THE TECHNOLOGY OF CONFLICT AS AN ECONOMIC ACTIVITY

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Abstract

Engaging in conflict, defined broadly to include non-violent actions like strikes and lawsuits as well as actual combat, is always an option for individuals and groups. Many stylized facts of political economy are explained by the competition between the technology of conflict and the technology of production and exchange. The Contest Success Function (CSF), which indicates how the resources respectively devoted to conflict yield outcomes in the form of losses and gains to the two sides, should incorporate ranges of increasing and decreasing returns. It should also be consistent with both one-sided peace (subjugation) and two-sided peace (settlement) outcomes. There are two canonical forms of the CSF, in which the outcome becomes a function of the ratio or alternatively of the difference of the fighting efforts. The technology can be parametrized by indexes that scale, among other things, the decisiveness of the effort disparities and the vulnerabilities of the contestants (the stakes at issue). Organizations exist, in large part, in order to exploit the advantage of numbers in conflict, but a critical-mass problem must be overcome in motivating group members to actually participate in privately costly fighting.

THE TECHNOLOGY OF CONFLICT AS AN ECONOMIC ACTIVITY

People can satisfy their desires by making goods (either for self-use, or for mutually beneficial trade with other parties) or else by taking what they want from someone else. Economists, being such nice people, have concentrated almost exclusively upon the first way of living -- peaceful production and exchange. Only very recently has an economics of struggle and conflict begun to emerge.[1] However, even this recent literature has paid little attention to the actual technology of conflict.

There is a technology of production, there is a technology of exchange, and there is a technology of conflict. Even as regards the technology of production, economic analysis has been surprisingly sparse. Adam Smith thought it worthwhile to open The Wealth of Nations with a discussion of the division of labor in pin manufacture, but current textbooks rarely even mention important technological issues such as the merits of batch production versus continuous operation, the theoretical and practical limits of fuel efficiency, sequencing and layout of factory operations, or the trade-off between reliability and redundancy in product design. The few aspects of the technology of production that are regularly addressed by modern economists include returns to scale or scope, and factor substitutability or complementarity -- topics that have received attention, perhaps, because of possible implications for anti-trust and related policy issues in the one case, and for growth theory and the functional distribution of income in the other. Even less heed, probably, has been paid to the technology of exchange. Failure to consider such matters is particularly surprising in view of the wide recognition that the technologies of production and of exchange compete, in a sense, in establishing the boundaries of the firm.[2]

Turning now to the technology of conflict, there is an "operations research" literature covering what might be called the industrial engineering of combat. The classic work of Morse and Kimball [1951] summarizes investigations of questions such as the vulnerability of submarines to depth bombs, the effectiveness of anti-aircraft guns placed on

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[1] I shall cite here only three pioneering works: Boulding [1962], Schelling [1960], and Tullock [1974].

[2] See, for example, Coase [1937] and Stigler [1951].

merchant ships, and the trade-off between training air crews versus actual mission time. I will be limiting attention here to the macro-technology of conflict: how generalized resources devoted to struggle generate outputs in the form of gains and losses to each side.

First, some points of terminology. I will be interpreting "conflict" broadly to cover not only war but strikes and lockouts, lawsuits, strife within families, and redistributive politics. However, military combat will serve as metaphor even for these ordinarily non-violent contests. Second, the word "technology" is employed here to represent an opportunity set as constrained possibly by societal rules as well as by the physical laws of Nature. To illustrate, trial by combat, as a method of determining who has the juster cause, has been replaced by trial by litigation. (A ghastly mistake, as it has turned out, but I can't go into that here.) My point is that a technology of lawbooks and logic-chopping has replaced a technology of swords and head-chopping. In either case, what can be achieved by conflict is socially modulated. Just as certain weapons and tactics were disallowed in trial by combat, so the modern champion at law is expected to lie and obfuscate, but only in certain permitted ways.

"War is the father of all things," said Heraclitus. And more specifically, the economic analysis of conflict can be applied to an enormous range of issues, including the existence of large and small nations, the distribution of power among social classes, the viability of two-party versus multi-party political systems, strikes and lockouts in industry, sibling rivalry, why there are more lawsuits nowadays, and who wins in the battle of the sexes.

The problems addressed can be grouped under four headings:

Peace or war: When (and to what extent) do competitors choose to engage in struggle rather than in peaceful production and mutually beneficial exchange?

The outcome of conflict: Who wins and who loses?

Viability and numbers: How many competitors remain viable in a conflict environment?

Grouping and association: In what ways does conflict affect the structure of collectivities and the motives for organizing them?

What I offer today are only some preliminary ideas, focusing upon how the

outcomes of social interactions are constrained by the technology of conflict.

I begin with some "stylized facts":

(1) "Cookie-cutter geography": the land area of the globe is rather sharply divided into territorial states, each one of which has normally effective control within its specific region.

(2) In battle preponderance of numbers has a disproportionately large effect, within certain limits at least. Evidently, this has to do with ranges of increasing and decreasing returns, as will be analyzed below.

(3) Related to the foregoing, battles normally have definite winning and losing sides. Wars, in contrast, often terminate inconclusively.

(4) We do sometimes observe peace. Also, roughly speaking, there are two types of peace: balanced settlement versus subjugation.

(5) What is perhaps surprising, in conflict interactions the poorer-endowed side often gains at the expense of the richer party. Consider redistributive politics: the ex-post distribution of income in modern societies, as processed through the political struggle, is much more equal than the ex-ante distribution. Much the same holds for crime. Or an example from ancient times: property-less nomadic tribes specializing in violence commonly levied tribute upon more affluent cities and empires.

(6) Superior military organization can often make up for deficiencies in numbers.

COOKIE-CUTTER GEOGRAPHY -- THE TERRITORIAL MODEL

Modelling of conflict can be said to begin with Lanchester [1916].[3] He distinguished between "ancient" and "modern" conditions, that is, conditions before and after the invention of missile weapons like arrows and bullets.

In the "ancient" case, letting F_1 and F_2 be the larger and smaller force sizes at any moment, and e represent the relative fighting effectiveness ratio or "exchange rate" dF_2/dF_1, the attrition rates of the two forces can be represented by:[4]

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[3] Samz [1970] surveys a number of precursors of Lanchester.

[4] I follow here the adaptation of the Lanchester models in Morse and Kimball [1951], Chapter 4.

(1) $dF_1/dt = -1/(1 + e)$ and $dF_2/dt = -e/(1 + e)$

If side #1's soldiers are twice as effective as #2's (e = 2), then in each time-period, on average side #1 loses 1/3 of a man and side #2 loses 2/3 of a man in each one-on-one duel.

