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THE ECONOMICS OF THE INTERNATIONAL ARMS TRADE

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ABSTRACT

The Economics of the International Arms Trade

Sales of arms are a significant component of international trade and raise a range of pressing policy issues. After a short review of the market, this paper provides a formal model of the trade which allows for competing, forward-looking suppliers whose welfare depends on both the economic benefits from the sales and the security repercussions of recipient behaviour. The recipient's behaviour depends on their military capability which is a function of the stock of arms they have acquired. We first examine myopic recipients, whose behaviour depends on current stocks, then forward-looking recipients for whom questions of the time-consistency and the credibility of supplier threats to embargo, or promises to resupply become crucial. Finally, we examine the impact of supplier cooperation of the sort currently being discussed in the UN Security Council.

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NON-TECHNICAL SUMMARY

Trade in arms is large and raises a range of pressing policy issues. There are currently discussions within the EC, UN and other fora to harmonize export regulations and make trade more transparent. Any process to regulate arms transfers must consider the trade-off that suppliers face between the economic benefits that they may gain from the sales, and the potentially adverse security repercussions if recipients use the weapons they acquire in ways that are harmful to the suppliers. During the Gulf War coalition members found weapons they had supplied to Iraq being used against them. For example, the French had to withdraw some of their Mirage jets from the conflict as they were indistinguishable on radar from the Mirages they had sold to Iraq. This paper provides an introductory analysis of the arms trade which allows for both economic and strategic influences.

The paper begins with a stylized review of the market. The main types of product are weapons of mass destruction, major conventional systems, dual-use technologies and small arms. The analysis in this paper applies primarily to major conventional systems (armoured vehicles, aircraft, warships) which account for the bulk of reported trade. Supply is largely determined by the government of the producer country because weapons exports are almost universally subject to control, and supplying governments are heavily involved in their sale. Demand depends on both strategic factors (regional wars, local arms races, etc.), and the resources available to purchasers. Prices reflect demand conditions, restrictions on supply and a range of implicit subsidies provided by selling governments.

We then examine the various types of security repercussions that can follow from arms transfers, distinguishing between four basic types. The two simple cases are where the recipient is an ally, in which case strengthening it through arms sales increases supplier security, and where the recipient is an adversary so that strengthening it through arms sales reduces supplier security. Two more interesting cases arise when the security repercussions change as the amount of arms supplied increases. In one case, increases in the recipient's stock of weapons up to some limit determined by its legitimate security needs are stabilizing, but beyond that limit become destabilizing as the client overarms. In the other case, supplying arms provides leverage over a hostile regime which allows it to be coopted into the international security order.

Our model assumes a forward-looking supplying government with both economic and security objectives. The arms sale will provide profits which contribute to the economic welfare of the country, but may also have (positive or negative) security repercussions. There are a number of similar oligopolistic supplier governments and we assume that price and quantity are determined through a Nash-Cournot type interaction. Recipients are characterized by a demand curve, which summarizes their security position and budget constraints. We initially assume

that recipient behaviour depends on their military capability at a particular moment in time. Military capability is determined by the stock of arms they hold given by depreciated past stock plus the sum of all the arms they buy from the various producers. The recipients' behaviour will feed back onto the security of the suppliers in one of the four ways discussed above, and thereby influence supplier welfare.

We solve the model under these assumptions and the main results accord with experience. In the case of a potential adversary, where supplier security is adversely affected by the recipient's military capability, transfers are lower than they would be in a free market where arms sales are sold by uncontrolled private firms who ignore the security repercussions. As the number of supplier governments increases the amount of arms transferred increases, but even with a very large number of supplying governments it remains below the free market amount. The solutions under the other three types of security repercussions are also examined and accord with experience.

More interesting results arise when we assume recipients are forward looking and base their behaviour not merely on their current military capability, but also their expected future military capability. This allows for their expectations about the probability of resupply in time of conflict or the likelihood of future arms embargoes to influence their behaviour. Once one allows for such forward-looking behaviour by the recipient, supplier credibility become important. We examine what happens when the supplier can credibly precommit to making announced deliveries. With a forward-looking recipient and the ability to precommit, the supplier can exert leverage over the recipient through its announcements, which results in transfers to a hostile forward-looking recipient being lower than in the case of a myopic recipient. If the supplier cannot precommit, however, the forward-looking recipient can exploit this and transfers are higher than with a myopic hostile recipient. This happens because although, in advance, the supplier would wish to have sold less, when the day comes it is optimal for the supplier to sell more; in technical terms to follow a 'time-consistent' path. The 'time-consistent' solution is interesting because it is not uncommon for suppliers to declare a policy to embargo or resupply and subsequently renege on that announced policy, which recipients can exploit.

The final section examines the effects of cooperation between a cartel of suppliers. As might be expected, cooperation reduces the amount transferred to a hostile recipient. In each of these models we examine steady-state solutions and the stability of the equilibrium. In some cases, however, no analytical solution is possible and we illustrate the results with simulations. This paper examines the main issues in the market, but there are a range of extensions which are possible and these are discussed in the conclusion. They include suppliers with different objectives and a more explicit characterization of what determines recipient behaviour.

1. Introduction.

Arms transfers are a quantitatively important component of international trade, worth just under $50bn in 1989 down from $64 bn (in 1989 prices) in 1984. Three quarters of the purchases were by less developed countries and over 80% of the sales were by the five permanent members of the United Nations Security Council, the P5: USSR, as it then was, US, France, UK and China; ACDA (1991). They are also a matter of much current policy interest. The Iraqi invasion of Kuwait, the Gulf War, where many suppliers found their own weapons used against them[1] and the proliferation of dangerous technologies, like nuclear weapons and ballistic missiles, have all increased interest in designing a control regime. The P5 met in 1991 and agreed to a set of guidelines for restraint; the UN agreed to establish a register of arms transfers to increase transparency; the IMF and World Bank, and some donors, have indicated that aid may be made conditional on levels of military spending; and the EC is trying to harmonise regulations on arms transfers, partly because completion of the internal market will make national controls much less effective. These developments are discussed in ORG (1992), SIPRI (1992) and Harvey (1992). Sampson (1992) provides a particularly readable description of the arms market.

