military expenditure as a percentage of GDP declined between 1985-1989 and 1990-1994 by 1.4% while for the smaller countries the decline was somewhat less i.e. 1%. During this period of time, the US GDP as a share of all-NATO GDP increased from 52.7% to 52.8%. In absolute terms the decrease in the security outlay of US was significantly large. Presently we will use our framework to explain the structure of these changes in NATO burden sharing.

There have been many candidates to explain why the OZ hypothesis failed both after and even during the Cold War --- non Nash-Cournot behavior, Lindahl behavior, systematic differences in recognition or evaluation of the "threat," inapplicability of a single utility function to represent the interests of an entire government or nation etc. Some studies have argued that the NATO-supplied-good was not purely public, especially after 1967. See, for instance, Sandler and Hartley (1995, 2001). These authors were skeptical about the plausibility of the exploitation hypothesis in 1970s. They developed a joint product model, as an important extension of the pure public good model. The theoretical analysis of a joint product model is provided by Cornes and Sandler (1984,1994). They provide comparative statics of the joint product model including the income effects, and show, among others, that the complementarity/substitutability between the private and public benefits of security expenditure affects not only the magnitude of the income effect but also the sign of that effect.

Our theoretical framework differs from those joint production models in several respects. First, defense good inferiority is far more plausible and likely to occur in our model. In the joint product model, contribution to the public good is inferior if the private and the public benefits of the contribution are strong complements (Cornes and Sandler 1994). In our model, defense good inferiority results from decreasing absolute risk aversion. Second, we formalize the uncertainty of the bad event following the state-of-the-world approach. The effects of risk aversion and of loss in the bad state on contribution to

alliance security can be explicitly investigated in our model. As we show below these factors help to

explain recent burden sharing in NATO. Thus, our model is complementary with the joint product model,

rather than a substitute. <u>Our theory developed above, does conform with the history of NATO burden

sharing as in Olson and Zeckhauser during the Cold War. But at the same time, we also explain the

failure of Olson and Zeckhauser after the Cold War.</u>

4.2 Specification for simulations

To highlight several changes in observed security spending in NATO, we report numerical

simulations of the impact of changes in income and possible loss. We specify the form of utility with the

constant relative risk aversion (CRRA) function:

$$U(C) = \frac{C^{1-q}}{(1-q)},\tag{19}$$

where $q(>0)$ is the measure of constant relative risk aversion. This function implies that absolute risk

aversion is decreasing with consumption. As shown in section 3, with CRRA utility the sign of income

effect on self-insurance, therefore, is negative.

We also specify the risk reduction function as [7]

$$p(M_1) = \frac{p_d M_1 + 1}{p_d M_1 + (1/p_0)}.\tag{20}$$

In equation (20), p_0 is the baseline probability of the good state when no expenditure is made on self-

protection, and p_d is a parameter for the marginal risk reduction from an increment of expenditure. This

marginal risk reduction is given by

$$\frac{dp}{dM_1} = \frac{p_d}{(p_d M_1 + (1/p_0))^2}\left(\frac{1}{p_0} - 1\right), \tag{21a}$$

which is positive but decreasing with M_1. Unlike Tullock's (1967) and Hirshleifer's (1989) contest

success functions, equation (20) assumes that self protection is a pure public good and hence the sum of

the outlays by allies determines the risk of the bad state. Using this functional form, the risk reduction

function has the following properties:

$$p_0 \leq p(M_1) < 1 \text{ and } p'(M_1) > 0 \text{ for any } M_1 \geq 0, \text{ and } \lim_{M_1 \to \infty} p(M_1) = 1. \tag{21b}$$

Note that there is no upper bound to the expenditure on self-protection.

For simplicity, we specify the loss reduction function as a linear function of the sum of

expenditures by the two allied countries:

$$F(M_2) = fM_2, \tag{22}$$

where f is the degree of loss reduction from one unit of expenditure. Then $1 > F' = f, F'' = 0$.

(TABLE 4.2)

Table 4.2 gives the values of parameters chosen for the simulation. For the parameter settings, in

a one country framework the income effect on self-insurance is negative, but the effect on self-protection

is positive.