In the "modern" case, the equations become:

(2) $dF_1/dt = -F_2/(1 + e)$ and $dF_2/dt = -F_1e/(1 + e)$

Under "modern" conditions numbers operate more powerfully. Instead of one-on-one engagements, now every fighter can bring his weapon to bear upon the enemy.

Solving the differential equations indicates that under "ancient" conditions strength varies linearly with numbers, under "modern" conditions with the square of numbers.[5] In either case the initially stronger force (weighting the force ratio F_1/F_2 by the effectiveness ratio e) inevitably grows stronger still. So, as illustrated in Figure 1, the weaker side's force always declines more rapidly, at least in relative terms, toward zero.

[FIGURE 1 HERE]

The first stylized fact above, the territorial division of the world's land area among nation-states, can be explained by conjoining Lanchester's analysis with diminishing returns due to distance.[6] Figure 2 represents two nations with respective resources (measured, say, by manpower) R_1 and R_2, whose capitals or home bases are separated by a linear distance S. The border between the nations is determined by the condition of equal fighting strengths $F_1 = F_2$. In order to project military force to any distance s_i from the home base, each side i has to split its manpower between fighting forces F_i and logistic or support forces L_i. Since the support manpower

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[5]Many other variants are of course possible. Another version, also suggested in Lanchester's original work, allows for the casualty-reducing effects of dispersal so that:

$$dF_1/dt = -F_2/[F_1(1 + e)] \quad \text{and} \quad dF_2/dt = -F_1e/[F_2(1 + e)]$$

A full analysis appears in the unpublished Ph. D. dissertation of Samz [1970], which also provides a valuable intellectual history of theories of combat.

[6]See Boulding [1988, Appendix to Ch. 12].

along the supply line needs to be supported logistically itself, there is a compounding effect making the achievable fighting force fall off sharply with distance. We can formalize this by defining a logistical effectiveness factor $0 \leq \lambda_i \leq 1$, where $\lambda_i'(s_i)$, $\lambda_i''(s_i) < 0$. That is, logistical effectiveness falls off with distance at an increasing rate. Thus:

(3a) $\quad F_i = R_i \, \lambda_i(s_i)$, for $i = 1,2$

(3b) $\quad F_1(s_1) = F_2(s_2)$, where $s_1 + s_2 = S$ (condition of equilibrium)

So, as shown in Figure 2, diminishing returns due to logistic support considerations combine with increasing returns to fighting forces proper so as to establish sharp boundaries between nation-states.

[FIGURE 2 HERE]

As a straightforward implication, larger resources R_i and/or greater ability to project those forces (higher λ_i) lead to bigger territories. What is somewhat less obvious, the division of territory will be a function of the absolute difference between the resource endowments R_1 and R_2. Thus, if the resources on each side were both to increase by the <u>same absolute amount</u>, there would be no change in the division of territory. But if they increased by the <u>same proportion</u>, the initially better-endowed side would end up with more territory than before. And in fact, the poorer-endowed side may become non-viable -- its strength even at its home base may be overmatched by the force the enemy can deliver. The implication is that growing wealth over time implies a trend toward fewer and larger states.

Within the cookie-cutter framework, many extensions and variations are possible:

(1) If the territory to be divided is an area rather than a linear distance, forces would have to maintained along a perimeter whose length is a multiple of the radius s_i. This consideration makes diminishing returns operate more powerfully than in the simple linear model. (2) The logistic effectiveness factor will evidently be more favorable along easy transport routes such as rivers or land valleys, and less favorable in difficult terrain like deserts or mountains. That is why empires have typically extended their power along easy transport routes (ancient Egypt along the Nile, Rome around the Mediterranean, early modern Britain along oceanic

trade routes). Conversely, we would expect a certain tendency for national frontiers to lie along mountain ranges or deserts. Difficult terrain helps explain why a smaller state like Switzerland was able to remain independent despite more powerful neighbors. (3) A countervailing force, cutting against diminishing returns due to distance, is the possibility of drawing resources from the controlled areas themselves. Evidently, this factor makes large empires more likely. The prospect of such provincial support was a major consideration in determining the intended boundaries of the Roman Empire.[7] The extension of British sway in North America would similarly have been impossible without utilizing the resources of the colonies themselves.

Two further comments on this geographical model: (i) Ability to project military strength over distance is of course not the sole determinant of the boundaries of nation-states. Many other factors, economic, linguistic, cultural and administrative, are involved.[8] (ii) Even for non-military struggles, territorial conflict can sometimes serve as a useful metaphor. One example might be a political contest between left and right parties competing for the support of an intermediate spectrum of voters.[9]

NON-TERRITORIAL MODELS

The territorial model of conflict postulates an extreme version of increasing returns in battle, the larger always totally overwhelming the smaller force, subject to diminishing returns in projecting power over distance. But the territorial model is not always applicable, even metaphorically. "Home bases" and "distance" have no clear interpretation in lawsuits, industrial struggles between capital and labor, or political pressure-group competition between manufacturing and agricultural interests.

Even in the absence of literal or metaphorical "distance" as source of diminishing returns, it is possible to obtain interior solutions in conflict

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[7] On the other hand, reliance upon the provincials affected the internal politics of the Empire. In consequence, it sometimes became necessary to defend territories that might more advisedly, from a central point of view, have been abandoned (Luttwak [1976]).

[8] See, for example, Friedman [1977].

[9] Compare the duopoly locational model of Hotelling [1929].

interactions provided that the marginal costs of fighting effort are rising (see below). However, as stylized fact #2 suggests, ranges of increasing and decreasing returns are an important aspect of the technology of battle.

In Figure 3 the horizontal axis represents side #1's force F_1, where by assumption the opposing force is fixed at $F_2 = 1$. (For simplicity, the exchange rate e is assumed equal to unity.) On the vertical axis is plotted p_1, the proportionate degree of success in terms of some prize such as wealth or income. Since the two sides have directly opposing goals, $p_2 = 1 - p_1$. (Thus p_1 and p_2 might alternatively be interpreted as the respective probabilities of winning.) The question at issue then is the shape of what may be called the Conflict Success Function (CSF).[10]

[FIGURE 3 HERE]

In the strict Lanchester model the CSF is the heavy dashed line: $p_1 = 0$ so long as F_1 is less than F_2, and immediately jumps to $p_1 = 1$ when F_1 exceeds F_2. In other words, whichever side has the smaller force loses everything. This can be regarded as a limiting instance of the generalized solid curve in the diagram, which is in fact more consistent with military experience.[11] That is, the marginal product of larger fighting forces is positive throughout, but is highest for the infinitesimal increment that shifts a side from numerical inferiority to numerical superiority. Or, put another way, we would expect increasing marginal returns to force size until equality is attained, and decreasing marginal returns thereafter.