Despite the importance of the market there has been relatively little economic, as distinct from political or military, analysis of the process[2]. This paper provides a simple economic model of the arms trade, which explains certain important features of the market and may provide a basis for policy analysis. After a stylised introduction to the market in section 2, the remainder of the paper develops the model. We are concerned with the case

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[1]French Mirages had to be withdrawn from the conflict because they were indistinguishable on radar screens from those France had sold to Iraq.

[2]Some econometric estimates of factors determining arms sales are provided in Smith, Humm and Fontanel (1985).

of a set of oligopolistic forward looking suppliers who in competing with each other consider not only the profits obtained from selling the weapons but the security repercussions that arise because weapons acquisition may change the behaviour of the recipients. In making the decision as to what quantity of arms to export, we shall assume that the supplier knows the demand function of the recipient, the recipients total military capability and how that capability may induce reactions by the recipient which will impact on the suppliers security. We shall confine ourselves to generic characterisations of the demand function and reaction function. While these should be derived from the strategic context, the strategic context differs so much from recipient to recipient that there is no widely applicable characterisation. However, the form that we shall use for the reaction function that maps capability of the recipient onto the security of the supplier, is sufficiently general to allow for a range of interesting responses. Section 3 sets out the basic model under the assumption that recipient behaviour depends only on their current level of military capability.

In section 4, we allow the recipient to base its reactions, not only on present capability but on expected future capability. This captures an important intertemporal aspect of the market. Arms transfers involve a continuing relationship since provision of spares and resupply in times of conflict is crucial to military capability and refusal to supply, embargo, is an important policy tool[3]. However, in these circumstances, the credibility of assurances becomes crucial. In fact, policy reversals are quite common in this area - suppliers renege on promises to supply or supply despite previous refusals once conflict begins - thus an analysis of time consistent behaviour is important.

In both sections 3 and 4 we characterise the inter-temporal optimisation problem,

[3]Pearson et al (1992) review the literature on the effect of embargo and resupply on conflict.

discuss the steady states and examine the dynamics of the solution. This does not completely characterise the solutions and section 4 goes on to use simulations to examine the solutions (particularly the dynamics) more precisely and to provide more of the intuition behind the analytical results.In sections 3 and 4 we assume non-cooperative behaviour among suppliers; section 5 examines the effect of a suppliers' cartel and cooperative agreements to restrict transfers. Section 6 provides conclusions and highlights the areas where the model needs development.

2.The Market for Arms.

2.1 Products.

Weapons are very heterogenous, but for the purpose of this analysis they can be divided into four categories: weapons of mass destruction; major conventional systems; dual use technologies and small arms. There is a general presumption that diffusion of weapons of mass destruction is not desirable and they are already subject to general, though not completely effective, agreements between suppliers to restrict transfer[4]. Nuclear weapons and technology are covered by the Non Proliferation Treaty and the London Suppliers group, chemical weapons by the Australia Group of Suppliers, biological weapons by the Biological Warfare Convention, long-range missiles by the Missile Technology Control Regime. There are no general restrictions on the transfer of major conventional weapons systems though the UN register will require transfer to be reported. The items to be reported are: battle tanks, armoured combat vehicles, large calibre artillery, combat aircraft, attack helicopters, warships and missile systems. Although there are some technical difficulties in defining these systems

[4]Anthony (1991) describes national regulations and multilateral controls on exports of various types of arms.

precisely, they are usually identifiably military. However, a lot of important military technologies also have civilian applications: computers, transport systems, machine tools, chemicals etc; and these dual use technologies raise major control problems. Finally, there is a large market in small arms which is very difficult to regulate. The analysis in this paper refers primarily to the second category, major conventional systems, which account for the vast bulk of the reported trade.

2.2 Supply.

The relevant supplying agent is the producing government. Arms exports are heavily regulated and to sell systems abroad the firm needs an end user certificate, which specifies who will hold the arms, and an export license[5]. Thus the supplying government is able to discriminate in quantity supplied (and thus price) between purchasers. In approving the transfer the supplying government will have to trade off the economic benefits of the sale (which may boost employment, help the balance of payments and reduce the costs of the weapons it buys itself) against possibly negative security repercussions. Not only is the decision to sell that of the government, the government is often more directly involved in the sale. Most large supplier governments have agencies to promote arms exports, like the UK Defence Exports Sales Organisation, and will be directly involved in negotiating the sale and providing marketing aid to the manufacturer. In many countries, including France, Spain, Italy and the former Warsaw Pact countries, the manufacturer is owned by the state. Thus our model below is cast in terms of the objective of the supplying government who sets the quantity supplied. Effective quantity is controlled not merely by restrictions on the number

[5]Anthony (1991) who describes the various national regulatory regimes notes that such control is very old. As early as the eighth century, Charlemagne imposed the death penalty on Frankish merchants selling swords to Vikings.

of systems supplied but by the quality of the systems. For instance, in the past the US would not supply F15E to Saudi Arabia, but was willing to supply other variants of the F15 which did not have the long-range bombing capability. Export versions of T72 tanks and Mig 29 aircraft also lacked capabilities included on the Soviet versions.

An important feature of supply is that it is not a one-off decision. Longer term relationships particularly for the supply of spares and resupply in times of conflict are crucial. This makes credibility of statements about future supply decisions an important issue. It can work either positively, an assurance to continue to supply in the future, or negatively, an assurance to impose or continue an embargo in the future. In both cases the supplier may have incentives to renege on the assurances, thus questions of the time consistency of the commitments are important.

2.3 Price.

Given that quantity supplied is constrained, price will be above the free-market price. In the mid 1980s the Iranians were paying over $12,000 for US TOW missiles which normally cost about $2,600, the profits from these US government sales being channelled to the Contras in Nicaragua to bypass Congressional vetos. Hard data on price is difficult to obtain. Partly this is because the suppliers wish to maintain secrecy. The UK government has gone to great lengths to ensure that neither the price the UK pays nor the price Saudi Arabia pays for Tornado aircraft is available in the public domain. Partly the lack of data reflects the complexity of the contracts which may cover: a package of products (spares, training, infrastructure) in addition to the systems; tied aid such as the US Foreign Military Assistance program; export credits and insurance; offsets (guarantees to purchase goods from the recipient); counter-trade (payment in goods, such as oil in the Saudi sale); and political concessions. Given the complexity of the deals, some have questioned whether once all the

implicit subsidies have been netted out there is in fact a positive net economic return to the country (as distinct from the arms manufacturers), see ORG (1992). However, below we shall assume that selling arms is potentially profitable.