（TABLE 4.3）

4.3 Numerical simulation of a scenario similar to NATO's history

Table 4.3 now shows --- in a compressed style --- elements of a scenario with GDP and defense

outlay changes similar to NATO's history and thus related to the history of changes in burden sharing

within NATO. We considered a bi-nation, asymmetric configuration where country B's income is 60% of

A's, and the potential loss of B is also 60% of that of A. This reflects the data shown in Table 4.1; in

1985-1989 the sum of the second to fourth largest GDPs (Germany, UK, and France) is 53% of US GDP,

and the sum of the second to fifth GDPs (adding Italy) is 67% of the US.

In 1970s, many empirical studies suggest that compared with small countries the big country

(US) reduced its security spending, which is inconsistent with the Olson-Zeckhauser exploitation

hypothesis. Here we explain this as a move from column 1 to column 2 in Table 4.2. This move follows

from an increase in income while loss in the bad state remained fixed. Row 19 shows that country A

reduces its security spending/GDP due to the negative income effects. On the other hand, in 1980s the

big country raised its security spending by a lot --- which is consistent with the exploitation hypothesis.

This could be reflected as a move from column 2 to column 3. This move includes both an increase in

income and an increase in loss in the bad state. A decline in loss reduces the expenditures of a big

country on self-insurance and self-protection more than those of small country. Yet within the parameters

(Table 4.2) of this simulation, raising both the loss and together with it the income of one country

produces minimal effects on welfare in Nash-optimized equilibrium. Still this outcome benefits both the

richer "partner" (country A) (despite its higher loss), and the poorer partner (country B) as well. The

correlated increase in loss in country A with the increase in income raises its security outlay and

generates positive spill-overs into country B. This move from Col 2 to 3 reflects the increase in loss from

the rising threat posed by the Soviet Union of the 1980's.

As shown by the move from column 3 to column 4, we examined a reduction of loss in both

countries, with income remaining fixed; and found that the decline in loss reduced expenditures of

country A on both self-insurance and self-protection more than those of country B --- results that directly

conflict with the exploitation hypothesis. After the Cold War in 1990s the big country reduced security

spending more than small countries. Here we may suppose that there was a decline in loss for the bad

state while income remained fixed. It seems reasonable to conjecture that the fall of the Soviet Union

reduced the loss in the bad state and caused a reduction in security outlays in the NATO countries[8].

Note that the reduction in self-protection by the big country, decreases the probability of the good state, p, and raises the probability of the bad state, 1-p. Row 9 in Table 4.3 also shows how a decrease in loss in the bad state leads to an increase in its likelihood. After 9/11 in the 2000's, the US raised its security spending substantially. This change corresponds to a reverse move from column 4 to column 3 in Table 4.3, i.e. an increase in loss in the bad state with income remaining fixed.

Thus, our approach where defense is disaggregated into two components, insurance and protection, potentially dominates the single public good OZ model. Our new models of burden sharing and the numerical examples used to illustrate them can explain these developments in security spending in the real world, and do it better than the traditional OZ model. Since our approach produces a variety of cases including multiple equilibria and corner solutions, it could plausibly explain recent changes in actual security spending as well.[9].

5. CONCLUSION

This paper has investigated two types of security spending available to expected utility maximizing agents faced with "costs of emergency", namely self-insurance and self-protection. We applied a model of self-insurance and self-protection to groups of two countries where such insurance

and protection are public goods. We demonstrated that since self-insurance is likely to be inferior, self

protection can also become inferior and hence an inherent potential exists --- due to a spillover income

effect --- for destabilizing incentives to generate corner outcomes in the provision of these public goods.

Specifically, we showed that even if the sign of the income effect on self-protection is normal in a one-

country model, it may become negative in a two-country setting due to the spillover income effect, and

hence with respect to self-protection corner solutions are more likely. When both self insurance and self

protection become inferior, the big country should provide less security spending than the small country,

(though this has not been observed yet or recorded). We call this seemingly paradoxical outcome the

"inferiority difficulty". To solve it, we considered changes in loss-in-the-bad-state and showed how this

problem can be avoided. Theoretically, if loss in the bad state increases, it stimulates security spending.

