Managing Asymmetric Conflict*

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Abstract

We consider conflicts between an incumbent, e.g. government or dominant firm, and potential challengers, e.g. guerrilla movement or entrants. It is not uncommon for challengers to win such conflicts despite their lack of resources. They can do this by exploiting a second mover advantage: choosing to attack the incumbent in ways that it had not prepared for, because it was locked in by past investments. To model such asymmetric conflict we use a three stage game. In the first stage the incumbent chooses effort; in the second stage the challengers choose the degree of differentiation from the incumbent and in the third stage each decide whether to attack or defend and collect their payoffs. This simple model has a number of interesting predictions, which may apply in certain types of legal, commercial and military conflicts.

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1 Introduction

Conflict is endemic: military combat, legal disputes, and commercial battles to establish market share or standards are examples. Economic models of conflict have agents allocating resources (e.g. military expenditures, legal fees, advertising or R&D budgets) to conflict as well as to productive activities, e.g. Hischleifer (2001). In this literature, the relative investments of the antagonists determines their probability of winning (or share of the prize) through a 'conflict success function', CSF. Like Voltaire, most CSFs assume that God is on the side of the big battalions: those who invest most are most likely to win. However, in real life, like Hollywood movies, the little guys win more often than one might expect. Japan beating Russia in 1905-6, Germany beating larger French and British forces in 1940, Vietnam beating the US in the 1970s. Using a large sample of battles, Rotte and Schmidt (2003) show that relative force size is a poor predictor of victory. It is often the case that a dominant incumbent is displaced by a smaller challenger, because the challenger uses tactics or technology that the incumbent had not prepared against. In the military context this is currently referred to as asymmetric warfare, though the concept is not new: attacking in ways that your opponent was unprepared for has been the basis of military thought since at least Sun Tzu in the fourth century BC (Newman, 2000). The current military discussion of asymmetric warfare is motivated by the observation that since the heavy US investment in technology appears to make it invincible in traditional warfare, adversaries have an incentive to resort to other types of warfare, which can exploit the vulnerabilities of the US and its allies. The asymmetries may be in technology, what each side fights with; tactics, how they fight; or in the stakes, i.e. the costs of conflict to each side. Similar arguments apply to terrorism. Enders and Sandler (2002) and Sandler and Arce (2003)) note that when a terrorists have a choice of targets (e.g. different countries or different objectives within the same country) effort being put into defending one target will provide incentives for the terrorists to substitute towards alternative targets[1]. The IRA moved from attacking military targets in Northern Ireland, to civilian targets in

[1] Our paper is also linked to the conflict literature (see e.g. Grossman (1991) and Grossman and Kim (1995)). In this literature, conflicting parties often choose whether to gather defensive or offensive weapons. Our focus though is on the technological nature of the weapons used, whether to use conventional or unconventional weaponry and how that choice affects the chances of preventing conflict.

Britain, to high value commercial targets in the City of London.

Although our interest is motivated by military examples, the phenomenon of powerful incumbents being displaced by challengers using different technology or tactics, is of much wider relevance. The large US automobile companies lost their dominant market share to small imports against whom they could not compete, Abernathy (1978) is a classic analysis of the lock-in dilemma they faced. IBM was the dominant player in the computing industry with a particular way of doing business and a well established customer base. But the industry changed dramatically, as instead of competing directly with the established leader, entrants opened up new market segments. Later, some of these entrants became challengers to IBM's power and those that prevailed were the ones who won the standardization war, Microsoft and Intel (Bresnahan and Greenstein, 1999; Sutton 2001). Microsoft's tactics for displacing software incumbents are discussed in Liebowitz and Margolis (1999). Now, Microsoft is the incumbent, potentially vulnerable to Open Source Linux and the virus or worm writing little guys.

Economic models tend not to capture the prevalence of such attacks, when new challengers, military or commercial, compete in ways that the incumbent was unprepared for. The objective of this paper is to present a model that captures the main features of the interactions involved in such asymmetric conflicts and to analyze the impact that possible challenger differentiation has on the ability of the incumbent to deter conflict. We will call the dimension that the challengers can differentiate over technology, what they fight with; but it could be tactics, how they fight; targeting, where they fight; or other dimensions in which the challengers perceive incumbent weakness.

We will call the contestants an incumbent and challengers; e.g. a government and a disaffected minority considering starting a guerilla war, or a monopolist and potential entrants. Asymmetric conflict arises when the contestants are themselves asymmetric. They differ in three dimensions. First, *resource availability,* the incumbent has large resources available, the challengers have limited resources. Second, *incumbent lock-in,* incumbents, not only military ones, tend to prepare to fight the last war, since that was the basis of their success and have made large fixed investments in that way of fighting or doing business[2] and while the incumbent has to prepare to be attacked from many

[2]In the case of the US military some evidence for inertia is provided by Trajtenberg (2003) who shows that the shares of US defence R&D expenditures across different categories have not changed since Sep-

directions, the challenger can choose how and when to attack. Third, *costs of conflict,* antagonists may have different valuations of the costs of conflict, what stakes they have and what costs they are willing to bear. Difference in the costs of conflict are most obvious in the case of suicide bombers, but small firms are more likely to bet the company on a risky venture than a large corporation. We will assume that the both parties are materially rather than ideologically motivated, they fight because they hope to capture a share of resources, and the expected value of fighting is greater than the expected value of peace. Collier and Hoeffler (1998) provide evidence that this describes most civil wars.

To capture these features, we model the process as a three stage game to obtain a prize. In Stage 1, the incumbent, who has ample resources, has to decide how much effort (military expenditures, legal fees, sunk costs) to invest to counter the threat. At this stage the incumbent chooses a technology. Like vintage-capital production functions, this is a free choice ex-ante but fixed ex-post and once chosen the incumbent is locked into the choice by the capital invested, uncertainty or inertia. After the French had built the Maginot line of fortifications, they could not move it when Germany decided to attack somewhere else. For commercial incumbents the dilemma often arises because the optimal technology in the absence of conflict is specialised and inflexible. In Stage 2, the challengers, who are resource constrained, allocate all of an exogenously determined amount of effort or resources to the conflict. But knowing the incumbent's technology, they can choose to differentiate: adopt a different technology which will give them an advantage in attacking the incumbent. Differentiation benefits the attacker but disadvantages the defender. The technology and tactics of Blitzkrieg, depending on speed and movement, gave the Germans a substantial advantage when they were attacking, but left them at a disadvantage when defending against attack by others. Differentiation is represented by a variable which increases with the difference between the type of the technology adopted by the challengers and the type used by the incumbent and takes a value of zero if they are exactly the same. The no differentiation case, which we will analyse, covers the case where the incumbent is not locked in but can match the challengers. Even if they are of the same type, the technologies may differ in quality or quantity, which is captured by the effort variable. Finally, in stage 3, incumbent and challengers simultaneously decide

tember 11th, 2001 with 30% of R&D expenditures still being allocated to big weapon systems.

whether to attack or defend. The probabilities of winning the conflict will depend on the attack/defend decisions of the two parties, their efforts and the degree of differentiation. In the commercial context, incumbent attack could be predatory pricing in potential entrants existing market in an attempt to bankrupt them.

There are four possible outcomes, which we will call peace, unprovoked attack by the incumbent, defensive conflict by the incumbent, and mutual attack. There is (hostile) peace, if both decide to defend and they get peacetime payoffs. There is unprovoked attack if the incumbent attacks peaceful challengers. We will rule out this case by assuming that the incumbent would rather avoid a conflict, in that their share of resources if no conflict erupts is bigger than the expected resources to be won through attacking a peaceful challenger. There is defensive conflict if the incumbent defends against attacks by the challengers. There is mutual attack, if both attack. There are costs of conflict, since if either attack some of the contested resources are destroyed in the resulting conflict. These costs differ by agent and type of conflict; e.g. destruction being higher in a mutual attack. Nobody is surprised in this game. We assume that contestants have complete information about both parties probabilities and payoffs. Although this is not necessarily realistic, it brings out the issues more starkly and means that there is no role for signalling or for a war of attrition: there is just a battle with some probability of winning. We return to this assumption in the conclusion. We also assume the status-quo, peacetime, shares of the prize are exogenous. In many cases it would be cheaper for the incumbent to bribe the challengers with the promise of a larger third-stage peace-time share rather than to deter, defend or attack. But rarely can an incumbent credibly pre-commit to do so and for commercial incumbents it is usually illegal. However, given that differentiation raises the risk of conflict and makes military efforts less effective, the need to find non-military routes to peace, which change the peacetime shares becomes important. We return to this issue in the conclusion.