The price will also reflect demand side conditions. The demand for weapons will depend on the recipients budgetary and security positions (e.g. its involvement in a regional war, such as between Iran and Iraq, or in a regional arms-race). The market peaked in the early 1980s because a firm oil price provided funds for OPEC members and because credit was easily available to non-OPEC members. The weakening of the oil price and the LDC debt crisis restricted finance for weapons purchase and the market dropped sharply in the late 1980s.

2.4 Security Repercussions.

Suppliers have to balance the economic gains from arms sales with the security repercussions[6]. The most direct form of security repercussion is the use of the arms against an enemy of the supplier (desirable) or against the supplier itself or its allies (undesirable). Even if not used, the arms may strengthen the assertiveness or negotiating strength of the recipient in ways that have adverse or beneficial security implications for the suppliers. The guidelines drawn up by the five Permanent Members of the UN Security Council, P5, list the type of security repercussions that suppliers should consider[7].

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[6]The relative weights given to economic and security consequences may change. For instance, the decision by President Bush to allow the sale of up to 150 F16s to Taiwan, despite the opposition of mainland China, was widely seen as reflecting an increased weight attached to American jobs in an election year relative to foreign policy objectives.

[7]The guidelines ask whether the proposed transfers will:
(a) promote the capabilities of the recipient to meet needs for legitimate self-defense;
(b) serve as an appropriate and proportionate response to the security and military threats confronting the recipient country;

long-run effect short-run effect	Positive	Negative
Positive	ALLIES	LEGITIMATE SECURITY LIMITS
Negative	POTENTIALLY COOPTABLE	ADVERSARIES

Table 2.1 The Security Repercussions of Arms Supply.

In the controversies about supplying arms we can distinguish four general types of security repercussion (table 2.1). Two are the straightforward cases of sales to an ally (adversary) where transferring arms will increase (reduce) the suppliers security. Thus most of the suppliers have programs, like the US Foreign Military Assistance, for subsidising arms transfers to their allies and programs, like COCOM, for preventing known adversaries obtaining weapons. There are two more interesting cases where the immediate and long run effects differ. The P5 guidelines refer to "needs for legitimate self defence". This covers the

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(c) enhance the capability of the recipients to participate in regional or other collective arrangements or other measures consistent with the Charter of the UN or requested by the UN.

The P5 say they will avoid transfers which would be likely to:
(a) prolong or aggravate an existing armed conflict;
(b) increase tension in a region or contribute to regional instability;
(c) introduce destabilising military capabilities in a region;
(d) contravene embargoes or other relevant internationally agreed restraints to which they are parties;
(e) be used other than for the legitimate defense and security needs of the recipient state;
(f) support or encourage international terrorism;
(g) be used to interfere with the internal affairs of sovereign states;
(h) seriously undermine the recipient state's economy.

case where transfers increase international security up to a point defined by legitimate needs, but increases in armed forces beyond that point are seen as potentially threatening. Overarming beyond a legitimate security limit signals potentially aggressive intentions. The reverse case is where the supply of arms to a potentially dangerous regime (e.g. military dictatorship) has, in the short-run, negative security repercussions, but allows the supplier, in the longer-run to "coopt" the regime into the legitimate international security system. This was the argument used by parts of the US administration to justify sales to Iran in the mid 1980s, by France about Iraq and by some UK conservatives about arms sales to South Africa: selling arms gives the supplier leverage over the recipient, and this leverage can be used to change their behaviour.

3. The Basic Model.

Governments decide the quantity of arms exported, thus the basis of the model is the objective function of the supplying government. We assume that the supplier knows the demand function of the recipient and can discriminate between recipients through export licenses and the like. In deciding how much to supply, the government must trade off the economic benefits and the security repercussions.[8] We assume that the supplier knows how the military capability of the recipient will impact on the supplier's security. The security element in the objective function creates an externality from the sale, but it is often argued by the arms industry that this externality should be discounted because of competition: "If we do not sell the arms someone else will and the country will get neither the money nor the security". Thus it is important to examine the effect that the number of suppliers has on the

[8]Smith (1989) reviews a range of papers in which welfare is made a function of economic and security variables in this way.

amount traded. We consider the case of a single customer in this paper because we are primarily concerned with supplier-recipient interactions. This means that the model does not treat such features as regional arms races between recipients explicitly. (These are considered in Intriligator and Brito 1989).

We regard the supplier countries as oligopolists producing a homogenous military good (which we can think of as a quality corrected composite of major conventional systems) and facing the inverse demand function of a particular recipient. Let q_{it}, i=1,..., n be the amount of arms that supplier i delivers to the recipient at time t; let $Q_t=Q_{it}+q_{it}$ be total amount of arms supplied to a particular recipient. Thus Q_{it} is the amount supplied by all countries other than country i. Let S_t be the end-of-period stock of military goods defined by

$$S_{t+1}=(1-\delta)S_t+Q_t \tag{3.1}$$

where δ is the depreciation rate. The level of its arms stock determines the military capability of the recipient country which in turn affects its behaviour. Write the single-period utility function of supplier i as

$$U_{it}=P(Q_t)q_{it}-C_i(q_{it})+V(S_t) \tag{3.2}$$

where $P(Q_t)$ is the recipient's demand function and $C(q_{it})$ is the supplier's cost function. The third term in (3.2) represents the security effect of recipients military capability on the welfare of the supplier. It is common in the defence literature to use such welfare functions which include both security and monetary terms. V(S) is a reduced-form relationship which captures the impact of the recipients military capability, S, on its behaviour which influences supplier security valued in monetary terms. Corresponding to (3.2) is an intertemporal welfare function

$$W_{i\tau}=\sum_{t=0}^{\infty}\left[\frac{1}{1+r}\right]^{\tau+t}[P_{\tau+t}q_{i\tau+t}-C_i(q_{i\tau+t})+V(S_{\tau+t})] \tag{3.3}$$

at time τ.