Thus, if we consider changes in both income and loss in the bad state, we can offer a better and more

realistic explanation of security spending of countries in an alliance.

Next, assuming CRRA utility functions, we reported simulation results of effects of a smaller

loss or greater national income upon Nash equilibria allocations. We showed that the big country A's

optimal self-insurance and self-protection increase when both loss in the bad state and income also rise.

We presented a range of hypothetical scenarios to depict recent developments of burden sharing in

NATO. Recent data on military expenditures suggested that the exploitation hypothesis may not be

relevant to the post Cold War era. No longer is the "exploitation of the great by the small" so crucial as in the early days of NATO. It seems reasonable to conjecture that the fall of the Soviet Union reduced the loss in the bad state and caused the reduction in security outlays in the countries of NATO. We may well explain these changes in security spending.

Although true that a 2-player formulation is limited, we conjecture that our model captures the essence of multiplayer games. Moreover, the analysis rests on the summation (linear) technology applying to both self-protection and self-insurance; and there are many other technologies including weakest-link or threshold that could apply to these questions and provide different outcomes. Extending all these limitations should be left for future research.

We do not insist that our explanation is the only one to deal with the observed expiration of OZ's exploitation hypothesis. The joint product model and other factors could explain its decline. But overall, our approach where defense is disaggregated into two components, insurance and protection, potentially dominates the single public good OZ model. Our simulations and a variety of cases of resource allocations implied by our theory --- including negative income effects --- could account for a good share of the recent changes in security spending. It is hoped that this paper may have highlighted the importance of issues of multiple public goods, instabilities, corner solutions, and conflicts of many-partner alliances in providing national security.

APPENDIX: Some Simulation Results

We first conducted numerical simulations in which country A's income increases from 40 to 80, while country B's income remains unchanged at 40. The result of this simulation is presented in Table A.1. When $Y^A = Y^B = 40$, there are multiple Nash equilibria, shown in column 1 to column 3. After country A's income exceeds 40, there is a unique Nash equilibrium in which A contributes nothing to self-protection.

The impact of A's economic growth decreases A's security expenditure on self insurance, but increases B's expenditure on self insurance. Row 6 shows the self-insurance of country A, and row 8 shows that of B. Comparing column 2 with column 4, A's self-insurance decreases with its income growth, while B's self-insurance increases when A's income rises. The increase in A's income reduces A's self-insurance, which, in turn, reduces B's full income and increases B's self-insurance since m_2^B is inferior. The increase in A's income also increases B's self-protection and finally it, therefore, reduces A's self protection. Thus, self protection becomes inferior in a two country setting. This is due to the spillover income effect, (of A upon B) explained in section 3.2. Because the decline in $m_2{}^A$ reduces B's full income, the increase in B's self-insurance that follows reduces A's marginal benefit of self-protection.

Row 15 and row 16 show the welfare impact of A's income growth. Country A's growth

improves the welfare of country A, but reduces that of B. In a sense, therefore, we have an 'inverse'

exploitation hypothesis, that is, "exploitation of the small by the great" --- just the opposite of Olson and

Zeckhauser. In other words, when the income effect becomes negative, the standard exploitation

hypothesis does not hold.

Next, Table A.2 shows results of a simulation where country A's loss in the bad state and its

income increase parametrically ($\alpha = 0.5$) while B's loss and income remain constant. Unlike Table A.1,

Table A.2 shows that at Nash equilibrium (after changes in both income and possible loss) country A's

optimal self-insurance as well as its self protection increase.

To investigate another effect --- specifically of changes in possible loss --- with income fixed in

an asymmetric economy, we conducted the numerical simulation of Table A.3. There we consider an

asymmetric configuration where country B's income is 60% of A's income, and the loss for B is also

60% of that of A. We reduce $\overline{L}^A(\overline{L}^B)$ from 21(12.6) to 7(4.2). This decline in loss reduces the

expenditure of rich-country A on both self-insurance and self-protection. Comparing column 7 and

column 3, we find that a decrease in $\overline{L}^B$ from 6.6 to 4.2 reduces m_2^B. However, comparing column 3 to

column 1, a decrease in loss from 12.6 to 6.6 raises B's self-insurance (from 0.0 to 0.422) --- which

seems paradoxical. The direct effect of a decrease in loss, as explained above, is to reduce insurance.