In principle, the incumbent can use its effort, e.g. military expenditures, to do three things. It can use its effort to deter, by setting it at a conflict-preventing level which cause the challengers to see no advantage in attacking. It can use the effort to defend against a challengers attack. It can use its effort to attack. The challengers face similar possibilities. It may be that the cost to the incumbent of deterring the challengers is very large relative to defending against an attack. The size of the sunk costs necessary to deter entrants may be very large relative to the cost of competing against them. In many guerrilla wars the efforts required to prevent the challengers attacking would be very large compared with the cost of defending against those attacks. During the Cold War, deterrence involved massive arsenals on each side, while war-fighting capability would have required just the handful of missiles needed to destroy the other. Intriligator (1976) provides a model. The vast cost of deterrence was thought by some worth paying because the costs of conflict were larger.

Although simple, the model has some interesting predictions. If there was no possibility of differentiation, we would never observe both sides attacking each other. When we introduce the possibility of differentiation, the challengers will block the mutual attack equilibrium by limiting differentiation. Differentiating too much provokes attack by the incumbent. Given that the challenger will block the mutual attack equilibrium and that the incumbent sees no benefits from attacking a non-threatening challenger; there are two candidates for equilibrium in the last stage of the game. These are peace, where the challengers are deterred, and a defensive conflict where the incumbent defends against attack by the challengers. Through its choice of effort, the incumbent may be able to implement either of these two equilibria as the unique equilibrium in the final stage of the game. It chooses the equilibrium with the highest level of utility. Introducing the possibility of differentiation increases the incentive for challengers to attack. To maintain peace the incumbent has to devote more effort to deterring the attack. From this we are able to conclude that the incumbent is less likely to want to maintain peace when differentiation is possible. It may be cheaper for the incumbent to defend against an attack than to incur the conflict-preventing level of effort. In this case, defensive conflict, incumbent effort is less when differentiation is possible, than when it is not. This happens because with differentiation, effort is less effective, military expenditure buys you less security, so you spend less on it. In this sense, a world where technological differentiation by challengers is feasible becomes a less safe world for the incumbent, because it is more difficult to deter the threat and avoid conflict. In fact, when differentiation is possible, there may be no level of effort by the incumbent which can maintain peace.

The paper moves from special cases, to provide intuition, to more general cases. Section

2 introduces the main features of the model, including the third stage of the game, which is common to the three cases we consider. Section 3 provides the benchmark case without differentiation. This is the case where the incumbent is not locked-in and can match the challengers. Section 4 finds the Subgame Perfect Nash equilibrium of the game with differentiation and compares it with the benchmark. Section 5 introduces a fixed cost to differentiation, this has the models of section 3 and 4 as special cases. We show that a reduction in such cost will make it less likely for the incumbent to choose, or even to be able, to prevent conflict by means of effort. Section 6 has some concluding comments.

2 The Model

2.1 Structure of the game

In our model incumbent, a, and challengers, b, are rational players of a sequential game to gain a prize of value V. This game determines the incumbent's effort, the challenger's technological differentiation, the nature of the conflict and the payoffs. Throughout the game, the incumbent's technology and challengers' effort are considered exogenous.

The interaction is represented by a three stage game:

Stage 1: The incumbent chooses its effort, e_a with cost $C_a(e_a)$. We assume that the cost increases with effort and that the second derivative is such to ensure that the expected utility function is concave. The challengers effort e_b is considered fixed since they use all their available resources, while the incumbent allocates its budget across a range of expenditures and so has more flexibility when it comes to choosing effort. These assumptions capture the position of resource constrained challengers facing an incumbent with ample resources.

Stage 2: The challengers choose the type of technology to acquire, determining the degree of differentiation, t. The technology used by the incumbent is considered to be given by prior investments.

Stage 3: Incumbent and challengers simultaneously decide whether to attack or defend and get their payoffs. Simultaneity approximates the uncertainty about which might be able to move first.

The game is solved backwards in order to find the Subgame Perfect Equilibrium which will contain the equilibrium effort level of the incumbent and the degree of differentiation by the challenger, which will then result in a unique pure strategy equilibrium in the third stage of the game.

2.2 Probability of winning

The probability of winning by each party (conflict success function or CSF) depends on whether each attacks or defends. The first argument in parenthesis refers to the incumbent's strategy and the second refers to the challengers' strategy. Thus $P_a(A, D)$ is the probability of the incumbent winning if incumbent attacks and challengers defend; and $P_b(D, A)$ is probability of the challengers winning if incumbent defends and challengers attack. Similarly for the other six probabilities. If neither side attacks, they get the peace-time shares of the prize s_a and $s_b = 1 - s_a$. If there is a conflict, the probabilities of winning depend on each side's choice to attack or defend; the ratio of the effort by incumbent, e_a and by challenger e_b; the degree of differentiation from the incumbent by the challenger $t \geq 0$ which takes the value zero if they are exactly the same[3]. Differentiation provides an advantage in attack and a disadvantage in defence. In a mutual attack, differentiation cancels out and disappear from the probabilities, which just depend on relative effort. The probabilities are:

$$\begin{aligned}
P_a(A, D) &= \frac{t + e_a}{t + e_b + e_a} \leq 1. \\
P_a(D, A) &= \frac{e_a}{t + e_b + e_a} \leq 1. \\
P_a(A, A) &= \frac{e_a}{e_b + e_a} \leq 1. \\
P_a(D, D) &= s_a = 1 - s_b,
\end{aligned}$$

[3]Hirschliefer (2001) discusses ratio and difference forms of the conflict success function. Siqueira (2002) uses similar CSFs without technological differention to model outside intervention in civil wars. He also includes a defensive advantage to capture the usual military rule of thumb that the attacker needs a local advantage of 3 to 1, to be sure of winning. In an earlier version of the paper we included such a defensive advantage, all the results here go through as long as the defensive advantage is not too large.

with

$$
\begin{aligned}
P_b(A,D) &= 1 - P_a(A,D) = \frac{e_b}{t + e_b + e_a} \leq 1 \\
P_b(D,A) &= 1 - P_a(D,A) = \frac{t + e_b}{t + e_b + e_a} \leq 1 \\
P_b(A,A) &= 1 - P_a(A,A) = \frac{e_b}{e_b + e_a} \leq 1 \\
P_b(D,D) &= s_b = 1 - s_a.
\end{aligned}
$$

Note that

$$
\begin{aligned}
P_b(D,A) &\geq P_b(A,A) \geq P_b(A,D) \\
P_a(A,D) &\geq P_a(A,A) \geq P_a(D,A).
\end{aligned}
$$

where equalities apply if both sides adopt the same technology, since the probability of winning just depends on relative effort.

These differ from the CSFs common in the conflict literature in two ways:, we allow for both parties to choose to attack or defend and we introduce technological differentiation by the challengers.

2.3 Payoffs and the cost of conflict

The payoffs are the expected utilities of the parties, $i = a, b$ incumbent and challengers, which follow from their stage 3 strategies, attack or defend, $S_i = A, D$, Expected utilities are the probability of winning, $P_i(S_a, S_b)$ times the share of the prize, V, that is left after the conflict, $\phi_i(S_a, S_b)$, less the cost of effort, $C(e_i)$:

$$
\begin{aligned}
EU_a(S_a,S_b) &= P_a(S_a,S_b)\phi_a(S_a,S_b)V - C_a(e_a), \\
EU_b(S_a,S_b) &= P_b(S_a,S_b)\phi_b(S_a,S_b)V - C_b(e_b),
\end{aligned}
$$

The cost of conflict differs with the type of conflict and the agent. For the incumbent the cost is $(1 - \phi_a(S_a, S_b))V$, for the challengers it is $(1 - \phi_b(S_a, S_b))V$, and they may differ in their perceptions of the cost of a particular type of conflict. If both defend, there is peace, costs of conflict are not incurred and the utilities are $s_aV - C_a(e_a)$ and $s_bV - C_b(e_b)$.

The costs of conflict are central to our analysis, because they determine the perceived payoffs to the various strategies available to the agents and thus the potential equilibria. We make four assumptions about the costs of conflict:

(a) that the incumbent prefers peace to unprovoked attack against peaceful challengers, they do not want to start a conflict if the challengers are not going to attack,

$$s_a > \phi_a(A, D);$$

(b) more of the prize is destroyed during mutual attack, so that the payoff for the incumbent is greater under (D, A) than (A, A)

$$\phi_a(D, A) > \phi_a(A, A);$$

(c) similarly for the challengers

$$\phi_b(D, A) > \phi_b(A, A);$$

(d) the challengers may have an incentive to attack

$$\phi_b(D, A) > s_b.$$

Assumption (d) just makes conflict a possibility; assumptions (b) and (c) make the reasonable assumption that when both sides attack more is destroyed than when one side attacks; assumption (a) excludes an incumbent who knows the challengers are not going to cause trouble, but attacks them just in case. Governments do this on occasion and if (a) does not hold a different game arises . This game may be interesting in certain circumstances, but is not the focus of our present analysis.

2.4 Last stage: choice of defence or attack

The last stage of the game is common to all three cases we examine below. In the last stage, effort or differentiation costs do not appear because they are sunk by then. There are four possible candidates for Pure Strategy Nash equilibria in the last stage. Consider the conditions for each to be an equilibrium.