In order to produce an analytical solution (and indeed any closed-form solution) we need to first specialise the functions $P(Q_t)$, $C(Q_t)$ and $V(S_t)$. We assume the following functional forms

$$P_\tau = a - bQ_\tau = a - b(Q_{it} + q_{it}) \tag{3.4}$$

$$C_i(q_{it}) = cq_{it} \tag{3.5}$$

$$V(S_t) = dS_t + eS_t^2 \tag{3.6}$$

The quadratic form of 2.6 captures the four types of security interaction described in table 2.1 of section 2.The particular functional forms that give rise to these four outcomes are given in table 3.1. To aid the intuition, below we shall use the case of a pure adversary $d<0$, $e=0$, for illustration. This is the case where there are negative security externalities both in the short and long run. This may arise, for example, if the recipient uses the arms to threaten the supplier or uses them on third parties, including its own population, in ways the supplier regards as strategically destabilising.

ALLIES $d>0, e \geq 0$	LEGITIMATE SECURITY LIMITS $d>0, e<0$
POTENTIALLY COOPTABLE $d<0, e>0$	ADVERSARIES $d<0, e \leq 0$

Table 3.1. Functional forms for $V(S_t)$ and their Interpretation

Given that the purpose of this paper is to provide a baseline analysis, equations (3.4)

and (3.5) abstract from some potentially very interesting complications. These include allowing for: asymmetric suppliers with different cost conditions and different security interests; endogenous determination of the recipients demand for weapons; and economies of scale which seem characteristic of weapons production. These are topics for further work.

The optimisation problem of supplier i at time $\tau=0$ is to maximise

$$W_0=\sum_{t=0}^{t=\infty}\lambda^t((a-c)q_{it}-b(Q_{it}q_{it}+q_{it}^2)+(dS_t+eS_t^2)) \tag{3.7}$$

where $\lambda=1/(1+r)$ and r is the discount rate, subject to the dynamic constraint (3.1), the non-negativity constraint $q_{it}\geq 0$ and the initial condition that S_0 is given. In this and the next section we consider **non-cooperative** behaviour leaving the analysis of cooperation between suppliers to section 5. Assume open-loop Nash behaviour so that (3.7) is maximised with respect to $\{q_{it}\}$ given the output of all other suppliers $\{Q_{it}\}$. To proceed we define a Lagrangian

$$\begin{aligned}L_{i0}=\sum_{t=0}^{t=\infty}\lambda^t[&(a-c-bQ_{it})q_{it}-bq_{it}^2+dS_t+eS_t^2\\&+p_{1t+1}((1-\delta)S_t+Q_{it}+q_{it}-S_{t-1})+p_{2t}q_{it}]\end{aligned} \tag{3.8}$$

where p_{1t} and p_{2t} are costate variables. By the maximum principle L_{i0} is then maximised with respect to $\{q_{it}\}$, $\{S_t\}$, $\{p_{1t}\}$ and $\{p_{2t}\}$ giving the first order conditions

$$a-c-bQ_{it}-2bq_{it}+p_{1t+1}+p_{2t}=0 \tag{3.9}$$

$$d+2eS_t+(1-\delta)p_{1t+1}-\lambda^{-1}p_{1t}=0 \tag{3.10}$$

$$p_{2t}q_{it}=0 \tag{3.11}$$

together with the original constraint (3.1). In what follows we shall confine ourselves to interior solutions with $q_{it}>0$. Then from condition (3.11) $p_{2t}=0$. The remaining costate variable p_{1t} is a non-predetermined variable satisfying the tranversality condition $\lim_{t\to\infty}\lambda^t p_{1t}=0$..

2.1 Analysis of the Steady-State.

From (3.1), (3.9) and (3.10) the steady-state of the Nash equilibrium is given by

$$\bar{q}_i=\frac{a-c-b\bar{Q}_i+\bar{p}_1}{2b} \tag{3.12}$$

$$\bar{p}_1=\frac{\lambda(d+2e\bar{S})}{1-\lambda(1-\delta)} \tag{3.13}$$

$$\bar{S}=\delta^{-1}(\bar{Q}_i+\bar{q}_i) \tag{3.14}$$

for i=1,n. Then putting $\bar{Q}_i=\sum_{i=0,i\neq j}^{n}\bar{q}_i$ and solving gives the Nash equilibrium. By the symmetry of the model this is easily found as

$$\bar{q}=\frac{\delta(a-c+\theta d)}{\delta(n+1)b-2ne\theta}\ ;\ \bar{S}=n\delta^{-1}\bar{q}\ ;\ \bar{P}=a-bn\bar{q}\ ;\ \bar{Q}=n\bar{q} \tag{3.15}$$

where $\theta=\lambda/(1-\lambda(1-\delta))$. To ensure that $\bar{q}\geq 0$ and finite we impose the conditions

$$\delta(n+1)b-2ne\theta>0\ ;\ a-c+\theta d\geq 0 \text{ or } \delta(n+1)b-2ne\theta<0\ ;\ a-c+\theta d\leq 0 \tag{3.16}$$

We shall show that if $\delta(n+1)-2ne<0$ then it leads to instability (see the discussion after (3.22)). Although instability is of some interest we rule this out and assume that the first

set of conditions in (3.16) hold. We now compare this outcome with that which would result

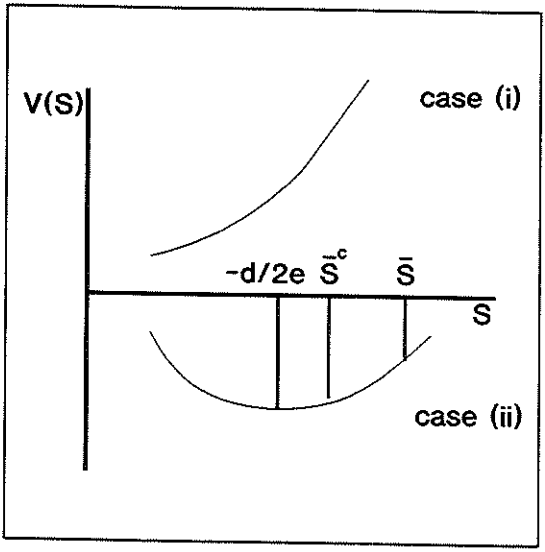

Figure 1: $\bar{S}>\bar{S}^c$

from 'pure' Cournot-Nash behaviour (i.e. in the absence of any security repercussions from the arms sale so d=e=0). This is given by $\bar{q}^c=(a-c)/(n+1)b$ and $\bar{S}=\delta^{-1}\bar{q}$. Then from (3.15) $\bar{q}\geq\bar{q}^c$ (and hence $\bar{S}\geq\bar{S}^c$) if and only if

$$d\geq -2e\bar{S}^c \tag{3.17}$$

This leads us to the following two propositions.

