

3 The economics of conflict, production, and exchange

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Introduction

Most economists, including those specializing in the economics of peace and conflict, have missed a crucial point. Yes, the use of resources for creating or defending against appropriation can be studied within the analytical categories of economics (Hirschleifer, 1988, 1989, 1991, 1994). It is true — crime, corruption, terrorism, warfare, and arms races are microeconomic choice problems (Becker, 1968; Usher, 1989; Laplan and Sandler, 1988; Wittman, 1979; McGuire, 1965). Moreover, weapons production and war produce major economic impacts and conflict is often associated with dramatic declines in human welfare (Boulding, 1978; Tinbergen, 1990). Although these topics make up the subject matter of conflict economics and researchers should continue to investigate them, a crucial point is being overlooked. The point is this: the use of resources for creating or defending against appropriation is intertwined with production and exchange (and therefore consumption) and *none of these major areas of economic analysis can be adequately understood apart from the others*.

Consider the economic transition in Russia. We cannot understand production and exchange in that society (or any society) without understanding how its economic institutions are shaped by people's resource allocations toward appropriation, protection, and the melding of the institutions themselves. The volume of trade, terms of trade, and welfare implications of standard production and exchange economics is shaped by, and in turn shapes, the allocation of resources toward appropriation and protection. To miss this point is the equivalent of studying international trade without production (i.e., merely a pure exchange model) or price determination with only a demand curve.¹ To exclude

exchange or production theory from our textbooks would be no more heretical than the exclusion of conflict, which persists.

The objective of our chapter is to support the assertion that conflict, as an analytical category, is as essential to economics proper as production and exchange. After reviewing the conflict economics literature we develop an Edgeworth-box model of conflict, production, and exchange. In our approach, the traditional Edgeworth-box is a special case of a general Edgeworth-box that incorporates conflict. In the general model, the interdependence of conflict, production, and exchange determines the size of the economy's productive sector, the equilibrium property and exchange institutions, and whether exchange or conflict predominates. Whereas we focus on how conflict affects production and exchange, production and the potential for exchange also affect conflict; the categories are interdependent.

Conflict, broadly defined, is the use of resources for creating or defending against appropriation. Appropriation can involve goods, incomes, resources, territories, or political power, and the players can be individuals, nations, governments, sub-national groups, or supra-national groups. The context of conflict is as broad as our definition and includes stealing, corruption, revolution, and warfare. Throughout the chapter we use the terms "weapons," "war," and "conflict technology" as metaphors for the implements, activity, and institutions of appropriation. We hope the terms will not detract from the broad definition and context of conflict that we assume.

Review of the conflict economics literature

One of the earliest allusions to conflict economics is Edgeworth (1881, pp. 16-17):

The first principle of Economics is that every agent is actuated only by self-interest. The workings of this principle may be viewed under two aspects, according as the agent acts *without*, or *with*, the consent of others affected by his actions. In wide senses, the first species of action may be called war, the second, *contract*.

Although Edgeworth's statement seems to point to conflict as economics proper, his model of contracting and recontracting falls short of what we mean by conflict in economics. In a two-person Edgeworth-box model of pure exchange, the point of contract is indeterminate; it lies somewhere on the contract curve in-between the indifference curves of the parties through the endowment point. This segment

of the contract curve is the set of points "along which the pleasure-forces of the contractors are mutually antagonistic" (Edgeworth, 1881, p. 29). The resolution of the mutual antagonism occurs through bargaining. The bargaining is a form of "war" because the parties' interests are antagonistic, although they have a mutual interest in reaching an outcome. But this so-called conflict is trivial compared to the more "muscular" kinds of conflict that might be represented by an Edgeworth-box. One of the players could murder the other and appropriate all of the goods. The players could transform some of their endowments into weapons in order to seize the goods of the other, seize the other player (slavery), or protect against such invasions. A party with more resources, weapons, and appropriative skills could establish itself as lord with the other player as serf. This is not what Edgeworth develops or what he seems to have in mind when he talks about "war." Throughout his analysis, even when the parties are in a mutually antagonistic position, "x and y [the goods traded] shall be varied only by consent (not e.g. by violence)" (Edgeworth, 1881, p. 20).