MUTUAL ATTACK , (A, A):

Payoffs are $P_a(A, A)\,\phi_a(A, A)\,V$ and $P_b(A, A)\,\phi_b(A, A)\,V$. For this to be an equilibrium, each agent must prefer mutual attack to defending against the other's attack, so this requires the (A, A) payoff for the incumbent to be greater than the (A, D) payoff and the (A, A) payoff for the challengers to be greater than the (D, A) payoff:

$$\begin{aligned} \phi_b(A, A)\,P_b(A, A) &\geq \phi_b(A, D)\,P_b(A, D) \\ \phi_a(A, A)\,P_a(A, A) &\geq \phi_a(D, A)\,P_a(D, A) \end{aligned} \qquad (1)$$

PEACE, (D, D)**:**

Payoffs are $s_a V$ and $s_b V$. For this to be an equilibrium, each agent's peacetime shares must be greater than the payoffs they would obtain from attacking:

$$\begin{aligned} s_b &\geq \phi_b (D, A) P_b (D, A) \\ s_a &\geq \phi_a (A, D) P_a (A, D) \end{aligned} \tag{2}$$

DEFENSIVE CONFLICT, (D, A)**:**

Payoffs are $P_a (D, A) \phi_a (D, A) V$ and $P_b (D, A) \phi_b (D, A) V$. For this to be an equilibrium, the challengers must gain by attacking and the incumbent must gain by defending:

$$\begin{aligned} s_b &\leq \phi_b (D, A) P_b (D, A) \\ \phi_a (D, A) P_a (D, A) &\geq \phi_a (A, A) P_a(A, A) \end{aligned} \tag{3}$$

UNPROVOKED ATTACK: (A, D)

This is not a candidate for Nash Equilibrium by assumption (a) $s_a > \phi_a(A, D)$.

Thus, we are left with three candidates for Nash Equilibrium in the last stage of the game.

3 The game without differentiation

When technological differentiation is not possible, we have a two stage game. The incumbent decides effort in the first stage and incumbent and challengers simultaneously decide whether to attack or defend in the last stage. We will see that defence is a dominant strategy for the incumbent, and it will set effort either to ensure peace by deterring the challengers, or to defend against attack by the challengers. Which it will choose depends on the relative cost of deterrence and defence. The payoffs are as given above with $t = 0$. If differentiation is not possible, (A, A) will not be a Nash Equilibrium, since for the incumbent the costs of conflict in a mutual attack are bigger than those of defending against attack by the challengers, $\phi_a (D, A) > \phi_a (A, A)$, by assumption (b). However, (D, A) defensive conflict will be a candidate for a Pure Strategy Nash Equilibrium in this stage as long as $s_b \leq \phi_b (D, A) P_b (D, A)$,since if differentiation is not possible, $P_a (D, A) = P_a (A, A)$ which with assumption (b) implies that the last stage payoffs to the incumbent of (D, A) are greater than $(A, A) : \phi_a (D, A) P_a (D, A) > \phi_a (A, A) P_a(A, A)$.

We thus have two possible Nash equilibrium: (D,D) peace or (D,A) defensive conflict and the incumbent's choice of effort in the first stage of the game will determine which of them is part of the Subgame Perfect Nash Equilibrium Strategy of the game.

3.1 Incumbent chooses effort

Let $e_a^{(D,D,t=0)}$ be the conflict-preventing level of effort the incumbent would choose when it prefers (D,D) and similarly $e_a^{(D,A,t=0)}$ be the conflict-anticipating level of effort it would choose when it preferred defensive conflict (D,A). To induce peace (D,D), from (2) the incumbent needs to choose its effort e_a to make the challenger to prefer peace to attacking the incumbent

$$P_b(D,A)\phi_b(D,A) = \frac{e_b\phi_b(D,A)}{e_b+e_a} \leq s_b$$

Given that $s_b < \phi_b(D,A)$, by assumption (d) some effort will be required to ensure this and the conflict-preventing effort is

$$e_a^{(D,D,t=0)} = \frac{e_b\left(\phi_b(D,A)-s_b\right)}{s_b} \tag{4}$$

If the incumbent implements this effort, peace will be the unique Nash Equilibrium of the stage 3.

If the incumbent wanted to induce defensive conflict (D,A), conflict-anticipating effort would maximize $EU_a(D,A)$. The first order condition which implicitly defines the optimal level of conflict-anticipating effort[4], $e_a^{(D,A,t=0)}$ is

$$\frac{dEU_a(D,A)}{de_a} = V\frac{e_b\phi_a(D,A)}{(e_b+e_a)^2} - \frac{dC(e_a)}{de_a} = 0. \tag{5}$$

Implicit differentiation shows that an increase in V has a positive impact on effort. The impact of challenger effort e_b on the effort the incumbent makes in anticipation of conflict $e_a^{(D,A,t=0)}$ is positive as long as incumbent effort is greater than challenger effort $e_a^{(D,A,t=0)} > e_b$, which seems likely to be the case.

Whether the incumbent chooses to induce (D,A) or (D,D) will depend on the amount of effort required to deter conflict relative to the effort required to defend against attack. This choice is discussed later.

[4] Note that $EU_a(D,A)$ is concave even with constant marginal costs.

4 The game with differentiation

In this section we obtain the Subgame Perfect Equilibrium of the game when differentiation is possible. Although the probabilities of winning are now different, the same conditions need to apply for each possible outcome to be a candidate for a Nash Equilibrium of stage 3. Whereas, without differentiation, defence was a dominant strategy for the incumbent, mutual attack now becomes a possible Nash Equilibrium. Differentiation can offset the higher cost to the incumbent of mutual attack that follows from assumption (b): $\phi_a(D, A) > \phi_a(A, A)$. With differentiation, even if assumption (b) holds, attack can be the incumbent's best response to a challengers' attack, because it neutralises the challengers differentiation advantage. Although t is assumed to be unbounded, we shall see that the challengers will choose to limit the degree of differentiation to preclude attack by the incumbent and thus block the mutual attack outcome (A, A). Thus we are left with the same two equilibria, which the incumbent has to choose between.

4.1 Stage 2: Choice of differentiation

In the second stage, the challengers choose t, differentiation, conditional on the level of effort chosen by the incumbent in stage 1. Assumption (a): $s_a > \phi_a(A, D)$, excludes (A, D) as an equilibrium. We need to determine which of the three possible equilibria (D, D), (D, A) and (A, A) the challengers will want to implement, through their choice of differentiation.

Peace, (D, D) occurs if the combination (e_a, t) makes the challenger better off by not attacking

$$P_b(D, A)\phi_b(D, A) = \frac{(t + e_b)\phi_b(D, A)}{t + e_b + e_a} \leq s_b.$$

To maintain peace, there are two threshold levels of differentiation, each just below the level that would induce one of the other two possible outcomes, defensive conflict or mutual attack. Call t_1 the level that blocks (D, A); t_2 the level that blocks (A, A). These will be a function of incumbent's effort, e_a, determined in the first stage. Peace (D, D) occurs iff

$$t \leq \left\{ \frac{e_a s_b}{\phi_b(D, A) - s_b} - e_b \right\} = t_1(e_a)\,;\ t_1' > 0. \tag{6}$$

The challengers will block mutual attack (A, A) by choosing t_2 the maximum differentiation which does not provoke attack by incumbent;

$$\underset{\{t\}}{Max} \qquad \phi_b\left(D,A\right)P_b\left(D,A\right)V = \phi_b\left(D,A\right)\frac{t+e_b}{t+e_b+e_a}V$$

$$subject\ to \qquad \phi_a\left(D,A\right)P_a\left(D,A\right) \geq \phi_a\left(A,A\right)P_a(A,A)$$

Since the challengers payoffs increase with t, they will choose the maximum possible differentiation, $t = t_2(e_a)$, which makes the incumbent's constraint bind:

$$\phi_a\left(D,A\right)P_a\left(D,A\right) = \phi_a\left(A,A\right)P_a(A,A).$$

This implies:

$$t_2(e_a) = \frac{\phi_a\left(D,A\right)\left(e_a+e_b\right)e_a - \phi_a\left(A,A\right)e_a\left(e_b+e_a\right)}{\phi_a\left(A,A\right)e_a}. \tag{7}$$

Given this, for (D,A) to be an equilibrium, requires that

$$\phi_b\left(A,A\right)P_b\left(A,A\right) < \phi_b\left(D,A\right)P_b\left(D,A\right)$$

for $t_2(e_a)$, otherwise, it would pay the challengers to force the (A,A) equilibrium. This holds since $\phi_b\left(A,A\right) < \phi_b\left(D,A\right)$ by assumption (c). Increases in the incumbent's effort have positive impact of the challenger's differentiation, given assumption (b) $\phi_a\left(D,A\right) > \phi_a\left(A,A\right)$:

$$\frac{dt_2(e_a)}{de_a} = \frac{\phi_a\left(D,A\right) - \phi_a\left(A,A\right)}{\phi_a\left(A,A\right)} > 0.$$

Our findings can be summarized in the following proposition:

Proposition 1. *There are two candidates for unique Pure Strategy Nash Equilibrium in the conflict game:* (D,D) *and* (D,A)*. Given* e_a*, the challengers can induce* (D,D) *by choosing* $t < t_1(e_a)$*. If* $t_2(e_a) > t_1(e_a)$*, the challengers will induce* (D,A) *and will block* (A,A)*.*

4.2 Stage 1: Incumbent chooses Effort

4.2.1 Incumbent effort that implements (D,D) as the unique Pure Strategy Nash Equilibrium in stage 3.

Through its choice of effort, the incumbent determines which of the two remaining candidates, (D,D) and (D,A), emerges as the unique equilibrium in stage 3.