Economists' attempts to model the conflict interaction in such terms begin with Tullock [1980], who addressed the problem in a rent-seeking context. Specifically, Tullock proposed that rent-seeking success depends upon the ratio of the fighting efforts:

$$(3) \qquad p_1/p_2 = (F_1/F_2)^m \quad \text{or equivalently} \quad p_1 = \frac{F_1^m}{F_1^m + F_2^m}$$

Here the "mass effect parameter" m reflects the decisiveness of effort disparities in determining the outcome of conflict. Figure 4a shows the CSF

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[10] Hirshleifer [1989].

[11] See, for example, Dupuy [1987].

in this formulation, for several values of m.

[FIGURE 4 HERE]

While appealing on grounds of tractability, the ratio version of the CSF does not fully square with the second stylized fact, as concerns the range of increasing returns. In fact, as shown in Figure 4a, for $m \leq 1$ there is no range of increasing returns at all. For $m > 1$ there is indeed an early range of increasing returns, but it terminates too soon -- before equality is attained at $F_1 = 1$.[12]

An attractive alternative functional form for the CSF is the logistic function[13] illustrated in Figure 4b:

$$(4) \qquad p_1/p_2 = \frac{\exp(kF_1)}{\exp(kF_1)+\exp(kF_2)} \quad \text{or} \quad p_1 = \frac{1}{1+\exp(k(F_2 - F_1))}$$

Here k serves as the mass effect parameter scaling the decisiveness of fighting effort disparities. Underlying this functional form is the premise that not the <u>ratio</u> but rather the numerical <u>difference</u> between the fighting efforts determines conflict success. Note also that, for the ratio form, p_1 is necessarily zero when $F_1 = 0$. For the logistic function, in contrast, p_1 remains positive even when zero fighting effort is invested.[14]

A possible interpretation is that the ratio form applies under "ideal" conditions such as an undifferentiated battlefield, full information, and unflagging weapons effectiveness. Then indeed, a side unable or unwilling to fight must lose everything. But where what Clausewitz called "friction" plays a role -- if there are sanctuaries and refuges, if information is imperfect, or where fatigue limits what a victor can do -- something can be

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[12]The inflection point approaches $F_1 = F_2$ as the mass effect parameter goes to infinity.

[13]Proposed in Hirshleifer [1988, 1989].

[14]A difference version of the CSF has been used, implicitly, by a number of authors including Bush and Mayer [1974], Skogh and Stuart [1982], and Garfinkel [1990]. These analysts generally postulate constant returns to fighting effort, or at any rate do not highlight the crucial role played by ranges of increasing returns.

saved while avoiding combat.[15] Battle in the sense of a single engagement typically more closely approximates these "ideal" conditions than does the much more extended and multi-dimensional interaction represented by war, which is of course consistent with the third stylized fact listed above: that wars are more likely to end inconclusively. And with regard to the fourth stylized fact, if the mass effect parameter k is sufficiently small, then the difference model leading to the logistic function is consistent with peace -- a peace either of subjugation (one side finds it optimal to choose zero fighting effort) or else of balanced settlement (both sides find it optimal to do so).[16] Another implication of the difference form, which parallels a result obtained from the territorial model above, is that proportionately growing wealth on the two sides works to the net advantage of the wealthier party. Thus, over time, smaller contenders may become non-viable, or at least become subjugated by larger ones.

This model could be generalized, among other ways, so as to allow for: (i) Differential fighting effectiveness, via an exchange ratio e that in effect makes the mass effect parameter (m or k) diverge for the two sides;[17] (ii) the possibly different technologies of offense versus defense;[18] (iii) damage, as either an intended or unintended consequence of fighting; (iv) the substitutability of capital versus labor in the generation of military power.[19] But I will address a different issue here. To wit, conflict may be more decisive or less, but with regard to what question? Put another way, what are the stakes of the game?

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[15]Such avoidance may be only a temporary maneuver, gaining time in order to gather one's forces for a later decisive battle. The Fabian tactics employed by the Romans against Hannibal are a classic example.

[16]Hirshleifer [1988]. See also Skaperdas [1990].

[17]In a contest between rulers and rebels, for example, the two sides might have very different miliary effectiveness (Grossman [1990]).

[18]For an extension of Lanchester in this direction, see Brackney [1959]. A general review of traditional politico-military thought on the meaning of the offense-defense distinction, and the factors determining the relative dominance of the one or the other in combat, is provided in Levy [1984].

[19]On this see Stockfisch [1976].

In terms of what is at risk, struggles may be total or limited. Pressure-group or rent-seeking competitions in the political domain have limited goals: rivals typically do not intend murder or enslavement but only a redistribution of income. And similarly, labor unions do not generally seek to take over the enterprise but only to gain a larger share of its product.

To set this question in a more general context, suppose that: (a) each side divides its endowed resources R_i between ordinary productive effort E_i and fighting effort F_i; (b) aggregate income I is generated by the two sides' productive efforts; and (c) the respective shares p_i depend upon the fighting efforts. Thus:

$$E_i + F_i = R_i \tag{5a}$$

$$I = \Omega(E_1, E_2) \tag{5b}$$

$$p_1 = \Gamma(F_1, F_2) \tag{5c}$$

where Ω is the aggregate production function reflecting a greater or a smaller degree of complementarity between the productive inputs E_1 and E_2, while Γ symbolizes the Contest Success Function. The implicit assumption here is that all <u>income</u> is contestable, while the underlying <u>resources</u> on each side are invulnerable.

A further limitation upon the scope of conflict can be represented by letting each side's income Y_i be the sum of its "protected income" H_i and a share of the aggregate "contestable income" at stake:

$$Y_i = H_i + p_i I \tag{5d}$$

Protection may be a gift of Nature like England's surrounding seas or Switzerland's mountains, or a product of human engineering like the "long walls" of Athens. Social instruments may also provide protection: policing to prevent illegal seizures of property, or constitutional rules to limit invasions via the political process. By reducing the decisiveness of conflict, such societal constraints make it less profitable to devote resources to divisive internal struggles.