Proposition 1.

The steady-state levels of output and military stock exceed and the price is below the 'pure' Cournot-Nash levels if

(i) The recipient nation is an ally so $V(S_i)$ is unbounded (i.e., $d>0$, $e\geq 0$ in table 1)

(ii) The recipient nation is potentially cooptable, i.e. $V(S_i)$ has a local minimum ($d<0, e>0$) and $\bar{S}^c > -\frac{d}{2e}$.

In case (ii) the recipient has in fact been coopted and its behaviour is improving as military stocks increase. Both cases are illustrated in figure 1 above.

Proposition 2.

The steady-state levels of output and military stock are below and the price above the pure Cournot-Nash levels if

(i) The recipient nation is an adversary so $V(S_i)$ is unbounded (i.e., $d<0$, $e\leq 0$).

(ii) The recipient nation has a legitimate security limit, i.e. $V(S_i)$ has a maximum (i.e., $d>0$, $e<0$) and $\bar{S}^c > -\frac{d}{2e}$.

In case (ii) the recipient has actually exceeded its legitimate security limits for its levels of arms and thus its behaviour is deteriorating as military stocks increase. Figure 2 below illustrates proposition 2.

We can examine the effect of increasing competition in the arms market by increasing the number of supplier countries n in (3.15). This leads to

Proposition 3

Total supply increases with competition and approaches a maximum as $n \to \infty$ given by

$$\bar{Q}=\frac{\delta(a-c+\theta d)}{\delta b-2e\theta}$$

Notice that for a pure adversary ($d<0$, $e=0$) total output is less than would be produced by purely profit-maximising private firms. For both an oligopolistic and a competitive market, government control reduces supply below the free market solution. Thus the steady states for this model agree with experience and intuition both about the effects of the externality on supply and the effects of competition.

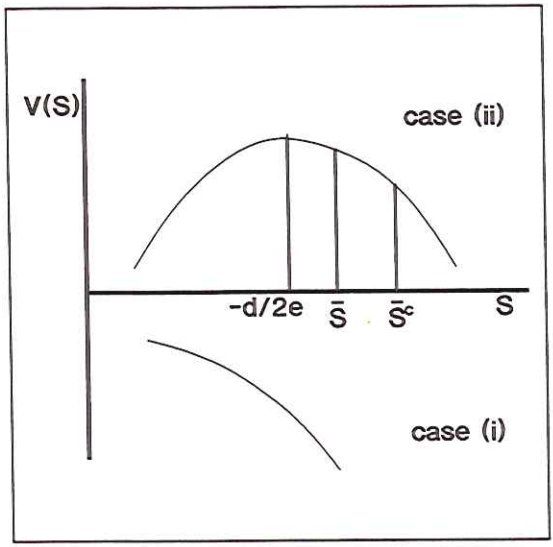

Figure 2: $\bar{S}<\bar{S}^C$

3.2 Analysis of Dynamics.

The first order conditions together with $Q_t=\sum_{i=0}^{n} q_{it}$, $Q_{it}=\sum_{i=0,i\neq j}^{n} q_{it}$ and the symmetry

assumption gives the following dynamic system in state-space form.

$$\begin{bmatrix} S_{t+1} \\ p_{1t+1} \end{bmatrix} = \begin{bmatrix} 1-\delta+\dfrac{2ne}{(1-\delta)b(n+1)} & \dfrac{n}{(1-\delta)\lambda b(n+1)} \\ \dfrac{2e}{1-\delta} & \dfrac{1}{\lambda(1-\delta)} \end{bmatrix} \begin{bmatrix} S_t \\ p_{1t} \end{bmatrix} + \begin{bmatrix} \dfrac{n(a-c)+d/(1-\delta)}{b(n+1)} \\ d/(1-\delta) \end{bmatrix} \tag{3.18}$$

Writing the dynamic matrix in (3.18), $A=[a_{ij}]$ the characteristic equation becomes

$$\psi(\mu)=\mu^2-(a_{11}+a_{22})\mu+a_{11}a_{22}-a_{21}a_{12}=0 \tag{3.19}$$

The state vector in (3.18) has one predetermined variable S_t and one non-predetermined variable p_{1t}. The system converges to the steady-state of section 2.1 if (3.18) is saddle-path stable i.e., if A has one eigenvalue inside and one outside the unit circle. It is easy to show that a necessary and sufficient condition for this to hold is $\psi(1)\psi(-1)<0$ i.e., from (3.19),

$$(1-a_{11}-a_{22}+a_{11}a_{22}-a_{21}a_{12})(1+a_{11}+a_{22}+a_{11}a_{22}-a_{21}a_{12})<0 \tag{3.20}$$

Substituting for a_{ij} from (3.18) the condition becomes

$$\left(\delta(1-\phi)-\frac{2ne}{(1-\delta)b(n+1)}\right)\left((2-\delta)(1+\phi)+\frac{2ne}{(1-\delta)b(n+1)}\right)<0 \tag{3.21}$$

where $\phi=1/((1-\delta)\lambda)>1$. From (3.21) a little algebra leads to the following necessary and sufficient condition for saddlepath stability:

$$-\infty<e<\frac{b(n+1)\delta}{2n\theta} \tag{3.22}$$

where θ is as defined after (3.15). The upper bound in (3.22) has been encountered before. It is precisely the first part of the condition (3.16) to ensure that output is positive and finite. The second possibility can now be ruled out on the grounds that the model is not stable. Our

results can be summarised in the form of

Proposition 4.

If $e<\frac{\delta(n+1)b}{2ne}$ and $a-c+\theta d>0$. Then the steady-state level of output is greater than zero

(reaching zero for adversary recipients at a-c+θd=0) and the model is stable.

3.3 Summary.

To illustrate the main features of the results, consider first the steady state total supply to a recipient who is an adversary or ally with e=0.

$$Q=[n/(n+1)][(a-c+\theta d)/b] \tag{3.23}$$

The first bracket just measures the usual effect of market structure and varies between a half (monopoly) and unity (perfect competition). Increasing competition increases supply, whatever the security relationships involved as long as supply is positive. Supply is positive as long as the economic benefit (a-c) outweighs the security repercussions, θd which is negative for an adversary.