As before, conflict-preventing effort by the incumbent must ensure that the challenger is better off not attacking:

$$s_b \geq \phi_b(D,A)\, P_b(D,A).$$

Let $e_a^{(D,D)}$ be the lowest level of effort that implements equilibrium (D,D). This is the lowest level of effort that makes $t_1 = t_2$,which from equations (6) and (7) happens iff

$$e_a^{(D,D)} = \frac{e_b \phi_a(D,A)(\phi_b(D,A) - s_b)}{\phi_b(D,A)\phi_a(A,A) - (\phi_b(D,A) - s_b)\,\phi_a(D,A)}. \tag{8}$$

Conflict-preventing effort is a positive function of challenger effort:

$$\frac{de_a^{(D,D)}}{de_b} = \frac{\phi_a(D,A)(\phi_b(D,A) - s_b)}{\phi_b(D,A)\phi_a(A,A) - (\phi_b(D,A) - s_b)\,\phi_a(D,A)} > 0$$

as long as $e_a^{(D,D)} > 0$. An increase in challenger effort e_b increases their probability of winning and increases the incumbent effort necessary to deter them. Similarly, an increase in the challengers peacetime share reduces the incumbent effort necessary to deter them:

$$\frac{de_a^{(D,D)}}{ds_b} = \frac{-e_b \phi_a(D,A)\,\phi_b(D,A)\phi_a(A,A)}{(\phi_b(D,A)\phi_a(A,A) - (\phi_b(D,A) - s_b)\,\phi_a(D,A))^2} < 0.$$

Unlike the no-differentiation case, it will not always be feasible for the incumbent to deter the challengers and ensure peace. Although the incumbent's effort has a direct negative impact on the challengers' probability of winning, it also has an indirect positive effect through its impact on the degree of differentiation that they would choose in a defensive conflict (D,A).

The conflict-preventing incumbent effort needs to ensure that the challengers prefer peace

$$s_b \geq \phi_b(D,A)\frac{t_2 + e_b}{t_2 + e_b + e_a},$$

substituting t_2, this can be rewritten as

$$s_b \geq \phi_b(D,A)\left[1 - \frac{e_a \phi_a(A,A)}{(e_a + e_b)\,\phi_a(D,A)}\right].$$

For peace to be feasible, given assumption (d) $s_b < \phi_b(D,A)$, we need

$$s_b \geq \phi_b(D,A)\frac{\phi_a(D,A) - \phi_a(A,A)}{\phi_a(D,A)},$$

which also ensures a positive incumbent peacetime effort $e_a^{(D,D)}$. If the incumbent thought mutual attack very destructive, $\phi_a(A,A)$ was very small, the above inequality might not hold. An increase in incumbent effort would encourage differentiation, since it is less difficult for the challengers to block mutual attack (A,A), making attacking a defending incumbent (D,A) relatively more attractive. Peace becomes more likely, if (i) the challengers perceive their attack as destroying more of the prize (a smaller $\phi_b(D,A)$), or (ii) challengers get a higher peacetime share s_b or (ii) the incumbent perceives a small difference between the costs of mutual attack and defending against challenger attack, (small $\phi_a(D,A) - \phi_a(A,A)$). Each of these decrease the challengers' incentive to choose attack relative to peace.

$$\begin{aligned}
e_a^{(D,D,t=0)} &< e_a^{(D,D)} \iff \\
\frac{e_b\left(\phi_b(D,A)-s_b\right)}{s_b} &< \frac{e_b\phi_a(D,A)\left(\phi_b(D,A)-s_b\right)}{\phi_b(D,A)\phi_a(A,A)-\left(\phi_b(D,A)-s_b\right)\phi_a(D,A)} \iff \\
\phi_b(D,A)\left(\phi_a(A,A)-\phi_a(D,A)\right) &< 0.
\end{aligned}$$

This means that if with differentiation, the incumbent can set effort to implement peace, this level of effort will be larger than the level required to implement peace in the no-differentiation case. This is because the challengers have more incentive to attack when they can differentiate, therefore the incumbent has to expend more effort to deter attack.

4.2.2 Incumbent effort that implements (D,A) as the unique Pure Strategy Nash Equilibrium in stage 3

Let $e_a^{(D,A)}$ be effort that the incumbent would make if it wanted to implement a defensive conflict (D,A). It would choose this effort to maximise its utility in a defensive conflict

$$\underset{\{e_a\}}{Max} \qquad EU_a(D,A) = \phi_a(D,A)\, P_a(D,A)\, V - C(e_a),$$

substituting for $P_a(D,A)$ we get

$$\underset{\{e_a\}}{Max} \qquad EU_a = \phi_a(D,A)\frac{e_a}{t_2(e_a)+e_b+e_a}V - C(e_a).$$

with First Order Condition:

$$\frac{dEU_a}{de_a} = \phi_a(D,A)\, V \left(\frac{t_2(e_a)+e_b}{(t_2(e_a)+e_b+e_a)^2} + \frac{-e_a \frac{dt_2(e_a)}{de_a}}{(t_2(e_a)+e_b+e_a)^2} \right) - \frac{dC(e_a)}{de_a} = 0.$$

Therefore, since $\frac{dt_2(e_a)}{de_a} > 0$, the fact that the incumbent is forward looking reduces the amount of effort required to implement (D, A).

Substituting for $t_2(e_a)$ in the expected utility equation, we get:

$$EU_a(D,A) = V \frac{\phi_a(A,A)\, e_a}{(e_a+e_b)} - C(e_a).$$

This is equal to the incumbent's expected utility if (A, A) was the equilibrium. This is because the incumbent knows that in the next stage the challengers will chose the degree of differentiation that just makes the incumbent prefer (D, A) to (A, A).

The first order condition which implicitly defines the optimal level of conflict effort in the presence of differentiation $e_a^{(D,A)}$ is

$$\frac{dEU_a(D,A)}{de_a} = V \frac{\phi_a(A,A)\, e_b}{(e_a+e_b)^2} - \frac{dC(e_a)}{de_a} = 0. \quad (9)$$

This implies that with differentiation, the effectiveness of effort in conflict is reduced, military expenditure provides less security, so the incumbent spends less on it.

Proposition 2. *If the incumbent prefers (D, A), when the challengers can differentiate, the outcome is a lower level of effort by the incumbent than in the absence of differentiation, as long as assumption (b) holds: $\phi_a(D,A) > \phi_a(A,A)$.*

Proof

With no differentiation, the first order condition for incumbent effort was:

$$\frac{dEU_a(D,A)}{de_a} = V \frac{\phi_a(D,A)\, e_b}{(e_b+e_a)^2} - \frac{dC(e_a)}{de_a} = 0.$$

Therefore optimal effort of the incumbent when it chooses (D, A) is lower than in the no-differentiation case if $\phi_a(A,A) < \phi_a(D,A)$,which holds by assumption (b)□

4.2.3 The incumbent's decision to induce (D, D) or (D, A)

The incumbent will induce peace if it gives greater expected utility than defending against attack, (D, D), iff $EU_a\left(e_a^{(D,D)}\right) > EU_a\left(e_a^{(D,A)}\right)$. They will not choose to attack because the challengers block it by choosing t_2, which makes the incumbent prefer (D, A).

If preparing for war requires more effort than maintaining peace, $e_a^{(D,A)} > e_a^{(D,D)}$ and for a given effort, the incumbent prefers peace to defending against attack, peace will be implemented and the challengers will be indifferent between any level of technological differentiation that ensures (D, D). In the reverse case, preparing for war requires less effort than maintaining peace[5], $e_a^{(D,A)} < e_a^{(D,D)}$. In this case, if

$$\begin{aligned} EU_a\left(e_a^{(D,A)}\right) &> EU_a\left(e_a^{(D,D)}\right) \Leftrightarrow \\ \phi_a\left(D,A\right)\frac{e_a^{(D,A)}}{t_2(e_a^{(D,A)}) + e_b + e_a^{(D,A)}}V - C\left(e_a^{(D,A)}\right) &> s_aV - C\left(e_a^{(D,D)}\right), \end{aligned}$$

then (D, A) will be the equilibrium. Note that, since costs are increasing in effort, the above condition requires that $e_a^{(D,A)} < e_a^{(D,D)}$ as a necessary, albeit not sufficient, condition.