However, we also have an indirect effect: a decrease in security spending by A reduces the positive

spillover into country B. Since m_2^B is inferior, this decline in positive spillover <u>raises</u> m_2^B. When A is large and B is small, the spillover income effect from country A may dominate the direct effect, leading to the paradoxical increase in m_2^B.

[1] On the other hand, Oneal and Diehl (1994) argued that Olson's original emphasis on the public nature of the good supplied by the alliance remains valid using pooled regression analysis for 1950-1986.

[2] Our "baseline risk" corresponds to what is sometimes referred to as "background risk" in economics of insurance analyses. Background risk distinguishes "independent" background risk where p(0) is not influenced by the value of L(0) as in our model here, versus "non-independent" background risk where p(0) and L(0) are interdependent, and asks how the choice of protection or insurance varies with the independence property (See Schlesinger, 2000).

[3] In an example of flood protection and insurance, as greater quantities of consumables are set aside during dry years, their costs of preservation and delivery during good years might increase more than proportionately.

[4] Note if self-insurance is fair and therefore (1-p) = pπ, then the numerator of (13) becomes p(U_{YY}^1 -U_{YY}^0).

[5] Our simple solution to the problem of diminishing returns and distribution of infra marginal costs/gains in a public good spillover environment will be to assume a "summation *finance* aggregator," M = ∑m, in the provision of public good, even though p(M), represents a "non-summation *consumption* aggregator" (e.g. p(M) ≠ ∑p_i(m_i)) Then, importing an idea from contest theory we take primitive preferences as being over *contributions* to insurance or to risk reduction, rather than insurance coverage or risk reduction itself.

[6] To conduct the numerical simulations, we used <u>Mathematica</u> 7.0.0.

[7] Eq(20) can be rewritten as $p(M_1) = p_0 + (1 - p_0)\left[\dfrac{M_1}{M_1 + (1/ p_0 p_d)} \right]$. The RHS can be interpreted as a convex combination of unity and a Tullock's contest success function where the weight of the former is p_0 and that of the latter is $1 - p_0$. We can think of a Tullock's contest with two competitors: one is the alliance of countries A and B, the other is an opposing alliance. The effort of the former is M_1 and that of the latter is

fixed at $(1/p_0 p_d)$. Eq.(18) means that even if the alliance of A and B loses the Tullock's contest, the alliance becomes a good state with probability p_0. In this paper, however, the bad state is not necessarily the loss of this kind of contest. Thus, we write the loss reduction function as in (18).

[8] If we treat national security as a whole with no disaggregation into self-insurance and self-protection (as in the conventional framework of public good provision) a decrease in the threat from an enemy reduces contribution (as a % of GDP), where the decline in the percent contribution of the smaller country is greater than that of the larger country. This outcome is consistent with the exploitation hypothesis. But we cannot explain the change of security outlays in 1990s by using this model. Thus, if the loss in bad state increases, the conventional framework of single public good is inadequate.

[9] One could argue that the big country will move first as a Stackelberg-leader. In other calculations (available on request) we considered a leader-follower model with country A the leader and B the follower. It turned out that those results of simulated NATO burden sharing were less consistent with the actual burden sharing history than the results reported here.

REFERENCES

Cornes, R., and Itaya, J. (2010) " On the Private Provision of Two or More Public Goods," *Journal of Public Economic Theory*, 12(2), 363-385.

Cornes, R. and T. Sandler (1984) Easy riders, joint production and public goods, *Economic Journal* 94, 580-598.

Cornes, R. and T. Sandler (1994) The comparative static properties of the impure public good model, *Journal of Public Economics*, 54:403-421.