There are interesting implications for a current topical issue: the litigation explosion. From the crowded state of the courts and the lengthy times to decision, it seems evident that legal conflict is no more <u>decisive</u> than it used to be. The explosion has come about because the <u>stakes</u> have

increased. Innovations like the deep-pockets rule, and the removal of obstacles to causes of action like medical malpractice (or the invention of new causes like pastoral or parental malpractice) have raised the expected payoff of conflictual activity.

THE TECHNOLOGY OF CONFLICT VERSUS THE TECHNOLOGY OF PRODUCTION AND EXCHANGE

I alluded earlier to the competition between the technology of production and the technology of exchange. In this section production and exchange are taken as merged, in order to underline the competition between the technology of conflict as an economic activity and the technology of peaceful production and exchange.

In Figure 5, for contender #1 the mp_F curve shows the marginal product of effort devoted to conflict (read from left to right), while mp_E represents the marginal product of productive effort (read from right to left). Given these curves, and in particular their declining shapes in the relevant ranges, the optimum is at the intersection.[20] However, the curves will themselves shift in response to the opponent's choice of F_2 versus E_2, and they will also be sensitive to exogenous factors like changes in preferences, in wealth endowments, or in the Ω and Γ functions. Two such variations are illustrated.

[FIGURE 5 HERE]

First, holding the opponent's choice of F_2 versus E_2 constant, Figure 5a indicates the consequence of increased <u>complementarity</u> between the parties' productive efforts.

For concreteness, suppose the production function Ω is such that:

$$(6) \qquad I = \Omega(E_1, E_2) = A(E_1^{1/s} + E_2^{1/s})^s$$

Here A is a measure of the total productivity of the "factors" E_1 and E_2, while s is an index of the complementarity between them. Other things equal, as s rises income I will increase as well. And, it is easy to

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[20] For simplicity here, the intersection is shown as occurring in the range of decreasing returns to conflict activity. Actually, there can be a maximizing intersection even within the range of increasing returns to conflict (positive slope of mp_F), provided that the mp_E curve is falling even faster.

verify, the marginal products $\partial I/\partial E_1$ and $\partial I/\partial E_2$ will also both rise.

Thus, as indicated in Figure 5a, the mp_E curve shifts upward. One's first impression might be that increased complementarity implies rationally devoting more effort to production and less to conflict. However, the increase in I puts more income at stake, so that conflict effort also tends to have a higher return. The marginal product $\partial I/\partial F_1$ having increased, the mp_F curve also shifts upward, so that the net effect upon the optimal choice remains unclear.

This consideration exposes the fatal flaw in assertions that the growing interdependence among nations is making war obsolete.[21] That same interdependence, unfortunately, also typically raises the stakes of conflict -- each side has more to gain from fighting and more to lose by failing to fight. The assertion might still on balance be correct, but a more careful analysis is called for.

In Figure 5b, contender #2 is taken as the protagonist, in order to examine the implications for his choice when the opponent #1 becomes richer than before. Normally, #2 can expect that an enriched #1 will be choosing higher levels of both productive effort and fighting effort -- larger E_1 and larger F_1. Given some positive complementarity, the larger E_1 will make the mp_E curve for #2 shift upward, so there is a force tending to induce #2 to revise his choice in the direction of productive effort E_2. But there are two more powerful considerations working the other way: (i) aggregate income being higher, there is more of a prize to be fought over, and (ii) the opponent's F_1 being larger means that #2 must devote more effort just to retain what he already had. Thus, the implication is, "#2 tries harder." This of course goes to explain the fifth stylized fact, that struggle often works to the advantage of the poorer side. Or, in other words, conflict tends to be an income-equalizing process.

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[21] Just before World War II, an immensely popular book by Angell [1911] argued that the growing economic absurdity of modern war meant that the major powers of Europe would no longer find it advantageous to fight one another -- or, at least, to persist in such a conflict for very long. On similar grounds, a recent well-received volume by Mueller [1989] contends that nations can simply opt out of the "war system," and are doing so.

CONFLICT AND ORGANIZATION

Organizations devoted to conflict -- armies, labor unions, political parties -- share many features with organizations of all types. There must be leadership, delegation, line versus staff responsibilities, and so forth. The question is, what specially characterizes conflict organizations?

For organizations engaged in actual combat, the fact that lives are at stake makes an evident difference. But I want to consider groups engaged in non-violent contests as well. A more general feature is the importance of numbers in determining the outcome even of metaphorical conflicts. The problem addressed here is that not all members of a group are equally willing to participate in the struggle.

In a military context, there are fighters and there are slackers. The crucial problem is a familiar one: each combatant wants his side to win, but at the same time he is tempted to shirk.[22] Similarly for political conflict: a legislator might not support his party when it takes a position that is unpopular in his own district. So group conflict is in one aspect a two-party game between the armies, but in another aspect an N-party game within each army.[23] Or, we might say, each general is playing one type of game with the enemy and another with his N-1 soldiers.

The issue here is how the number of actual fighters F_i on a side, within the total number N_i, is determined. The basic idea is that each soldier will be balancing the benefit he derives as the marginal fighter versus the cost to him of fighting rather than shirking. The ranges of increasing versus decreasing returns play a crucial role in determining the aggregate consequences of these individual choices.

Figure 6a pictures the choice situation of a soldier on side #1, as a function of the number of fighters F_1 on his side, and assuming given enemy fighting effort F_2. His estimate of the benefit of fighting, the

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[22]Ardant du Picq describes one of Napoleon's battles: "Out of twenty-two thousand men, from three thousand to fifteen hundred reached the [enemy] position....Were the nineteen thousand missing men disabled? No. Seven out of twenty-two, a third, an enormous proportion may have been hit. What became of the twelve thousand unaccounted for? They had lain down on the road, had played dummy in order not to go on to the end." (Quoted in Possony and Mantoux [1943].)

[23]See the pioneering paper by Brennan and Tullock [1982].

curve B_1, can be interpreted as the marginal contribution to the probability of victory (the first derivative of the Conflict Success Function pictured in Figure 3) multiplied by the value V_1 of victory to him. Thus:

$$(7) \qquad B_1 = V_1(dp_1/dF_1)$$

Victory is a collective good, but the value V_1 placed on it may reflect private benefits as well, e.g., booty or medals. The curve C_1 represents the cost he incurs by fighting rather than shirking. C_1 is shown as a declining function of F_1; the risks of fighting generally decline as the number of fighters on your side rises. Evidently, the individual here will choose to fight if he estimates that the number of fighters on his side will range between F_1' and F_1''.