Irrespective of market structure, supply to an adversary ($d<0$) is less than supply when there is no security repercussions, $d=0$. Correspondingly, supply to an ally $d>0$ is always greater than when $d=0$. In the cases where the security function is not monotonic, the results switch when the "adversary" can be coopted ($d<0$, $e>0$) or the "ally" goes beyond its legitimate security limit ($d>0$, $e<0$). All this is exactly what we would expect. Some more interesting and less intuitive insights arise when we allow for forward looking behaviour by the recipient.

4.Credibility.

The reputation of suppliers for making binding commitments becomes an issue if we introduce a forward-looking aspect into the behaviour of the recipient country. Suppose that their behaviour depends upon a weighted average of the future level of military stock X_t i.e.,

$$X_t=(1-\xi)(S_t+\xi S^e_{t+1,t}+\xi^2 S^e_{t+2,t}+...) \tag{4.1}$$

where $S^e_{t+i,t}$ denotes expectations of S_{t+i} formed at time t and $\xi\epsilon[0,1)$ is a measure of the recipient's myopia. The case $\xi=0$ is the case of extreme myopia and reduces to the model of the previous section. $V(S_t)$ in the welfare function is now replaced with $V(X_t)$.

Now write (4.1) in the equivalent form

$$\xi X^e_{t+1,t}-X_t=-(1-\xi)S_t \tag{4.2}$$

First consider the case where the suppliers individually are able to make binding commitments. Then we may put $X^e_{t+1,t}=X_{t+1}$ in (4.1) in our deterministic setting and write down an analogous Lagrangian to (4.8):

$$\begin{aligned} L_0=\sum_{t=0}^{\infty}\lambda^t[&(a-c-bQ_{it})q_{it}-bq_{it}^2+dX_t+eX_t^2+p_{1t+1}((1-\delta)S_t+Q_{it}+q_{it}-S_{t+1}) \\ &+p_{2t}q_{it}+p_{3t+1}(-(1-\xi)S_t+X_t-\xi X_{t+1})] \end{aligned} \tag{4.3}$$

The first order conditions are

$$a-c-bQ_{it}-2bq_{it}+p_{1t+1}+p_{2t}=0 \tag{4.4}$$

$$(1-\delta)p_{1t+1}-\lambda^{-1}p_{1t}+(1-\xi)p_{3t+1}=0 \tag{4.5}$$

$$p_{2t}q_{it}=0 \tag{4.6}$$

$$d+2eX_t+p_{3t+1}-\lambda^{-1}\xi p_{3t}=0 \tag{4.7}$$

plus the tranversality conditions

$$\lim_{t\to\infty}\lambda^t p_{it}=0,\ i=1,3 \tag{4.8}$$

and the initial condition

$$p_{30}=0 \tag{4.9}$$

As before we confine ourselves to interior solutions with $p_{2t}=0$.

4.1 Analysis of the Steady-state.

From the first order conditions above, (4.1) and (4.2) we arrive at the steady-state Nash equilibrium given by

$$\bar{X}=\bar{S} \tag{4.10}$$

$$\bar{q}_i=\frac{a-c-b\bar{Q}_i+\bar{p}_1}{2b} \tag{4.11}$$

$$\bar{p}_1=-\frac{\lambda(1-\xi)\bar{p}_2}{1-\lambda(1-\delta)} \tag{4.12}$$

$$\bar{p}_2=-\frac{\lambda(d+2e\bar{S})}{(\xi-\lambda)} \tag{4.13}$$

$$\bar{S}=\delta^{-1}(\bar{Q}_i+\bar{q}_i) \tag{4.14}$$

Comparing (4.10) to (4.14) with the previous steady-state (3.12) to (3.14) for the case of no forward-looking behaviour, $\xi=0$, we can see that the equations are identical except that $\theta=\lambda/(1-\lambda(1-\delta))$ has been replaced by

$$\eta = -\frac{\lambda^2(1-\xi)}{(1-\lambda(1-\delta))(\xi-\lambda)} \tag{4.15}$$

The solution to the steady-state Nash equilibrium is then given by (3.15) with η replacing θ.

We can now examine the effect of recipient forward-looking behaviour on the steady-state output and stock levels. Replacing θ with η in (3.15) and differentiating with respect to η gives

$$\frac{d\bar{q}}{d\eta} = \frac{(n+1)b(d+2e\bar{S}^C)}{(\delta(n+1)b-2ne)^2} \tag{4.16}$$

But from (4.15) we have that

$$\frac{d\eta}{d\xi} = -\frac{\lambda^2(\lambda-1)}{(1-\lambda(1-\delta))(\xi-\lambda)^2} > 0 \tag{4.17}$$

since $\lambda < 1$. We know from (3.17) that for the case of a myopic recipient $\bar{q} \geq 0$ iff $d+2e\bar{S}^C \geq 0$. Hence the following proposition.

Proposition 5.

If $\bar{q} > \bar{q}^C$ ($\bar{q} < \bar{q}_C$) in the myopic case ($\xi = 0$) and if the suppliers can precommit, then the effect of forward-looking behaviour by the recipient country is to **increase (decrease)** the steady-state levels of output and stock.

Now consider what happens when suppliers are not able to precommit. The only credible policy is one which is **time consistent** i.e., an optimal policy evaluated at time $t=0$ which remains optimal at subsequent times $t>0$. This can be evaluated using dynamic programming but this results in an analytically intractable solution. Below we present numerical simulations of time consistent policies found by dynamic programming but first we

provide analytical results for an equilibrium which captures the idea of a loss of credibility without being our preferred time consistent solution.

A supplier with a reputation for precommitment can affect recipient expectations with its promises of future deliveries policy and exert the maximum leverage over the behaviour of the recipient countries. Without reputation, expectations cannot be controlled in this way. At worse expectations must be taken as exogenous and $X^e_{t+1,t}$ regarded as given in the previous optimisation exercise. The first order condition (4.7) is replaced by

$$d+2eX_t+p_{3t+1}=0 \tag{4.18}$$

The analysis of the steady state then goes through as before with γ replacing η where

$$\gamma=\frac{\lambda(1-\xi)}{(1-\lambda(1-\delta))}<\theta<\eta \tag{4.19}$$

From this and the results preceding proposition 5 we conclude that a loss of reputation reverses the effect reported in the latter proposition i.e., we have

Proposition 6.