Pareto (1927, p. 341), however, truly captures the appropriative theme of conflict economics: "The efforts of men are utilized in two different ways: they are directed to the production or transformation of economic goods, or else to the appropriation of goods produced by others." Hirschleifer (1994, p. 3) interprets Pareto as follows: "... decision-makers will strike an optimal balance between the way of Coase and the way of Machiavelli — between the way of production combined with mutually advantageous exchange and the dark-side way of confiscation, exploitation and conflict."

It wasn't until Haavelmo (1954, pp. 91-98) that Pareto's thought was developed in formal economic theory. Haavelmo provided a canonical model of the allocation of resources between appropriation and production (Grossman and Kim, 1994a, p. 2). Haavelmo's formalization was separately and more richly developed by Winston Bush, James Buchanan, Jack Hirschleifer, and others two to three decades later (more on Bush, Buchanan, and Hirschleifer below).

During the 1960s and 1970s, strands of conflict economics literature began to emerge. Most of the literatures seemed unmotivated by Edgeworth, Pareto, and Haavelmo, even though they were consistent with the theme of conflict in economics. Pioneering theoretical work by Kenneth Boulding (1962), Thomas Schelling (1960, 1966), Martin McGuire (1965), Mancur Olson, Jr. and Richard Zeckhauser (1966), Walter Isard (1969), Michael Intriligator (1975), and Gordon Tullock (1974) brought the study of nation-state hostility within the domain of microeconomics.² The tradition continued with a burgeoning economics literature on international conflict,³ alliances,⁴ revolution,⁵ terrorism,⁶ and the predatory state.⁷ Gary Becker (1968) provided a seminal contribution on the economics of

crime.⁸ Each of the contributions represents an extension of economics into domains that are not traditionally viewed as economic.⁹

More recently, two other economics of conflict models have arisen. Though cousins of the earlier literature, they are fundamentally different in one important respect: they represent an imperialism within economics itself. The first is the Bush-Buchanan model that describes, among other things, the emergence of "law" from Hobbesian anarchy (Bush, 1972; Bush and Mayer, 1974; Buchanan, 1975). In the Bush-Buchanan model, people exist in a Hobbesian war where production and appropriation are equally viable entrepreneurial activities. People come to recognize the mutual gains that are available when appropriation is reduced. A constitutional contract emerges where property rights are defined and respected, appropriation is eliminated, and cheating is protected against. The constitutional contract is the institutional foundation of post-constitutional contract, i.e., the mutually beneficial production and exchange of traditional neoclassical economics. The standard neoclassical model generally takes property rights as given and then explores mutually beneficial production and exchange. The Bush-Buchanan model treats property rights endogenously and shows how they might be altered when underlying production and appropriation abilities change. Skogh and Stuart (1982) extend the Bush-Buchanan approach by developing a model of social contract where property rights and a sanction for enforcing them are established. The Skogh/Stuart model also includes a criminal justice system and a tax payments regime to support it.

The second of the new models is the production/conflict model developed by Jack Hirschleifer (1988, 1989, 1991, 1994). Hirschleifer's model is similar to the Bush-Buchanan model, but where Bush and Buchanan study the emergence of "law" arising from a disarmament of appropriation, Hirschleifer investigates how the technology of conflict influences the appropriation equilibrium and the distribution of a common output produced by the rivals.¹⁰ Skaperdas' (1992) work on production and conflict in the absence of property rights is an extension of the Hirschleifer model. Skaperdas identifies conditions under which rivals will and will not allocate resources to appropriation. He shows that when redistribution technology is ineffective and players' contributions to useful production are similar, an absence of property rights can be consistent with no appropriative resource allocations.¹¹

Grossman and Kim (1994a, 1994b) extend the Hirschleifer/Skaperdas models in three ways. First, they explicitly distinguish between offensive and defensive appropriation activities. The security of claims to property and the amount of predation are significantly influenced by the relative strength between offense and defense. Second, parties fight over claims to flows of resources as opposed to consumption goods. Third, their predator/prey model (in 1994b) is a sequential

move game as opposed to a simultaneous move game. The three variations provide a wider array of applications and insights into conflict economics.