[FIGURE 6 HERE]

However, there will be considerable variation from one soldier to another. There are die-hards who fight even if everyone else runs away. And there are cowards (or, possibly, disaffected individuals placing no value V_1 upon victory) who will never fight. Most soldiers will fall between these extremes.

Moving to the aggregate level of analysis, Figure 6b illustrates a "critical mass" problem.[24] For a given enemy force F_2, the larger is the friendly force F_1 that soldiers anticipate, the larger will be the number willing to fight -- at least, up to a point. The equilibrium, the number actually fighting, occurs where the F_1 curve cuts the 45° diagonal line.

The implications for organizational structure and policy are mainly straightforward. A general should try to make the individual soldiers' perceived cost of fighting rather than shirking, the C_1 curve, as low as possible. He might do this by employing tactics that reduce the casualty toll, or on the other hand by severely punishing malingerers. And he can try to heighten the perceived benefit of fighting, the B_1 curve, by raising the soldier's valuation of victory (possibly through ideological indoctrination, or else by offering a slice of the action in the way of booty). What is somewhat less obvious, while a general will normally want

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[24] Compare Schelling [1978], Ch. 3.

to have as large an army as possible in relation to the enemy, in order to maintain the incentive to fight he will not always want his soldiers to believe the enemy is either too strong or too weak.

SOME IMPLICATIONS OF CONFLICT TECHNOLOGY -- SUMMARY

As regards peace or war: Peace is more likely to the extent that the decisiveness of conflict is low or the stakes are small, and if the conditions of conflict are not "ideal" (so that the ratio form of the Conflict Success Function, in which it never pays to withdraw totally from conflict, is ruled out in favor of the logistic form). Among the implications noted were that: (1) constitutional rules may reduce either the decisiveness of intra-society conflict or the stakes at issue; (2) increased productive complementarity between the parties does not systematically favor peace; (3) the recent litigation explosion is mainly due not to increased decisiveness of conflict, but to the stakes at issue having been enlarged.

As regards relative success: Evidently, a favorable military effectiveness ratio (high "exchange rate" e) promotes success, while greater decisiveness of conflict increases the advantage derived from a favorable force ratio. But initial resource differentials have rather less effect than might have been anticipated -- or, put the other way, on balance conflict tends to be an income-equalizing activity. An implication: #2 will try harder.

As regards viability and numbers: I did not offer very much on this topic, but a tendency was noticed for increasing wealth levels to be associated with a smaller number of viable contenders.

As regards groups and shirking: Since numbers play so critical a role in conflict interactions, control of shirking is critical. Military organization is in large part a set of mechanisms for reducing the benefit and raising the cost of shirking.

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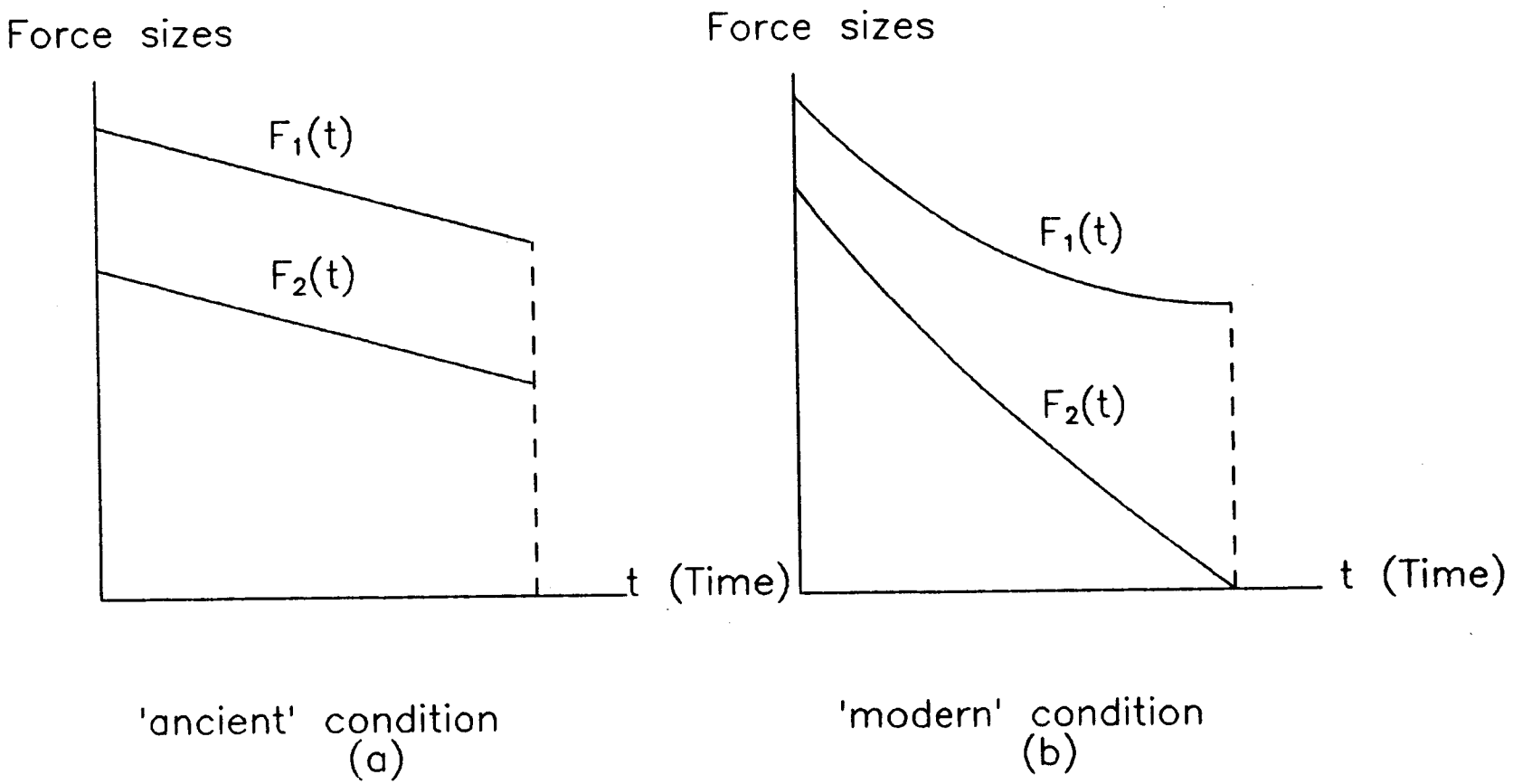


Figure 1: Lanchester model: Force attrition over time, under 'ancient' and 'modern' conditions