Ehrlich, I. and G. Becker (1972) Market insurance, self-insurance, and self-protection, *Journal of Political Economy* 80: 623-648.

Hirshleifer, J. (1989) Conflict and rent-seeking success functions: Ratio vs. difference models of relative success, *Public Choice* 63, 101-112.

Ihori, T. and M. C. McGuire (2007), Collective risk control and group security: The unexpected consequences of differential risk aversion, *Journal of Public Economic Theory,* 9, 231-263.

IIhori, T. and M. C. McGuire (2010), National self-insurance and self-protection against adversity: Bureaucratic management of security and moral hazard. *Economics of Governance,* 11, 231-263.

Ihori, T., M. C. McGuire, and S. Nakagawa (2011), International Security, Insurance, and Protection: Failure of the Conventional Model of Alliances, mimeo.

Kerschbamer, R. and C. Puppe (1998), Voluntary Contributions when the Public Good Is not Necessarily Normal, J*ournal of Economics* 68, 175-192.

Murdoch, J. C. and T. Sandler (1984) Complementarity, free riding, and the military expenditures of NATO allies, *Journal of Public Economics* 25, 83-101.

Olson, M. and R. Zeckhauser (1966) An Economic Theory of Alliances, *Review of Economics and Statistics* 48, 266-279.

Oneal, J. R. and P. F. Diehl (1994) The Theory of Collective Action and NATO Defense Burdens: New Empirical Tests, *Political Research Quarterly* 47, 373-396.

Sandler, T. (1992) *Collective Action: The Theory and Application*, Ann Arbor: Univ of MI Press

Sandler, T. (1997) *Global Challenges: An approach to environmental, political, and economic problems.* New York: Cambridge University Press.

Sandler, T. (2005) Collective versus unilateral responses to terrorism, *Public Choice.*

Sandler, T. and Forbes, J. F, (1980) Burden Sharing, Strategy, and the Design of NATO, *Economic Inquiry*, 18, 425-44.

Sandler, T. and K. Hartley (1995), *The Economics of Defense*, Cambridge UP

Sandler, T. and K. Hartley (2001), Economics of Alliances: The Lessons for Collective Action, *Journal of Economic Literature*,39, 869-896.

Sandler, T. and H. Shimizu (2012) NATO Burden Sharing 1999–2010: An Altered Alliance, *Foreign Policy*

Analysis , forthcoming.

Schlesinger, H. (2000) The Theory of Insurance Demand, Ch 5 in Dionne ed., *Handbook of Insurance*, Kluwer,.

Tullock, G. (1967) The Welfare Costs of Tariffs, Monopolies, and Theft, *Western Economic Journal* 5, 224-232.

Table 4.1(a): 5-year average of military expenditures as % of GDPs (based on current prices)

Country Name	1975-1979	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2009
Belgium	3.2	3.2	2.8	1.9	1.5	1.3	1.2
Denmark	2.4	2.4	2.0	1.9	1.7	1.5	1.4
France	3.8	4.0	3.8	3.3	2.9	2.5	2.3
Germany	3.4	3.3	3.0	2.1	1.6	1.4	1.3
Greece	5.6	5.3	5.1	3.9	4.1	3.2	2.8
Italy	2.0	2.1	2.3	2.0	1.9	2.0	1.6
Luxembourg	0.9	1.0	1.0	0.7	0.7	0.7	0.5
Netherlands	3.1	3.0	2.8	2.3	1.8	1.5	1.5
Norway	2.9	2.7	2.9	2.8	2.2	1.9	1.5
Portugal	3.4	2.9	2.7	2.3	2.1	1.7	1.5
Turkey	4.4	4.0	3.3	2.8	3.2	3.2	2.0
United Kingdom	4.9	5.2	4.5	3.7	2.7	2.3	2.5
Canada	1.9	2.0	2.1	1.8	1.3	1.2	1.3
United States	5.0	5.6	6.0	4.6	3.3	3.4	4.5

Sources: North Atlantic Treaty Organization (1996, 2000, 2011) "Financial and Economic Data Relating to NATO defense" Table 3, < http://www.nato.int/cps/en/natolive/index.htm >