If $\bar{q}>\bar{q}^C$ ($\bar{q}<\bar{q}_C$) in the myopic case ($\xi=0$) and the suppliers lack a reputation for precommitment, then the effect of forward-looking behaviour by the recipient country is to decrease (increase) the steady-state levels of output and stock.

4.2 Summary.

It is instructive to consider again the case an adversary or ally with e=0. The general form of the steady state total output is given by

$$Q=[n/(n+1)][(a-c+zd)/b] \qquad (4.20)$$

For myopic recipients $z=\theta$. For non-myopic recipients $z=\eta$ if the supplier can precommit and $z=\gamma$ if they cannot. $\gamma<\theta<\eta$ so for an adversary ($d<0$) supply is lower than that for myopic recipients with precommitment but higher without precommitment. Forward-looking behaviour on its own increases the amount the adversarial recipient obtains. But a supplier who can credibly precommit can exploit this forward looking behaviour to drive long-run deliveries below the level a myopic adversary would obtain. Then the supplier enjoys both the short-run benefits of high output and the desirable behaviour of adversaries which is brought about by the long-run commitment to lower deliveries. All this is reversed for an ally ($d>0$). The simulation results of section 4.4 provide further insights into these results.

4.3 Stability.

The system of dynamic equations describing the non-cooperative equilibrium with forward-looking behaviour by the recipient is given by (3.1),(4.2) and (4.4) to (4.7). This is fourth order and did not prove amenable to eigenvalue analysis. For both the examination of stability and the simulations that follow we choose the following parameter values. The number of suppliers, $n=3$; the rate of depreciation of military stock, $\delta=0.2$ assuming an annual model; the suppliers' discount factor $\lambda=0.95$ which corresponds to an annual discount rate of around 5%; normalise $a-c=b=1$ so that for our 3-country oligopoly of suppliers the pure Cournot-Nash level of output is 1/4. The parameter a is now free to be any value sufficient to ensure a positive price $P_t=a-bQ_t$.

For other parameters we examine the range $\xi\epsilon[0.1,0.9]$ for the recipient's discount factor ξ ranging from a partly myopic lower bound to an upper bound close to that of the suppliers. Given these parameter values we examine values of e and d such that output in the

non-cooperative steady state is positive. From (4.16) and the analysis of section 3 this implies the following restrictions.

$$e<\frac{\delta(n+1)b}{2n\eta} \quad ; \quad a-c+\eta d\geq 0 \tag{4.21}$$

where η is given by (4.15).

In fact stability is not dependent on the value for d. For these values of n,δ,λ; for all $\xi\epsilon[0.1,0.9]$ and for all e satisfying the first inequality in (4.21) we find that the forward-looking non-cooperative equilibrium is stable for both the reputational and non-reputational cases of section 3.

4.4 The Dynamics of the Non-cooperative Equilibrium.

In the simulations of the following sub-sections we only consider the case where the supplier is an adversary ($d<0$). If there is no local minimum, i.e. the recipient is not potentially cooptable, then $e<0$ and we refer to this as **case (a)**. Following the analysis preceding proposition 1 we further divide the remaining case $d<0$ and $e>0$ into **case(b)** where $\bar{S}^c>-d/2e$ and case(c) where $\bar{S}^c<-d/2e$ recalling that $\bar{S}^c=n(a-c)/((n+1)b\delta)$ is the pure Cournot-Nash level of stock. In case (b) the adversary has been actually coopted in the myopic case or the non-myopic case with reputation (see propositions 1 and 5). For case (c) the reverse is true: the adversary although cooptable has not, in fact, been coopted.

For cases (b) and (c) we put $-d/2e=x\bar{S}^c$ so that $x<1$ corresponds to case (b) and $x>1$ to case (c). Substituting for $\bar{S}^c$ the first inequality in (4.21) becomes

$$e\leq\frac{\delta(n+1)b}{2n\eta x} \tag{4.22}$$

which is stronger than the first inequality if $x>1$ but weaker if $x<1$. We now choose x and e so that both inequalities hold and put $d=-2ex\bar{S}^c$. Then the non-cooperative equilibrium is both stable and displays positive output.

Now consider the following illustrative examples. For case(a) we choose $d=e=-0.1$. For $\xi e[0.1,0.9]$, $\eta e[3.98,7.75]$ and condition (4.21) is satisfied. For case (b) we put $x=1/2$, $e=0.01$ giving $d=-0.037$. Then $-d/2e=1.85$ which is less than $\bar{S}^c=3.75$. For case(c) we set $x=2$, $e=0.005$ giving $d=-0,075$. Thus $-d/2e=7.5>\bar{S}^c$. Table 4.1 displays the results for these three cases for the partially myopic and forward-looking extreme values of ξ. We also distinguish between the equilibria where the suppliers enjoy a reputation for precommitment (denoted by R in the table) and the non-reputational case where they do not (NR). The values given in the table are $(q_0,\bar{q})$ denoting the output of each supplier in the initial period and the steady-state respectively. Since the paths are monotonic, the essential dynamics of the equilibria can be grasped from these extreme values.[9]

[9]The model under the non-cooperative equilibrium is available from one of the authors (P.L.) as an executable program on disc with facilities to change parameter values and examine the simulations more carefully.

	Myopic recipient (ξ=0.1)		Non-myopic recipient (ξ=0.9)	
	R	NR	R	NR
Case (a)(not cooptable) e=d=-0.1	(0.07,0.04)	(0.08,0.04)	(0.08,0.03)	(0.12,0.18)
Case(b) (coopted) e=0.01,d=-0.037	(0.25,0.30)	(0.25,0.30)	(0.26,0.41)	(0.25,0.25)
Case(c) (not coopted) e=0.005,d=-0.075	(0.19,0.21)	(0.20,0.21)	(0.23,0.15)	(0.25,0.25)

Table 4.1 Dynamic Properties of the Non-cooperative Equilibrium, Initial and Steady-State values of output.

All long-run values of output are as confirmed by propositions 5 and 6. Case (b) is where $\bar{q}>\bar{q}^c$ in the myopic case and cases (a) and (b) where $\bar{q}<\bar{q}^c$. Thus in case (b) the effect of making recipient behaviour more forward-looking by increasing ξ from 0.1 to 0.9 is to increase the long-run level of output and military stock if the suppliers enjoy reputation and to bring about a decrease without reputation. For cases (a) and (b) these effects are reversed.