The models, and especially the inquiries of conflict economists, are quite diverse and should not be grouped hastily under a single rubric. Nevertheless, they have a family likeness in their departure from the standard neoclassical model of production and exchange. Each operates in a production and conflict setting where appropriation is explicitly treated as a form of economic activity. They also have a family likeness in what they fail to do. To date, none of the formal models of production and conflict have explicitly modeled exchange.¹² For example, in the Hirshleifer/Skaperdas and Grossman/Kim models, which are core models in conflict economics, production and conflict are equally viable economic activities, but exchange is excluded. Incorporating conflict into economics is vital, but it is also problematic if an equally vital aspect of economics (i.e., exchange) is excised. The conflict economics literature moved away from production/exchange thinking to production/conflict thinking, but what is needed is a general equilibrium model of conflict, production, and exchange. Why? Because exchange can affect conflict and production and vice versa. The categories are interdependent, none of the major areas of economic analysis — conflict, production, and exchange — can be adequately understood apart from the others.

Some economists maintain that "conflict cannot be reconciled with the neoclassical model however ingenious the analyst and whatever the degree of complexity introduced" (Varoufakis and Young, 1990, p. 3). We maintain that not only can conflict be reconciled with the neoclassical model, but that in such a reconciliation, economists will have a stronger theoretical foundation for understanding production and exchange economics. Throughout history, production and exchange have occurred in the context of potential or actual conflict and vice versa. An economics discipline that excises the reality of conflict from its mainstream will be ill-equipped to understand many historical or present day economic problems (like the economic transition in Russia).

Edgeworth-box model of conflict, production, and exchange

We present a two-player Edgeworth-box model of conflict, production, and exchange. A mathematical version is in the appendix to this chapter. The model illustrates (a) the interdependence between production, exchange, and conflict and (b) the special-case nature of the traditional Edgeworth-box. It also illustrates that the size of the productive pie, welfare of the players, terms of trade, and whether or not trade even takes place at all, are all dependent on what is happening in the conflict sphere.

The traditional Edgeworth-box

Assume two players, Adam and Eve, each with an endowment of player-specific resources. Adam and Eve use their resources to produce food and clothing. The amount of food produced in the two-player economy is $F = F_A + F_E$ where F_A is the amount of food produced by Adam and F_E is the amount produced by Eve. Similarly, $C = C_A + C_E$ the economy-wide production of clothes where C_i ($i = \text{Adam, Eve}$) is the production of clothes by player i . F and C represent the size of the economy's gross output. This is shown in figure 3.1 where F is assumed to be 20 and C is 10. The pre-trade allocation of food and clothing is shown by a point on or inside the rectangle of figure 3.1. For example, point D illustrates the case where Adam has produced 8 food and 4 clothes while Eve has produced 12 food and 6 clothes. Adam's origin is O_A and his goods are measured outward from O_A . Eve's origin is O_E and her goods are measured inward from O_E . The size of the Edgeworth-box varies with the total production of the two goods. The pre-trade allocation (point D) varies with the players' production patterns.

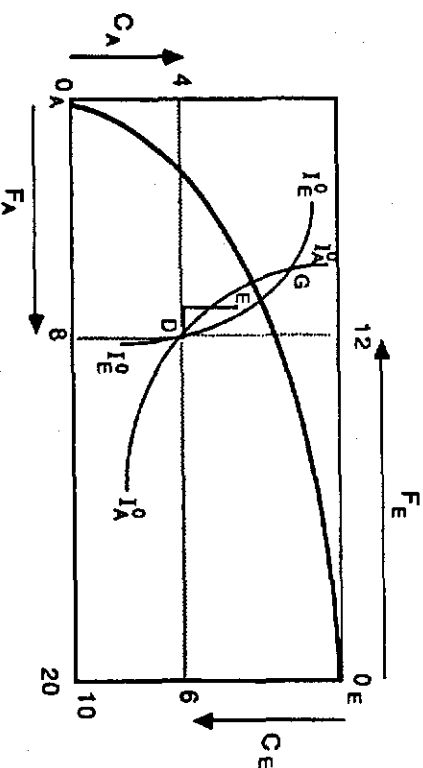


Figure 3.1 The traditional Edgeworth-box

The Edgeworth-box illustrates mutual gains from voluntary exchange. The indifference curve, I_A , drawn through point D represents combinations of food and clothing where Adam is equally well off as at D . I_E represents combinations of food and clothing where Eve is equally well off as at D . The cigar-shaped area between D and G is the region of mutual gain, i.e., a region that would make both

players better off if they traded into it. For example, if Adam gives up one food in exchange for two clothes (with Eve the other side of the trade), the consumption allocation E would put each player on a better indifference curve (better indifference curves are not shown in the graph).