Comparing our results in this section with the benchmark, no differentiation case, gives

Proposition 3. *A decision by the incumbent to induce* (D, D)*, that is, to prevent conflict, will become less likely, or possibly not feasible, if differentiation by the challenger is a possibility.*

Start from peace in the no-differentiation case. Then with differentiation, it takes the incumbent more effort to deter the challengers, persuade them not to attack. This makes peace less attractive: $e_a^{(D,D,t=0)} < e_a^{(D,D)}$. Differentiation also reduces the incumbent's incentive to cut effort to just above the level that would provoke mutual attack (A, A) and therefore, $e_a^{(D,A)} < e_a^{(D,A,t=0)}$. The necessary condition for the incumbent to prefer conflict, $e_a^{(D,A)} < e_a^{(D,D)}$ is more likely when differentiation is possible. In addition, with differentiation peace may not be feasible: no level of incumbent effort can induce (D, D). Figure 1 represents this situation. The top part shows the challengers payoffs as a function of incumbent effort, with and without differentiation. It shows how the optimal conflict-preventing effort with differentiation will always be higher than without. Without

[5]Note that $e_a^{(D,A)} < e_a^{(D,D)}$ implies that $t_2\left(e_a^{(D,A)}\right) > t_1\left(e_a^{(D,A)}\right)$ since otherwise, by the definition of $e_a^{(D,D)}$(lowest level of effort that ensures $t_2 = t_1$), we would have a contradiction.

differentiation there is always some effort that will induce peace. With differentiation the challengers payoff may not intersect the peace payoff line, however large the incumbent's effort. The bottom figure represents the incumbent's conflict payoff functions with and without the possibility of differentiation. It can be clearly seen that the optimal defensive conflict effort with differentiation, $e_a^{(D,A)}$ will be lower than optimal effort without differentiation, $e_a^{(D,A,t=0)}$ and will result in a lower equilibrium conflict payoff. Which one is implemented by the incumbent will depend on the incumbent's expected utility comparison, which will depend on its pay-off in (D, D) not shown in the figure.

If the incumbent had decided not to implement peace in the no differentiation case, the impact of differentiation on the possibility of peace becomes ambiguous. It would still be negative as long as the cost of effort is sufficiently high. Also note that a necessary condition for conflict to be preferred in the no differentiation case is that optimal conflict effort is lower than conflict-preventing effort. The introduction of differentiation will not reverse this condition, so conflict remains a possible choice.

5 The game with fixed costs of differentiation

In the previous two sections, we analyzed the cases with and without differentiation. This section integrates the two by introducing a fixed cost of differentiation. We assume there is a cost F of choosing to differentiate (this is like set-up costs in location models). For high F challengers do not differentiate, giving the model of section 3; for low F they differentiate giving the model of section 4. At the switch point there is a discontinuity in the incumbents payoffs. We now proceed to solve the game backwards using the results from previous sections.

The last stage of the game remains the same as before, since by then F is sunk and differentiation, if any, is a given parameter. In the second stage of the game, the challengers chooses the degree of differentiation t. In previous sections, we obtained the optimal degree of differentiation, should the challengers decide to differentiate t_2. Now, if fixed costs are sufficiently high, the challengers might decide not to differentiate, even if they expect to attack (D, A) in stage 3. The payoff from differentiating is higher than that of not differentiating (for a given level of the incumbent's effort) if:

$$V\phi_b\left(D,A\right)\,P_b\left(D,A\right)|_{t=t_2} > V\phi_b\left(D,A\right)\,P_b\left(D,A\right)|_{t=0}\,.$$

Therefore, to persuade the challengers not to differentiate (even when expecting a (D,A) equilibrium in stage3), fixed costs F, need to be bigger than F^*:

$$\begin{aligned}
F^* &= V\phi_b\left(D,A\right)\,P_b\left(D,A\right)|_{t=t_2} - V\phi_b\left(D,A\right)\,P_b\left(D,A\right)|_{t=0} \\
&= V\phi_b(D,A)\left(\frac{(t_2+e_b)}{t_2+e_b+e_a} - \frac{e_b}{e_b+e_a}\right) \\
&= \frac{V\phi_b(D,A)e_a}{(e_a+e_b)}\frac{\phi_a\left(D,A\right)-\phi_a\left(A,A\right)}{\phi_a\left(D,A\right)}.
\end{aligned}$$

An increase in the incumbent's effort e_a, will increase F^*,

$$\frac{\partial F^*}{\partial e_a} = \frac{e_b}{\left(e_a+e_b\right)^2}V\phi_b(D,A)\frac{\phi_a\left(D,A\right)-\phi_a\left(A,A\right)}{\phi_a\left(D,A\right)} > 0.$$

In order to ensure that the challengers prefer peace (D,D), incumbent effort must ensure that the challengers have no incentive to attack when the incumbent defends. This will have to be ensured both with and without differentiation. The peace condition is:

$$Vs_b \geq \max\left\{V\phi_b\left(D,A\right)\,P_b\left(D,A\right)|_{t=t_2} - F, \qquad V\phi_b\left(D,A\right)\,P_b\left(D,A\right)|_{t=0}\right\}.$$

The payoff for the challengers, if they do not attack, needs to be higher than the maximum of the challengers' payoffs when they attack, whether or not they differentiate in stage 2[6].

Since

$$t_2 = \left(e_a+e_b\right)\frac{\phi_a\left(D,A\right)-\phi_a\left(A,A\right)}{\phi_a\left(A,A\right)},$$

the peace condition can be written as:

$$Vs_b \geq \max\left\{V\phi_b(D,A)\frac{\phi_a\left(D,A\right)\left(e_a+e_b\right)-\phi_a\left(A,A\right)e_a}{\phi_a\left(D,A\right)\left(e_a+e_b\right)} - F, \qquad V\phi_b\left(D,A\right)\frac{e_b}{e_b+e_a}\right\}. \tag{10}$$

[6]Note that if $\left[V\phi_b\left(D,A\right)\,P_b\left(D,A\right)|_{t=t_2} - F\right] > \left[V\phi_b\left(D,A\right)\,P_b\left(D,A\right)|_{t=0}\right]$, the challengers will differentiate only if $Vs_b < \left[V\phi_b\left(D,A\right)\,P_b\left(D,A\right)|_{t=t_2} - F\right]$. Otherwise, they will not differentiate and therefore, there will be no conflict, even if $Vs_b < V\phi_b\left(D,A\right)\,P_b\left(D,A\right)|_{t=t_2}$.

The peace condition can be represented graphically[7] once the following two points are considered:

- The difference between the first and second term in (10), the payoffs from differentiating or not differentiating, is zero at $F^* = 0$ (the level where the challengers are indifferent between differentiating or not) and is increasing in the incumbent's effort e_a:

$$\frac{\partial\left(V\phi_b(D,A)\dfrac{\phi_a\left(D,A\right)-\phi_a\left(A,A\right)}{\phi_a\left(D,A\right)}\dfrac{e_a}{\left(e_a+e_b\right)}\right)}{\partial e_a}$$

$$=V\phi_b(D,A)\frac{\phi_a\left(D,A\right)-\phi_a\left(A,A\right)}{\phi_a\left(D,A\right)}\frac{e_b}{\left(e_a+e_b\right)^2}>0.$$

- The first and second term in (10) intersect at the level of the incumbent effort equal to

$$e_a^I=\frac{Fe_b}{V\phi_b\left(D,A\right)\dfrac{\phi_a\left(D,A\right)-\phi_a\left(A,A\right)}{\phi_a\left(D,A\right)}-F}.$$

This is zero for zero fixed cost and increases with F. Note that if

$$F>V\phi_b\left(D,A\right)\frac{\phi_a\left(D,A\right)-\phi_a\left(A,A\right)}{\phi_a\left(D,A\right)},$$

not differentiating would always be better for the challengers[8].

The effort level which makes the challenger indifferent between differentiating or not, e_a^I, is an interesting new parameter in our analysis, which is a result of the introduction of

[7] For the shake of clarity, we will use linear functions to represent terms 1 and 2 of the right hand side of the conflict preventing condition. In reality, they are convex in the incumbent's effort. This does not affect the comparative statics.