Table 4.1(b): 5-year average of national GDP as % of the total GDP of 14 member countries of NATO

(based on constant 2000 US$)

Country Name	1975-1979	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2009
Belgium	1.6	1.5	1.4	1.4	1.3	1.3	1.3
Denmark	1.1	1.0	1.0	0.9	0.9	0.9	0.9
France	9.0	8.6	8.1	8.0	7.6	7.4	7.2
Germany	12.9	12.2	11.3	11.8	11.1	10.3	9.9
Greece	1.0	0.9	0.8	0.7	0.7	0.7	0.8
Italy	7.5	7.3	7.0	6.9	6.4	6.1	5.7
Luxembourg	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Netherlands	2.4	2.2	2.1	2.1	2.1	2.1	2.1
Norway	0.9	0.9	0.9	0.9	1.0	0.9	1.0
Portugal	0.6	0.6	0.6	0.7	0.6	0.6	0.6
Turkey	1.3	1.2	1.3	1.4	1.5	1.5	1.8
United Kingdom	9.7	8.7	8.7	8.3	8.3	8.4	8.4
Canada	4.3	4.1	4.1	3.9	4.0	4.1	4.2
United States	47.7	50.7	52.7	52.8	54.4	55.5	56.1

Sources: The World Bank (2011) "World Development Indicators & Global Development Finance," 15 December, 2011, < http://data.worldbank.org/data-catalog/world-development-indicators >

Table 4.2: Parameter values

q	f	$\bar{L}$	p_0	p_d
0.9	0.9	10	0.25	1

Table 4.3 Numerical simulations corresponding to burden sharing in NATO

	1	2	3	4
1 Y^A	40	50	60	60
2 Y^B	24	30	36	36
3 $\bar{L}^A$	10	10	15	10
4 $\bar{L}^B$	6	6	9	6
5 m_1^A	1.316	1.348	2.690	1.380
6 m_2^A	2.569	2.098	5.234	1.619
7 m_1^B	0.000	0.000	0.000	0.000
8 m_2^B	0.505	0.392	0.192	0.280
9 $p(M_1)$	0.436	0.439	0.552	0.442
10 $F(M_2)$	2.767	2.241	4.884	1.709
11 C^{1A}	35.356	45.971	53.055	56.580
12 C^{0A}	31.450	40.892	47.193	50.329
13 C^{1B}	23.346	29.500	35.844	35.647
14 C^{0B}	20.767	26.241	31.884	31.709
15 W^A	14.190	14.568	14.798	14.874
16 W^B	13.613	13.936	14.229	14.203
17 $Y^A + m_1^B + \rho m_2^B$	40.654	50.500	60.156	60.353
18 $Y^B + m_1^A + \rho m_2^A$	28.644	34.029	42.945	39.420
19 $(m_1^A + \rho m_2^A)/Y^A$	11.609%	8.058%	11.576%	5.700%
20 $(m_1^B + \rho m_2^B)/Y^B$	2.726%	1.667%	0.434%	0.981%

Table A.1: Impact on Nash equilibrium of increase in A's income in two-country model

	1	2	3	4	5	6	7
1 Y^A	40	40	40	50	60	70	80
2 Y^B	40	40	40	40	40	40	40
3 $\bar{L}^A$	10	10	10	10	10	10	10
4 $\bar{L}^B$	10	10	10	10	10	10	10
5 m_1^A	0.485	0.000	0.981	0.000	0.000	0.000	0.000
6 m_2^A	1.786	1.750	1.831	1.177	0.520	0.000	0.000
7 m_1^B	0.485	0.981	0.000	1.137	1.312	1.447	1.447
8 m_2^B	1.786	1.831	1.750	2.163	2.560	2.884	2.884
9 $p(M_1)$	0.396	0.398	0.398	0.416	0.435	0.449	0.449
10 $F(M_2)$	3.216	3.223	3.223	3.006	2.772	2.596	2.596
11 C^{1A}	36.795	37.349	36.247	48.347	59.326	70.000	80.000
12 C^{0A}	32.730	33.223	32.242	43.006	52.772	62.596	72.596
13 C^{1B}	36.795	36.247	37.349	35.827	35.366	35.017	35.017
14 C^{0B}	32.730	32.242	33.223	31.869	31.459	31.149	31.149
15 W^A	14.240	14.262	14.219	14.638	14.944	15.200	15.417
16 W^B	14.240	14.219	14.262	14.206	14.190	14.179	14.179
17 $Y^A + m_1^B + \rho m_2^B$	43.205	43.753	42.651	54.173	64.634	74.983	84.983
18 $Y^B + m_1^A + \rho m_2^A$	43.205	42.651	43.753	41.653	40.674	40.000	40.000