Figure 3.1 also illustrates the contract curve. Points along the contract curve are Pareto-optimal (also called Pareto-efficient), i.e., once on the contract curve there is no feasible reallocation of goods that would make one player better off, while not hurting the other player. For example, at point E (off the contract curve) it is possible for the players to trade again and improve their utilities. Once trade has moved the consumption bundle to the contract curve, mutual gains have been exhausted. Moving from a point like E to *any* point on the contract curve does not necessarily imply mutual gains. Rather, when the players are off the contract curve, there are *some* points on the contract curve that the players could trade toward and experience mutual gains.

Introducing conflict into the Edgeworth-box

Consider the Edgeworth-box in figure 3.2 (temporarily ignore the smaller box). Assume that with his player-specific resources, Adam can only produce food (F), and he produces 20 units. Eve, with her player-specific resources can only produce clothes (C), and she produces 10 units.¹³ Adam and Eve gain from trade in moving to a point like e. Figure 3.2 is a traditional neoclassical model of production and exchange.

There is a second possibility. Assume that we have a one-time interaction between Adam and Eve (i.e., no continuous dealings). Assume that Adam and Eve can transform some or all of their resources into weapons and fight over the goods that are produced. Suppose that Adam uses some of his resources to produce weapons, but Eve does not. Adam's food production will fall, say from 20 to 18, but he can take the clothes produced by Eve and end up at a better point A_B . If Adam has no weapons, but Eve does, her clothes production will fall, say from 10 to 9, but she can achieve a better point E_B . If Adam and Eve both produce weapons, then coordinate point (F=18, C=9) can be viewed as common output that will be distributed based on the relative weapons strength of the two players. For example, if Adam and Eve are equally strong, then each might receive half of the common pie which is point D in the smaller-dimensional box of figure 3.2. (Equal weapons strength does not necessarily imply an equal split of the output; it depends on the technology of conflict which we discuss below). Although the indifference curves are not labeled in figure 3.2 (and later figures), the further Adam's indifference curves are from his origin, the higher his utility.

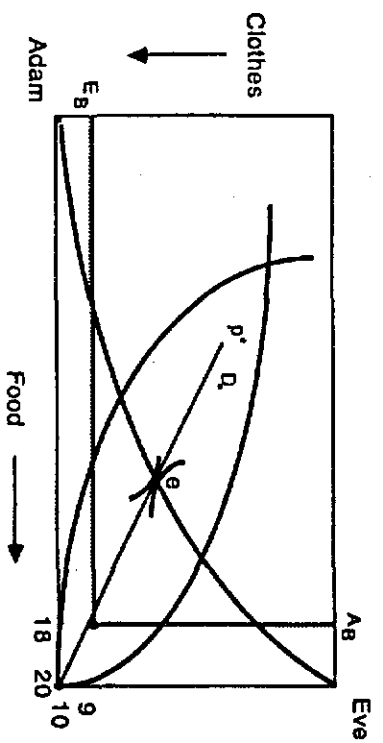


Figure 3.2 The Edgeworth-box with conflict

The further inward Eve's indifference curves are from her origin, the higher her utility.

Figure 3.3 (on the next page) shows the smaller Edgeworth-box from figure 3.2, but we incorporate the possibility of an exchange to point e'. In the formal economic models of conflict developed to date, there is no exchange, only production and conflict. We assume, however, that exchange will take place instead of conflict if both players prefer the exchange to the conflict (we assume no simultaneous conflict and exchange in a 2-player model). Figure 3.3 shows that both players prefer the exchange to a conflict that leaves them at D (ignore A_1 and E_1 for now). Mutually beneficial trade takes place in the presence of weapons production and the potential for fighting.¹⁴ The exchange occurs at price p^* which is not necessarily the same as the exchange price p^* from figure 3.2. The relative prices that emerge in an economy depend not only upon the resources and abilities of the players in the productive sphere, but also upon the appropriation/protection abilities of the players and the technology of conflict in the conflict sphere.