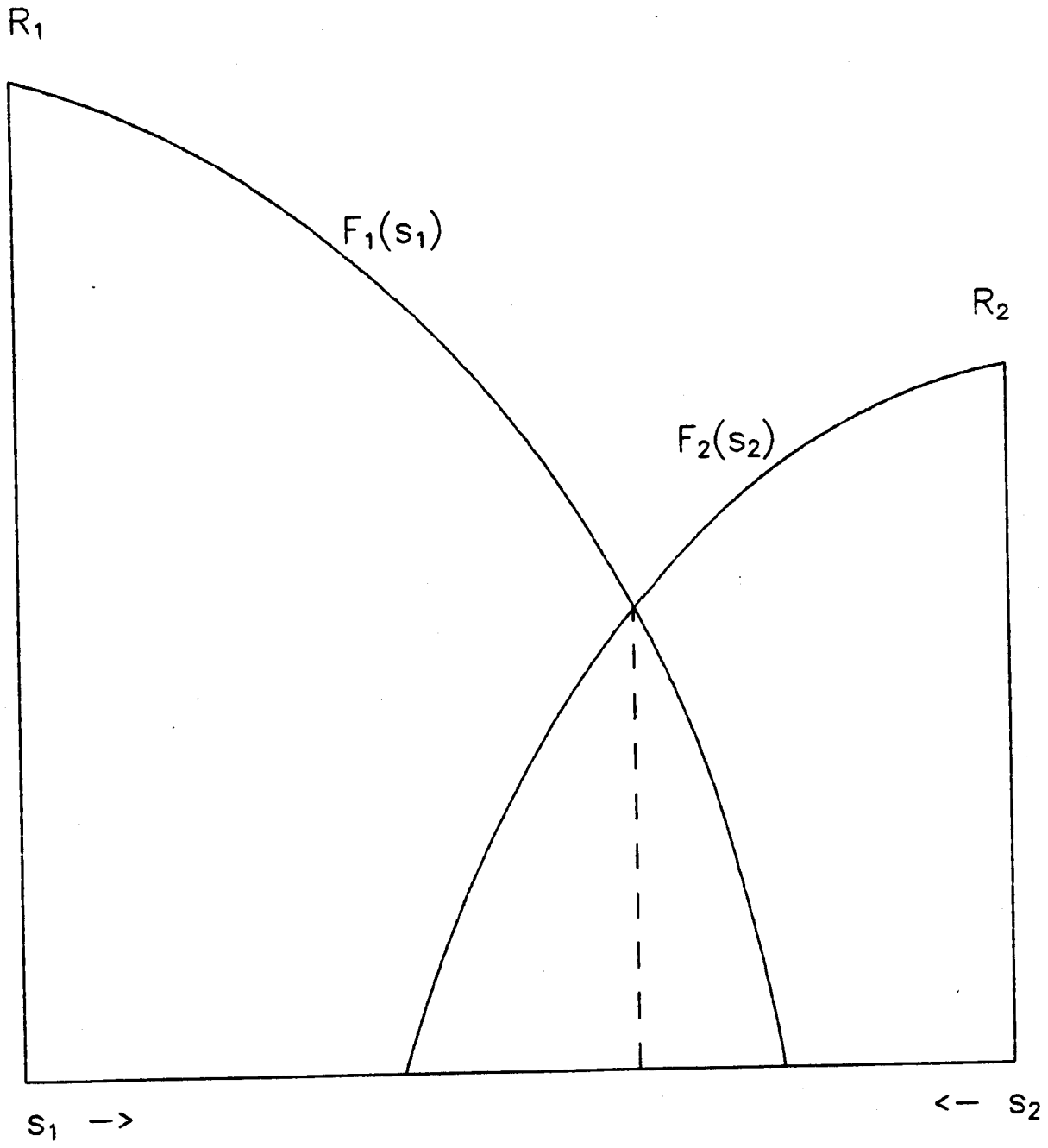


Figure 2: Boulding model: The decay of forces with distance, and equilibrium division of territory