Table A.2: Impact of increasing income combined with loss in the bad state: two-country model

	1	2	3	4	5	6	7
1 Y^A	40	40	40	50	60	70	80
2 Y^B	40	40	40	40	40	40	40
3 $\bar{L}^A$	10	10	10	15	20	25	30
4 $\bar{L}^B$	10	10	10	10	10	10	10
5 m_1^A	0.485	0.000	0.981	2.704	3.819	4.777	5.643
6 m_2^A	1.786	1.750	1.831	5.956	9.488	13.065	16.736
7 m_1^B	0.485	0.981	0.000	0.000	0.000	0.000	0.000
8 m_2^B	1.786	1.831	1.750	0.136	0.000	0.000	0.000
9 $p(M_1)$	0.396	0.398	0.398	0.552	0.616	0.658	0.689
10 $F(M_2)$	3.216	3.223	3.223	5.483	8.539	11.759	15.063
11 C^{1A}	36.795	37.349	36.247	42.472	50.274	58.438	66.799
12 C^{0A}	32.730	33.223	32.242	37.779	44.720	51.982	59.419
13 C^{1B}	36.795	36.247	37.349	39.890	40.000	40.000	40.000
14 C^{0B}	32.730	32.242	33.223	35.483	38.539	41.759	45.063
15 W^A	14.240	14.262	14.219	14.472	14.730	14.960	15.167
16 W^B	14.240	14.219	14.262	14.382	14.441	14.483	14.515
17 $Y^A + m_1^B + \rho m_2^B$	43.205	43.753	42.651	50.110	60.000	70.000	80.000
18 $Y^B + m_1^A + \rho m_2^A$	43.205	42.651	43.753	47.528	49.726	51.562	53.201

Table A.3: Asymmetric two-country model: impact of a smaller loss in the bad state

	1	2	3	4	5	6	7
1 Y^A	50	50	50	50	50	50	50
2 Y^B	30	30	30	30	30	30	30
3 $\bar{L}^A$	21	16	11	10	9	8	7
4 $\bar{L}^B$	12.6	9.6	6.6	6	5.4	4.8	4.2
5 m_1^A	4.022	2.939	1.623	1.348	1.068	0.781	0.483
6 m_2^A	11.123	6.781	2.751	2.098	1.504	0.973	0.514
7 m_1^B	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8 m_2^B	0.000	0.116	0.422	0.392	0.334	0.254	0.157
9 $p(M_1)$	0.626	0.568	0.466	0.439	0.408	0.372	0.331
10 $F(M_2)$	10.011	6.207	2.856	2.241	1.654	1.105	0.604
11 C^{1A}	39.334	41.897	45.230	45.971	46.751	47.580	48.476
12 C^{0A}	34.988	37.268	40.234	40.892	41.586	42.324	43.121
13 C^{1B}	30.000	29.912	29.517	29.500	29.515	29.571	29.683
14 C^{0B}	27.411	26.607	26.256	26.241	26.254	26.305	26.404
15 W^A	14.374	14.455	14.549	14.568	14.587	14.607	14.627
16 W^B	14.004	13.976	13.941	13.936	13.932	13.928	13.927
17 $Y^A + m_1^B + \rho m_2^B$	50.000	50.088	50.483	50.500	50.485	50.429	50.317
18 $Y^B + m_1^A + \rho m_2^A$	40.666	38.103	34.770	34.029	33.249	32.420	31.524