It can be shown (Anderton and Anderton, 1993) that for a wide range of preferences and production technologies, both players would have preferred an exchange to e' in the larger Edgeworth-box (figure 3.2) relative to an exchange to e' in the smaller Edgeworth-box (figure 3.3). In the larger Edgeworth-box,

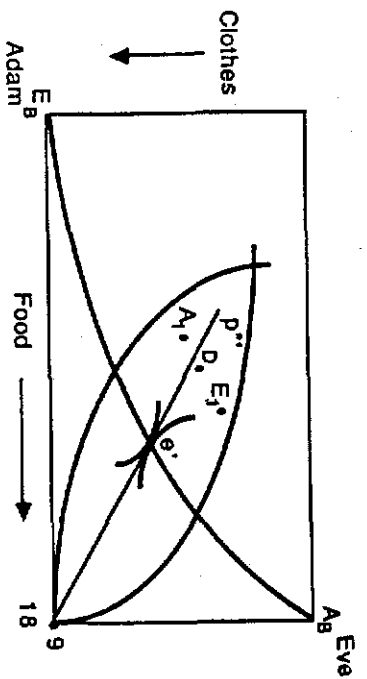


Figure 3.3 Exchange or conflict in the Edgeworth-box

however, each player has a unilateral incentive to allocate resources to appropriation and move toward a better point (i.e., A_B and E_B). The end result is a smaller Edgeworth-box, a "balance of power" where conflict would lead to point D, and the dominance of exchange to e' over the conflict. The move from a large Edgeworth-box to a smaller Edgeworth-box represents the prisoners' dilemma aspect of appropriative resource allocations.

The technology of conflict

When we consider the technology of conflict, point D in figure 3.3 is separated into two points unless there is no advantage to offense or defense (i.e., conflict technology is neutral). If the technology of conflict favors the defense, then each player finds that initiating conflict is less rewarding than defending in the conflict. When Adam is an attacker, he may end up with point A_1 in figure 3.3. A_1 is better for Adam than his initial bundle of goods ($F=18, C=0$), but it is worse than an exchange to e' . Similarly, Eve as an attacker may be able to achieve E_1 , but E_1 is worse for her than e' . Both players prefer an exchange to e' compared to initiating a conflict, even though each player is better off initiating conflict relative to his/her initial holding of goods. In figure 3.3, the presence of exchange in human affairs becomes an alternative to a conflict that might otherwise occur. Simultaneously,

the presence of off-setting conflict potential is what makes the exchange preferable to conflict.

But what if the technology of conflict favors the offense? In this case, initiating conflict is more rewarding than defending in the conflict. When Adam is an attacker, he may end up with point A_1 in figure 3.4. Eve as an attacker would be able to achieve E_1 . Nevertheless, both players still prefer an exchange to e' compared to initiating a conflict. This is true even though there is an advantage to the offense and each player is better off initiating conflict relative to his/her initial holding of goods. Once again, exchange is an alternative to a conflict that might otherwise occur and it is the off-setting conflict potential that makes exchange preferable to conflict.

But, there is only so much technology advantage to the offense that the production/exchange sphere can absorb before it is undermined (i.e., there is a level of stress beyond which the production/exchange sphere crumbles or never comes into being). Another possibility illustrated in figure 3.4 is where each side prefers attacking over the exchange. Suppose that Adam attacks first and because of the technology of conflict he is able to achieve A_2 . If Eve attacks first, she achieves E_2 . Each player prefers to attack rather than trade.

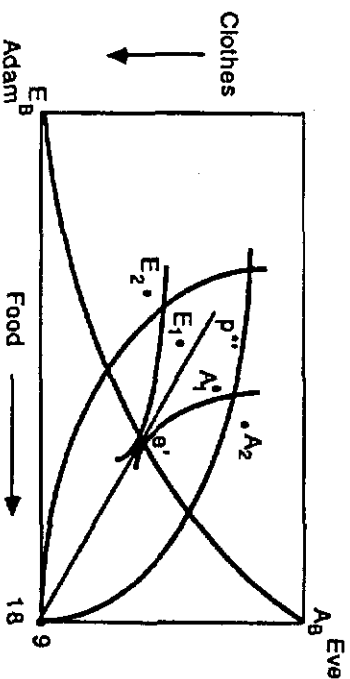


Figure 3.4 Exchange or conflict under offensive technology

As an extreme example of offensive technology undermining production and exchange, suppose that Adam and Eve each have one weapon, say a gun (as opposed to a knife or a club). Adam and Eve are at equal relative strength in the

quadrant IV (the technology of conflict function is not shown on the graph). The consumer goods production levels not only represent the aggregate pie to be divided in conflict, they also define the dimensions of the Edgeworth-box and the prospect for trade in quadrant IV. Under certain conditions, exchange in the Edgeworth-box is better for both players than what either of them get from initiating conflict. Under other conditions, one or both players perceive that conflict brings higher utility than exchange.