[8] Whether the challengers differentiate or not, their expected utility at e_a^I is:

$$V\phi_b\left(D,A\right)\frac{e_b}{e_b+e_a^I}=V\phi_b\left(D,A\right)\frac{e_b}{e_b+\dfrac{Fe_b}{V\phi_b\left(D,A\right)\dfrac{\phi_a\left(D,A\right)-\phi_a\left(A,A\right)}{\phi_a\left(D,A\right)}-F}}$$

$$=\frac{V\phi_b\left(D,A\right)\left[\phi_a\left(D,A\right)-\phi_a\left(A,A\right)\right]-\phi_a\left(D,A\right)F}{\phi_a\left(D,A\right)-\phi_a\left(A,A\right)}.$$

fixed differentiation costs. As long as these costs are positive, $F > 0$ it may be possible for the incumbent to prevent differentiation, even if conflict is chosen or cannot be prevented. This level of effort will also provide a connection with the conflict analysis in previous section as it introduces a discontinuity point in the conflict payoff for the incumbent, which jumps from the differentiation payoff to the nondifferentiation payoff if the incumbent's effort falls bellow e_a^I (see for instance, bottom figure in Figure 3).

Figure 2 provides a graphical representation of the first and second terms of (10), the payoffs from differentiating or not, as a function of the incumbent's effort. It shows the minimum level of incumbent effort to prevent conflict $e_a^{(D,D)}$ for a given peacetime payoff for the challengers Vs_b. It also shows the impact of an increase in the fixed cost from, $F = 0$ to $F = F^*\left(e_a^I\right)$, on the conflict-preventing effort by the incumbent.

To understand the comparative statics, note:

- First, increases in F, starting at $F = 0$, will cause downward shifts to function represented by the first term of the peace condition (10). This will reduce the minimal conflict-preventing effort $e_a^{(D,D)}$, until the shift reaches the intersection between the other two functions: the second term of the of the peace condition and Vs_b. This will happen at effort level e_a^I defined above. This intersection will happen at $F^*\left(e_a^I\right)$, defined by

$$V\phi_b\left(D,A\right)\frac{e_b}{e_b+e_a^I} = Vs_b,$$

where, substituting for e_a^I we get

$$Vs_b = \frac{V\phi_b\left(D,A\right)\left[\phi_a\left(D,A\right)-\phi_a\left(A,A\right)\right]-\phi_a\left(D,A\right)F}{\phi_a\left(D,A\right)-\phi_a\left(A,A\right)} \Longleftrightarrow$$

$$F^*\left(e_a^I\right) = \frac{\left(\phi_a\left(D,A\right)-\phi_a\left(A,A\right)\right)V}{\phi_a\left(D,A\right)}\left[\phi_b\left(D,A\right)-s_b\right].$$

Any increase in F within the $\left[0, F^*\left(e_a^I\right)\right]$ interval will cause the conflict-preventing effort $e_a^{(D,D)}$, to decrease. The conflict-preventing condition in that interval is:

$$Vs_b \geq V\phi_b(D,A)\frac{\phi_a\left(D,A\right)\left(e_a+e_b\right)-\phi_a\left(A,A\right)e_a}{\phi_a\left(D,A\right)\left(e_a+e_b\right)} - F.$$

Therefore, the conflict-preventing effort is[9]

[9] Note that the previous equation is equivalent to:

$$e_a^{(D,D)} = \frac{e_b \phi_a (D,A) (V\phi_b(D,A) - Vs_b - F)}{\phi_b(D,A)\phi_a (A,A) V - (\phi_b(D,A) - s_b) \phi_a (D,A) V + F\phi_a (D,A)}$$

which is clearly decreasing in F.

Note also that at $F = F^* \left(e_a^I\right)$, effort coincides with $e_a^{(D,D,t=0)}$ (obtained above). That is, increases in F decrease the optimal level of conflict-preventing effort until this reaches the level of conflict-preventing effort one would obtain if differentiation was not possible.

- Second, if $F > F^* \left(e_a^I\right)$, the conflict-preventing effort will coincide with the one obtained when differentiation was not possible,

$$e_a^{(D,D,t=0)} = \frac{e_b \left(\phi_b(D,A) - s_b\right)}{s_b}.$$

Increases in F beyond $F^* \left(e_a^I\right)$ will not affect the level of conflict-preventing effort. The following proposition summarizes the above discussion

Proposition 4. *Increases in fixed differentiation costs F will reduce the level of conflict-preventing effort $e_a^{(D,D)}$, until fixed costs reach the level that prevents differentiation F^*.*

We have analyzed the condition on the incumbent's effort that would prevent conflict. Now, we analyze the impact of changes in F on the optimal effort the incumbent would implement should it decide not to prevent conflict. In finding such optimal effort, we must bear in mind that the incumbent's payoff function when (D,A) is preferred is likely to be discontinuous. This is represented in Figures 3 and 4. Both figures represent the incumbent's expected payoff functions when the (D,A) equilibrium is expected for the differentiation and no differentiation cases (already analyzed in previous sections (thinner curves)). However, the relevant expected payoff function is now represented by the thicker

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$$\frac{Vs_b + F}{V\phi_b(D,A)} \phi_a (D,A) (e_a + e_b) - \phi_a (D,A) (e_a + e_b) + \phi_a (A,A) e_a \geq 0,$$

itself equivalent to:

$$e_a \left(\frac{Vs_b + F}{V\phi_b(D,A)} \phi_a (D,A) - \phi_a (D,A) + \phi_a (A,A) \right) + e_b \left(\frac{Vs_b + F}{V\phi_b(D,A)} \phi_a (D,A) - \phi_a (D,A) \right) \geq 0.$$

discontinuous curves. As already discussed, the discontinuity point is the incumbent's level of effort at the point the first and second terms in condition (10) intersect, e_a^I. Higher levels of effort will make the challengers prefer to differentiate and therefore the payoff with differentiation becomes the relevant one. When F is big enough, differentiation will not be observed even if conflict erupts, Figure 3 represents such a situation, which corresponds to our earlier analysis without differentiation.

However, if the fixed cost of effort F is sufficiently low the optimal level of defensive effort $e_a^{(D,A)}$ will not prevent differentiation from taking place, Figure 4 represents this situation. Finally note that starting from a sufficiently high F, decreases in F force a reduction in the optimal defensive effort which will follow e_a^I so as not to induce differentiation. There will be a point though, represented in Figure 5, where attempts to prevent differentiation will stop and effort level will jump up to the optimal differentiation effort level analyzed in previous sections. Further decreases in F will have no impact on the optimal defensive effort $e_a^{(D,A)}$. We can summarize the above as:

Proposition 5. *In the presence of fixed differentiation costs, it may be better for the incumbent to reduce defensive effort in order to discourage differentiation. The choice for the incumbent will be between preventing conflict by deterring attack or defending against an attack without differentiation. However, if differentiation costs are low enough, the choice will be between preventing conflict or defending against an attack with differentiation.*

Finally consider the impact of decreases in F on the chance of peace. Starting from peace, an easier access to alternative technologies (lower F) will increase the likelihood of conflict, as it will increase the chances of the necessary condition for conflict to be satisfied, $e_a^{(D,A)} < e_a^{(D,D)}$. There is one point though at which decreases in F force a upward jump in conflict effort, when the incumbent gives up preventing differentiation. After that, the incumbent's expected payoff is not affected by F, though F continues to affect the peace payoff negatively until $e_a^I = 0$. Also, as previously discussed, peace may not be feasible, below a critical value of F (again, see Figure 1).

The above discussion starts from an initial condition of peace and examines how changing the cost of differentiation affects the probability of peace. A more complete analysis would involve the derivation of the impact of changes in F on the difference between the incumbent's expected conflict and non conflict payoff. Conflict will happen if

$EU_a\left(e_a^{(D,A)}\right) > EU_a\left(e_a^{(D,D)}\right)$. Decreases in F that move the optimal conflict effort from the no differentiation conflict effort to the differentiation conflict effort will tend to decrease the incumbent's expected peace payoff, as well as, peace effort. Figure 5 represents such situation. In this figure, both initial and final (after the decrease in F) optimal conflict efforts are lower than the conflict preventing efforts. We cannot therefore tell with certainty either at the initial or final point whether peace or conflict will prevail; nor can we tell how the change in the cost of differentiation will affect the chances of peace. Therefore, it is in this region that changes in F may actually turn conflict into peace. Still, as long as the cost of effort is sufficiently high, a lower cost of differentiation will make peace less likely even in such a region. Anywhere outside this region the impact of differentiation on peace will be negative and even within that region, if the starting point is peace, differentiation can open up the possibility of conflict because it becomes relatively more expensive for the incumbent to prevent conflict.