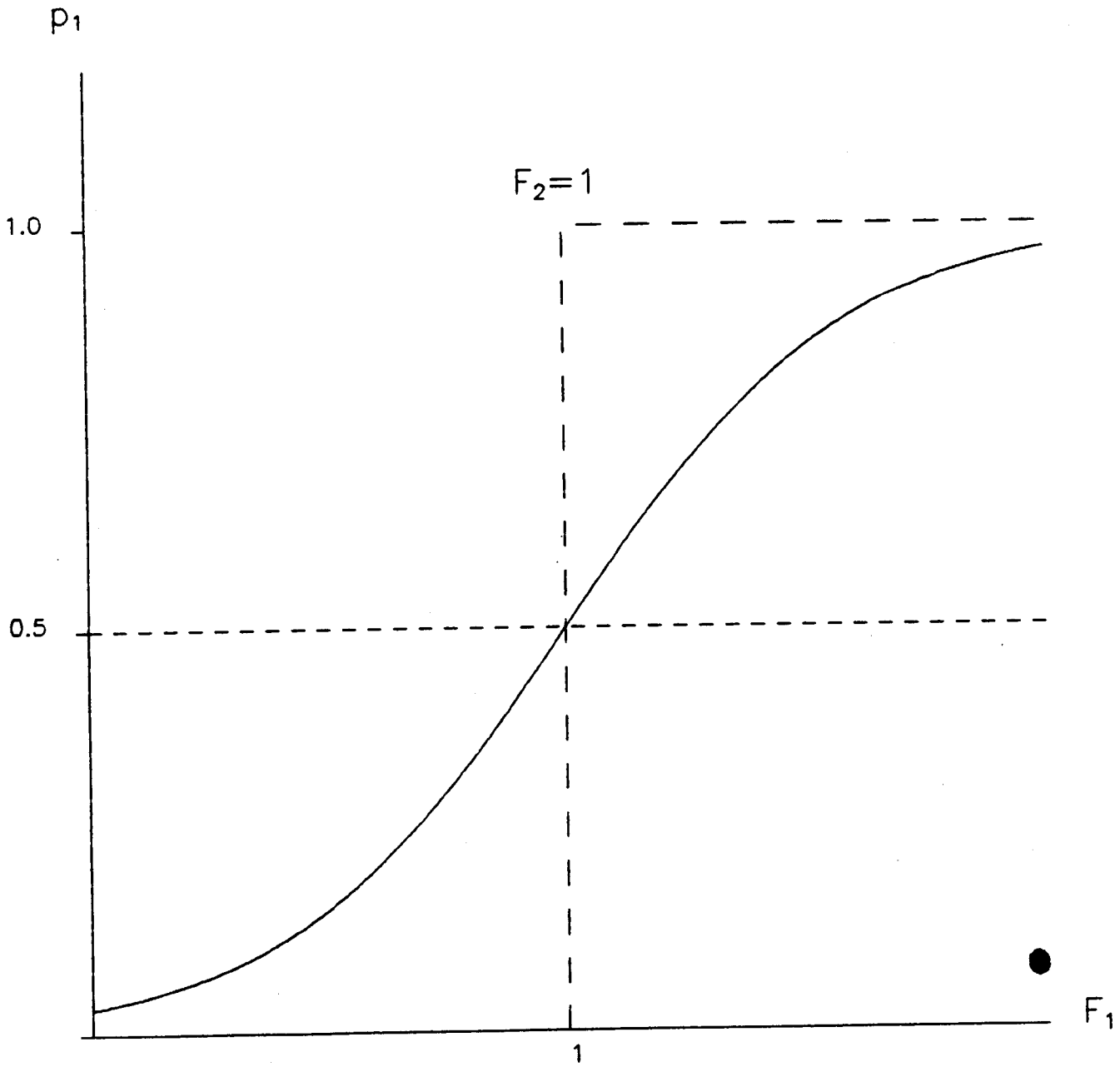


Figure 3: Contest Success Function (CSF): Lanchester model versus generalized model based on military experience

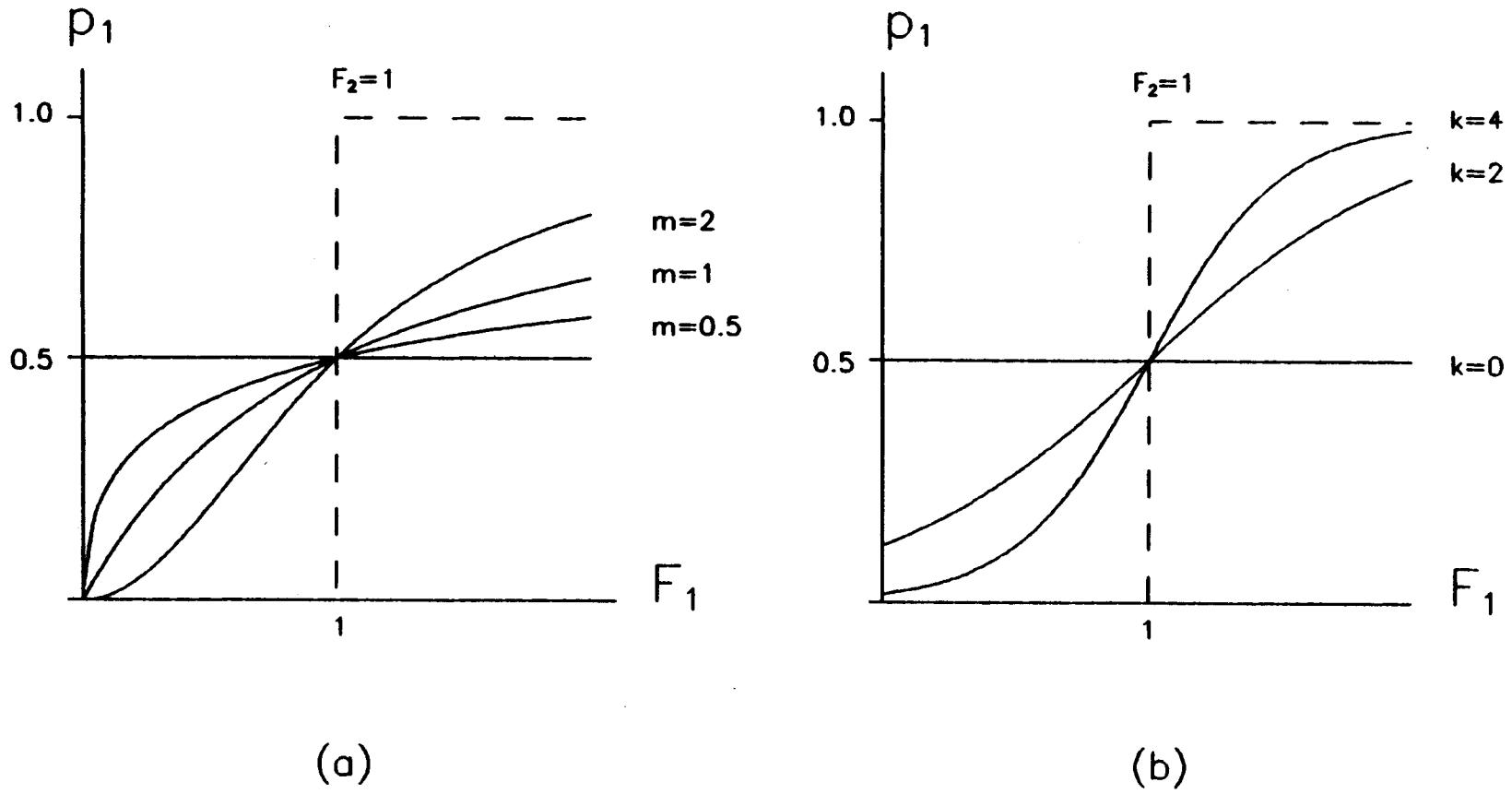
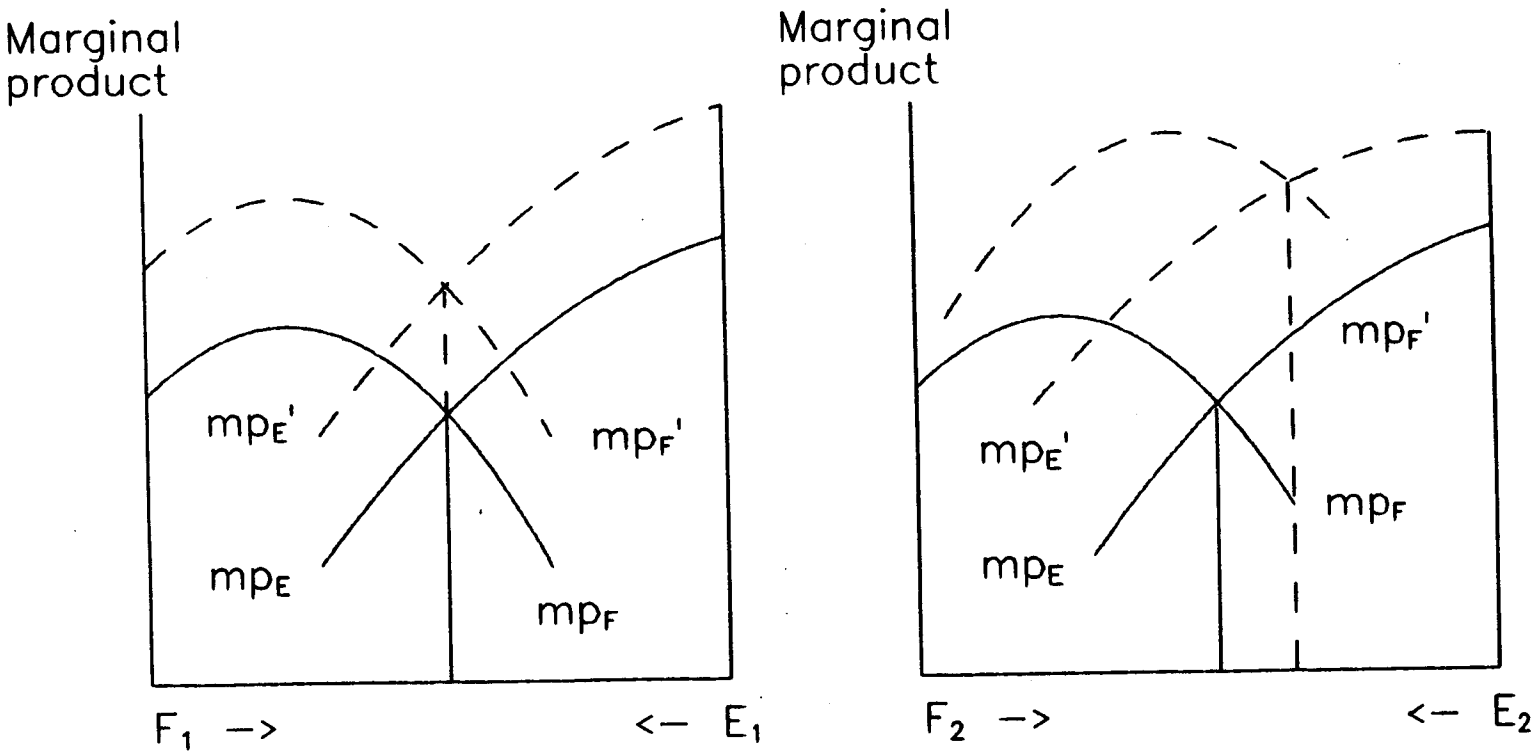