Some implications of the Edgeworth-box with conflict

In the traditional Edgeworth-box, an equilibrium in competitive markets is Pareto-optimal (First Welfare Theorem on competitive economies). In addition, any Pareto-optimal allocation can be sustained under competitive markets with an appropriate adjustment of initial resources (Second Welfare Theorem on competitive economies). Neither of these welfare theorems hold when conflict is introduced into the Edgeworth-box.

In a model where exchange occurs in the presence of weapons production, the Edgeworth-box is endogenous. When Adam and Eve produce weapons, which they generally will do even if they have no intention of initiating conflict, the Edgeworth-box is smaller than it would otherwise be (see quadrant IV of figure 3.6). The "Pareto-optimal points" along the contract curves of all of the shrunken Edgeworth-boxes of figures 3.2 to 3.6 are not Pareto-optimal. We refer to them as sub-Pareto optimal. In a model of conflict, production, and exchange, the Pareto-optimal points are defined in only one of a family of possible Edgeworth-boxes, i.e., the Edgeworth-box where weapons production is zero. In general, the "Pareto-optimal Edgeworth-box" will not be the equilibrium Edgeworth-box. This implies that we can have a sub-Pareto optimal competitive market equilibrium, which contradicts the First Welfare Theorem on competitive economies. Since most Pareto-efficient points cannot be supported by competitive markets regardless of redistribution of resources, the Second Welfare Theorem is contradicted also. Of course, economists have presented a number of conditions under which the welfare theorems do not hold (e.g., consumption and production externalities, income and consumption taxes). Conflict should be added to the list and carry great weight given its pervasiveness in human affairs.

At a fundamental economic level, the welfare of the players, size of the productive economy, equilibrium relative prices, security of property, and whether exchange even takes place at all depend upon what is happening in the conflict sphere. The point must not be glossed over. One of the major challenges for the economics discipline is to understand and explain *value*. Relative prices reflect relative value. Relative values of commodities and resources are significantly

influenced by conflict as our analysis shows. Further, economists strive to understand and explain the human capacity to "truck, barter and exchange." These aspects of human behavior are also significantly influenced by the conflict sphere. Finally, the size of the economy's GDP, the "equilibrium institutions" that emerge in society, and the patterns of specialized production and exchange depend upon the conflict sphere.

Conclusion

Our model could be criticized for its particular assumptions, but such criticisms would miss the point. We have chosen a core model in microeconomic theory to argue our case. We have presented that model in relatively simple terms. Extensions to more than two players, strategic behavior, continuous dealings, and other variables will not eliminate the reality that conflict has a profound effect on the production/exchange sphere of human behavior (and vice versa). But suppose that such extensions did indeed reduce the importance of conflict in influencing economic activity. Then we would have a serious problem indeed. It is a fact of history and present day experience that conflict has a profound effect on production and exchange. A theory and discipline where the reality of conflict is diluted or excised won't be very useful. So we conclude where we began: the use of resources for creating or defending against appropriation is intertwined with production and exchange (and therefore consumption) and *none of these major areas of economic analysis can be adequately understood apart from the others.*

Appendix

Each player, Adam and Eve (labeled A and E), possesses one unit of a resource which is allocated to the production of a consumer good and weaponry:

$$(A1) \quad x^i + y^i = 1$$

where for $i = A, E$:

- x^i — resources allocated to producing consumer good.
- y^i — resources allocated to producing weaponry.

Player A produces food, f , and player E produces clothes, c , according to their respective production functions:

(A2) $f = f(x^A)$ $f(0) = 0, f' > 0, f'' < 0$
 (A3) $c = c(x^E)$ $c(0) = 0, c' > 0, c'' < 0$

Each player produces weapons, w_i , according to their respective weapons production functions ($i=A,E$):

(A4) $w^i = w^j(y^j)$ $w^i(0) = \phi, w^i > 0, w^{i'} < 0$

When no resources are allocated to coercion, we assume that each player has some extremely small amount of conflict goods, ϕ . The assumption facilitates the interpretation of conflict when neither side allocates resources to weapons. If $y = (0,0)$, a conflict can still be fought with the ϕ 's. The ϕ 's also make it possible to prove the existence of a Nash equilibrium, although we do not do so here.