6 Conclusion

We have presented a simple model in which the big guy, the incumbent, makes a choice to which it becomes locked in, while the little guys, the challengers, can choose to differentiate their technology, tactics or targets from the incumbent. This allows them to attack the incumbent in ways that it had not prepared for. Although simple, this idea describes a number of interesting commercial, military and legal conflicts. The possibility of differentiation gives the little guys an edge and increases their probability of winning should they attack. Without differentiation the incumbent can always deter the challengers by sufficient effort. With differentiation attack may be inevitable, deterrence may be impossible, whatever the incumbent's investment in efforts like legal fees, sunk costs or military expenditures. In addition, since differentiation reduces the effectiveness of the incumbent's efforts, if conflict comes the incumbent's efforts will be lower with differentiation than without it. The incumbent faces a difficult dilemma, the more effort it invests, the more incentive the challengers have to differentiate. The incumbent can easily push the challengers to adopt more dangerous tactics against the incumbent. However, if the incumbent can increase the fixed costs of differentiation, e.g. through controls on the diffusion of particular technologies, it can make differentiation less likely.

Although the model is very simple, the calculations the contestants are required to make are quite complicated and depend on their ability to evaluate the probabilities and the costs of conflict to their opponent. We have assumed full information, but our results are quite fragile. The optimum effort or differentiation is often a boundary solution; e.g. if the challengers decide to attack, they will set differentiation at just the level where the incumbent is indifferent between defending and attacking. In such cases, small errors of calculation can cause catastrophe for either side. We regard this as a realistic feature of such conflicts: big decisions turn on difficult calculations about the opponents expected payoff and the model brings this out. Once one allows for asymmetric information, issues of signalling become important. A number of papers within the terrorism literature have used models of incomplete information. Lapan and Sandler (1993) and Overgaard (1994) present an attack by a terrorist group as a signal of the terrorist effort. The introduction of such type of asymmetric information in our model could be an interesting future line of research.

We have treated the peacetime shares as exogenous. In many cases, if the incumbent could credibly pre-commit to change the peace-time shares in the challengers favour, it would wish to do so. Doing so would be cheaper than either the effort required to deter the challenger or the cost of conflict. Real conflicts are often protracted because neither side believes the other's promises and it often takes a third party guarantor to resolve the conflict. Such guarantors may be hard to find. Non-military incentives are discussed in more detail by Frey and Luechinger (2003). Our paper suggests that differentiation will increase the need for alternative non military methods to achieve peace. We have treated both the challengers effort and the fixed costs of differentiation as exogenous, they cannot choose an optimal allocation of resources between the two. This could be relaxed.

We imposed a number of assumptions on the cost of conflict, which defined a particular type of game, which we think is quite common. But it would be interesting to relax those assumptions and ask, for instance, under what circumstances would an incumbent want to attack a non-threatening challenger. Our model provides a way to address that question. Essentially, powerful incumbents never feel safe, because they do not know how the little guys will attack them, therefore they may be pre-disposed to take any action that may negate the threat. Our model is of a single conflict, but there could be cycles:

the challengers displace the incumbents, become the new incumbents and are themselves challenged. In our model, the contestants decide to attack or defend simultaneously, we think this is a realistic representation, since in reality neither side can guarantee to get their attack in first, but the sensitivity to this assumption deserves investigation.

References

Abernathy, W. J. (1978) *The Productivity Dilemma: Roadblock to Innovation in the Automobile Industry*, Johns Hokins Press.

Bresnahan, T. F. and Greenstein, S. (1999) Technological competition and the structure of the computer industry, *Journal of Industrial Economics*, **47**, 1, 1-40.

Collier, P. and Hoeffler, A. (1998) On economic causes of civil war, *Oxford Economic Papers*, 50,4, p563-573.

Enders, W. and Sandler, T. (2002) What do we know about the substitution effect in transnational terrorism? MIMEO, University of Southern California.

Frey, Bruno S. and Luechinger, Simon (2003) How to fight terrorism: alternatives to deterrence, *Defence and Peace Economics*, August, 237-250.

Grossman, H. I. (1991) A general equilibrium model of insurrections, *American Economic Review*, **81**, 4, 912-921.

Grossman, H. I. and Kim, M. Swords or plowshares? (1995) A theory of the security claims to property, *Journal of Political Economy,* **103**, 6, 1275-1288.

Hirshleifer, J. (2001) *The Dark Side of the Force, Economic Foundations of Conflict Theory*, Cambridge University Press.

Intriligator, Michael (1975) Strategic considerations in the Richardson model of arms races. *Journal of Political Economy*, **83**, 2, 339-353.

Lapan, H. E. and Sandler, T. (1993) Terrorism and signalling. *European Journal of Political Economy*, **9**, 3, 383-397.

Leibowitz, S.J. and Margolis, S.E. (1999) *Winners, Losers & Microsoft*, The Independent Institute, Oakland CA.

Newman, N.J. (2000) *Asymmetric threats to British Military Intervention Operations*, Whitehall Paper 49, Royal United Services Institute.

Overgaard, P. B. (1994) Terrorist attacks as a signal of resources. *Journal of Conflict Resolution*, **38**, 3, 452-478.

Rotte, R. and Schmidt, C. M. (2003) On the production of victory: empirical determinants of battlefield success in modern war, *Defence and Peace Economics*, 14, 3, 175-193.

Sandler, T. and Arce, M. D. G. (2003) Terrorism and game theory. MIMEO, University of Southern California.

Sandler, Todd and Enders, Walter (2002) An economic perspective on transnational terrorism, MIMEO, University of Southern California, Los Angeles.

Siqueira, K. (2002) Conflict and third party intervention. MIMEO, Clarkson University, New York.

Sutton, J. (2001) *Technology and Market Structure: Theory and Market History.* The MIT Press.

Trajtenberg, M. (2003) Defense R&D policy in the antiterrorist era. NBER working paper number 9725.

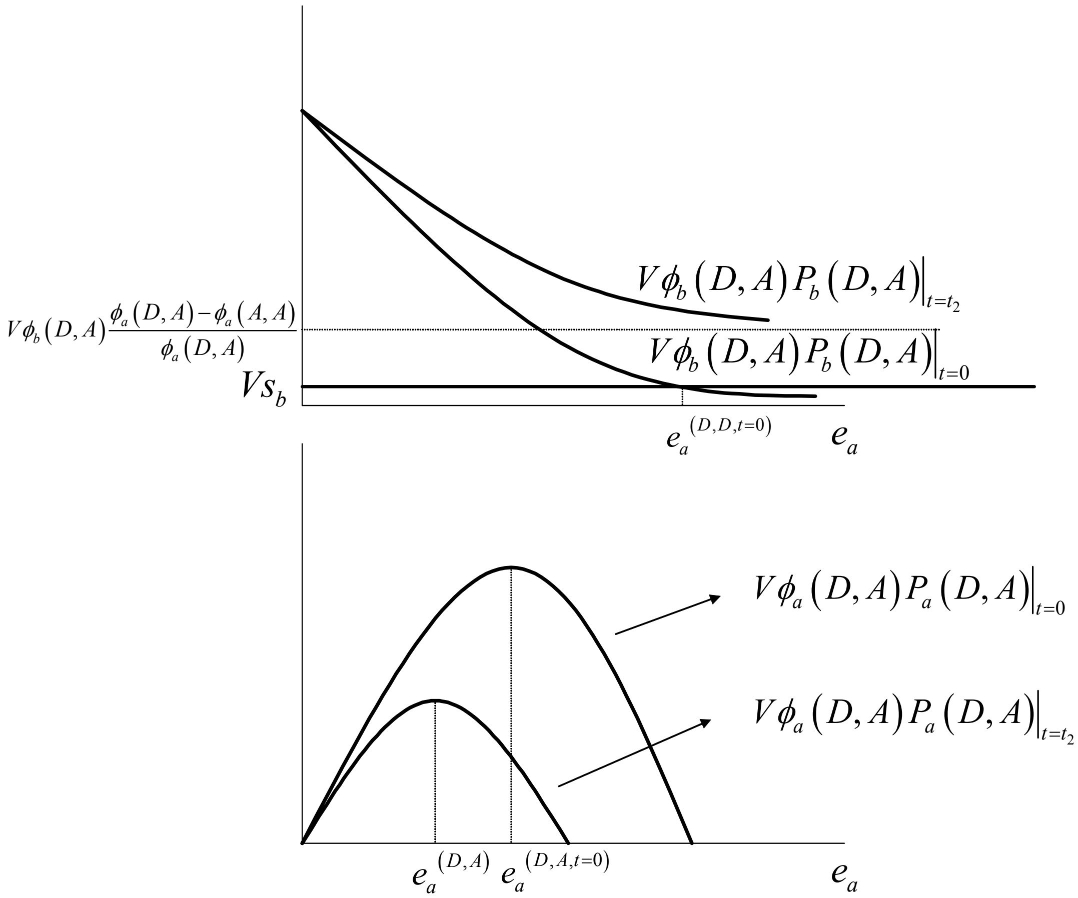

Figure 1: Example of peace becoming unfeasible with differentiation.