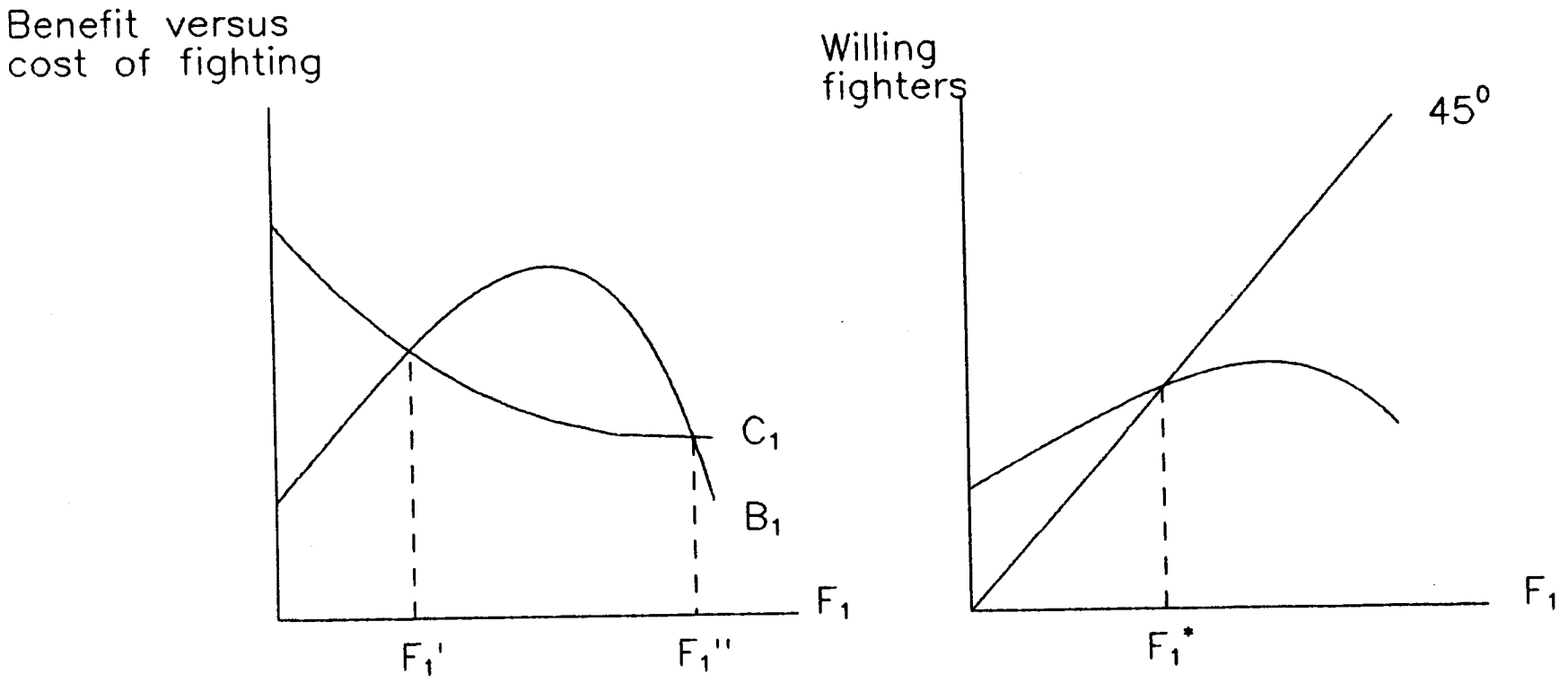
Figure 4: Contest Success Function (CSF) as the mass effect parameter (m or k) varies



(a) Effect of increased complementarity

(b) When #1 gets richer, #2 fights harder

Figure 5: The balance between fighting effort F_i and productive effort E_i -- Two parametric variations



(a) Individual choice: fight or shirk?

(b) Collective outcome: how many fight?

Figure 6: Determination of the number of fighters