The dynamic path helps us to grasp the intuition behind these results. Let us focus on case (b) where $\bar{q}>\bar{q}^c$ and the recipient has been coopted unless, in the non-myopic case, the suppliers lacks reputation. If the recipient is forward-looking then suppliers can affect its political behaviour immediately by promising a high level of output with a corresponding low

price in the long run. This moves the long run further along the $V(X_o)$ curve where increased expected military capability is having a beneficial effect on the behaviour of the recipient. Compared with the myopic case the degree of cooption increases. But the low price lowers the monetary component of welfare and the resulting output path is time inconsistent. Everywhere along this path there exists an incentive to let bygones be bygones and not deliver the lower price. In the time consistent non-reputational solution the recipient anticipates this incentive to renege and the resulting outcome is for the initial high price and low output to persist indefinitely. Cooption now disappears and output remains near the Cournot level of 0.25. All this is reversed for cases (a) and (b) but again the non-reputational solution is for the initial higher level of output to continue indefinitely.

5. The Gains From Coordination.

Up to now we have focused exclusively on the non-cooperative equilibrium. Now consider the effect of cooperation among suppliers.[10] There are now two dimensions to the problem: cooperation or non-cooperation and reputation or non-reputation. This leads to four equilibria in table 4.2 abbreviated to CR, CNR, NCR and NCNR.

[10]We do not consider the issue of cartel stability which is likely to be a problem in practice.

	Cooperation (C)	Non-Cooperation (NC)
Reputation (R)	CR	NCR
Non-Reputation (NR)	CNR	NCNR

Table 5.1 The Possible Equilibria.

Our final simulations are for the forward-looking model with $\xi=0.9$. For these simulations we use our preferred non-reputational solution bases upon dynamic programming. (see Currie and Levine (1992) for full details of solution procedures for all four equilibria). However results for NCNR computed using this correct concept are in fact close to those in Table 5.1 (under NR) which employs an informal but tractable concept of 'loss of credibility'. Results are shown in tables 5.2 to 5.4.

	Cooperation (C)	Non-Cooperation (NC)
Reputation (R)	Zero Output	(0.08,0.04)
Non-Reputation (NR)	(0.03,0.04)	(0.12,0.08)

Table 5.2 Case (a) (not cooptable) d=e=-0.1. Values for initial and steady-state output.

	Cooperation (C)	Non-Cooperation (NC)
Reputation (R)	Zero Output	(0.26, 0.41)
Non-Reputation (NR)	(0.17,0.18)	(0.26,0.27)

Table 5.3 Case (b) (coopted) e=0.01,d=-0.037 . Values for initial and steady-state output.

	Cooperation (C)	Non-Cooperation (NC)
Reputation (R)	Zero Output	(0.23,0.15)
Non-Reputation (NR)	(0.11,0.12)	(0.23,0.23)

Table 5.4 Case (c) (not coopted) e=0.005,d=-0.075. Values for initial and steady-state output.

Only three solutions give consistently meaningful results in that output is always positive. For CR output eventually became negative and we report these results simply as zero output (i.e., a complete embargo). The results show that cooperation with or without reputation leads to a fall in output and a rise in price as one would expect. The detailed results can be explained in terms of two negative externalities which cooperation internalises:

the reduction in price and the effect of military stock on recipient behaviour as output of any one supplier increases. These work together in cases (a) and (c) but against each other in case (b) where the recipient is coopted. Thus at least as far as the CNR/NCNR comparison is concerned cooperation has a far greater effect in the cases (a) and (c). The CR/NCR comparison has to be suspect because the solution under CR ran up against the non-negativity constraint. But this does indicate that even where there are economic benefits, a cooperative group of suppliers who can precommit can operate a complete ban on weapons transfers.

6. Conclusion.

There is a tendency for some economists to regard arms sales as driven largely by political factors, and for political scientists as to regard it as driven by economic factors.[11] This paper provides a simple model that allows both to operate and for the security repercussions to take four different forms. The relative size of the economic and security effects in particular cases is, of course, an empirical matter, but, regarding these as knowable (a strong assumption) the model allows us to examine the effect of various factors on the size of the transfer. To summarise, consider the case of a potential adversary. With a myopic recipient, the security externality makes transfer lower than in the absence of the externality; increased competition increases transfers, but transfers remain below what they would be in the absence of the externality. A forward looking recipient can exploit time-consistency to increase transfers unless the supplier can precommit in which case transfers are below the myopic case. If suppliers form a cartel, they benefit both from internalising the security

[11] Kolodziej (1987) in a very detailed analysis of the politics of French arms export policy emphasises the economic imperative.

externality and the monopoly power, both tending to reduce transfers. The security externality may be sufficiently important to drive transfers to zero.

In order to provide a broad framework this paper has concentrated on a single generic recipient and the case of identical supplying governments. This captures the essence of the current policy concerns; the effect of competition and cooperation and the credibility problem. However the model could be extended in a number of different ways to capture other features of suppliers, markets and recipients.

We have assumed that the weapons are already in production. But the prospects of exports sales will influence the decision to develop a particular system. There are differences of interests between supplier governments and the firms (nationalised or private) who actually produce the weapons. Suppliers differ and it would be interesting to examine how the market operated under different strategic relationships. For instance there might be a Stackelberg leader, the US, who has world-wide security concerns, and a number of 'small' followers (Britain and France) who are purely motivated by the economic return.

We characterised recipient behaviour by a demand function and a fixed reaction function from military capability to supplier security; but recipient decisions could be endogenised in terms of their security and economic objectives and budget constraints. Multiple interacting recipients could be allowed for.[12]

Finally although the data in this area are, for obvious reasons, rather unreliable, it may be possible to conduct some empirical analysis.

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[12] See van der Ploeg and de Zeeuw (1989) for an arms race model between a decentralised market economy and a command economy. Although this work addresses quite a different set of issues, it utilises the same equilibrium concepts as our paper: an open-loop Nash equilibrium with precommitment (our NCR of table 5.1) and what they refer to as a 'feedback Nash' or subgame-perfect equilibrium which corresponds to our NCNR concept.

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