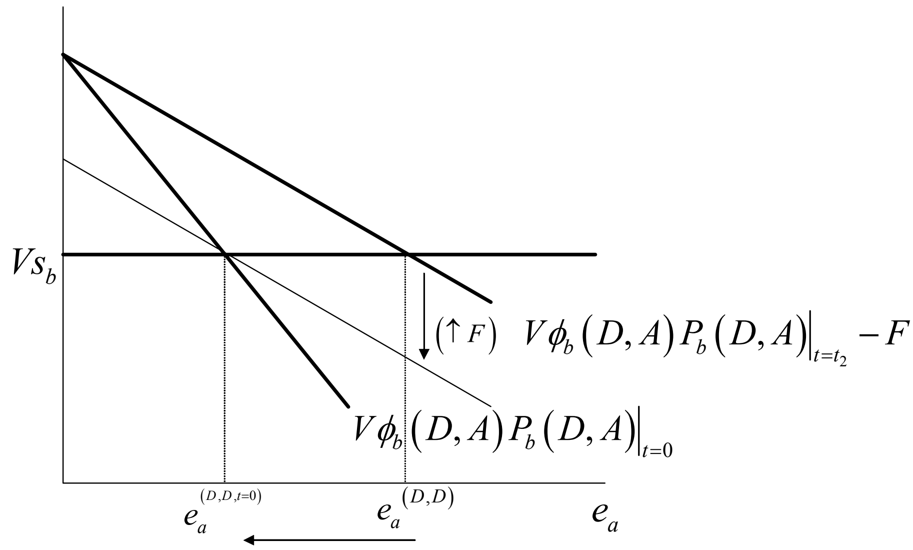

Figure 2: Impact on the conflict preventing level of effort of an increase in fixed costs of differentiation (from $F = 0$ to $F = F^*\left(e_a^I\right)$).

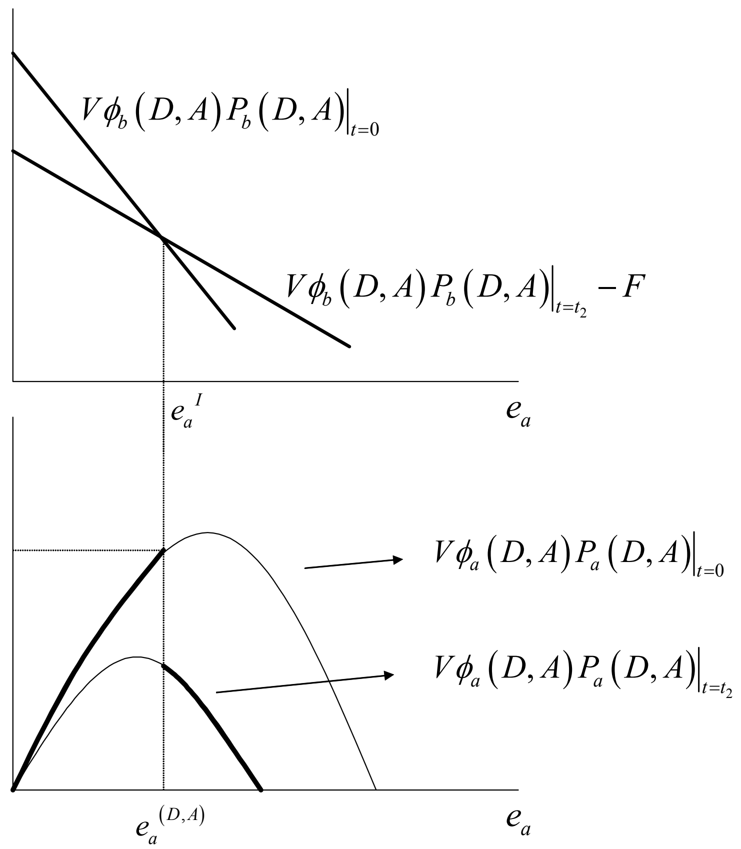

Figure 3: Thicker discontinuous curve represents the expected payoff for the incumbent for high F if defensive conflict is expected.

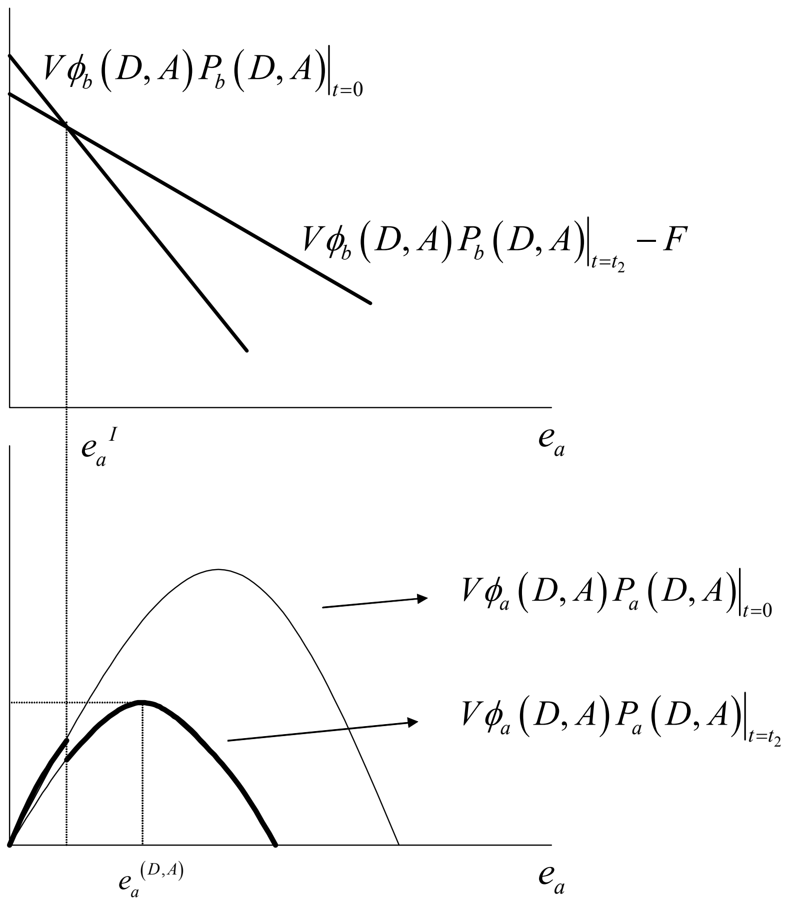

Figure 4: Thicker discontinuous curve represents the expected payoff for the incumbent for low F if defensive conflict is expected.

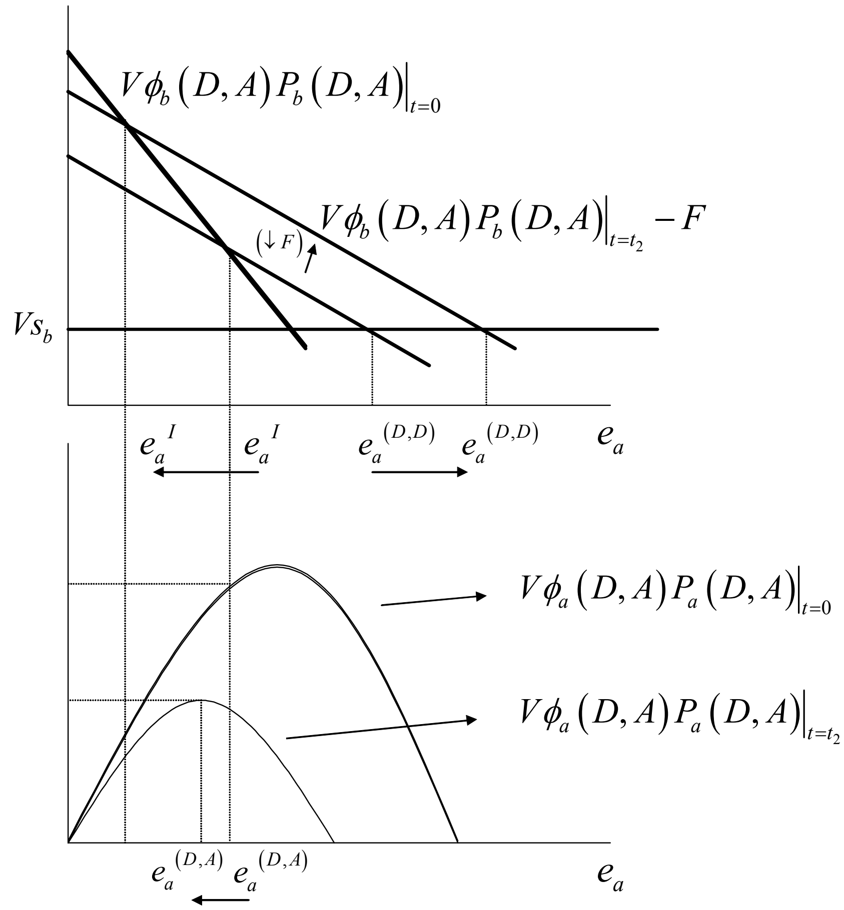

Figure 5: Impact on $e_a^{(D,A)}$ and $e_a^{(D,D)}$ of a decrease in F.