Conflict technology and weapons production determine the proportions of consumer goods that A and E get, P^A and P^E , when they are defenders in a conflict:

(A5) $P^A = P^A(w^A, w^E, \beta)$ $0 \leq P \leq 1, P^A > 0, P^A < 0, P^A < 0$
 (A6) $P^E = P^E(w^A, w^E, \beta)$ $0 \leq P \leq 1, P^E < 0, P^E > 0, P^E < 0$

where β is a parameter that reflects the offensive/defensive technology of conflict as follows:

$\beta = 1$ \Rightarrow offensive/defensive technology is neutral.
 $0 < \beta < 1$ \Rightarrow offensive/defensive technology favors the defense.
 $\beta > 1$ \Rightarrow offensive/defensive technology favors the offense.

In propositions 1 to 3 developed below we assume that conflict technology is neutral ($\beta = 1$) and the following conflict distribution function holds:

(A7) $P^i = \left[\frac{w^i(y^i)}{w^i(y^i) + w^j(y^j)} \right]^\beta$ $i, j = A, E$

In proposition 4 below, we only assume that (A7) holds (i.e., we allow β to vary). Each player ($i = A, E$) allocates resources to maximize an identical linearly homogeneous utility function:

(A8) $U^i = U(F^i, C^i)$ $U_i > 0, U_{ii} < 0$

where F^i, C^i are the amounts of food and clothes that i gets in a conflict or in an exchange. Assume that each player makes its resource allocation to consumer good production and weaponry under the assumption that conflict will take place. *Ex post*, if exchange is better than conflict for both players then exchange will take place. Player i 's utility maximization problem from a conflict with j is:

(A9) Maximize $U^i = U(P^i F^i, P^i C^i) = P^i U(F^i, C^i)$
 s.t. $x^i + y^j = 1$

where, again, P^i is the proportion of the consumer goods that i gets in a conflict and (F^i, C^i) are production levels of food and clothes. We assume that the utility function in (A9) is twice continuously differentiable and strictly quasi-concave in x^i and y^j .

Proposition 1: A fully cooperative weapons equilibrium $y^* = (0,0)$ results when

$$\frac{1}{2\phi} \leq \left[\frac{c^i f^j}{w^A c^i f^j + w^E f^j c^i} \right]$$

Proposition 1 identifies when we will have a "Pareto-optimal Edgeworth-box," i.e., an Edgeworth-box with full dimension. If consumer goods productivities c^i and f^i are large, weapons productivities w^A and w^E are small, and there is sufficient endowment weaponry ϕ , then no resources will be allocated to conflict.

Derivation of Proposition 1:

(A10) $\frac{dU^A}{d\phi^A} = \frac{-w^A U^A f^E}{w^A + w^E} + \frac{U^A w^A w^E}{(w^A + w^E)^2} \leq 0$ at $y = (0,0)$

A similar derivative dU^E/dy^E would give rise to a condition like (A10) for E. $w^A(0) = w^E(0) = \phi$ and $U = U(F^i + U_\phi^i, C^i)$ by Euler's theorem. Substitute this information into dU^i/dy^i for $i=A,E$. This gives rise to the following condition which is sufficient for $y=(0,0)$ to be an equilibrium:

$$(A11) \quad \frac{w^A c}{(2\phi f - w^A f)} \leq \frac{U_1}{U_2} \leq \frac{2\phi c^2 - w^E c}{w^E f}$$

Take the left side of (A11) and make it \leq the right side of (A11). Rearranging yields the condition of proposition 1.

Proposition 2: A sub-optimal Edgeworth-box results when at $y^*=(0,0)$

$$\frac{1}{2\phi} > \left[\frac{c^2 f}{w^A c^2 f + w^E f c} \right]$$

Proposition 2 implies that as $\phi \Rightarrow 0$, a sub-Pareto optimal Edgeworth-box results. At $\phi=0$, the left side of the condition is infinite and a sub-Pareto optimal Edgeworth-box is guaranteed (assuming non-zero weapons and consumer goods productivities). The derivation of proposition 2 follows from the methods of proposition 1.

Now define a pure predator/prey relationship as one in which a player, say A, allocates all resources to weapons while E produces weapons and a consumer good.

Proposition 3: Player A will be a pure predator when
$$\frac{U_1}{U_2} \leq \frac{w^A (w^E)^2 c^2}{w^E (w^A)^2 f}$$

Proposition 3 says that if A's relative weapons productivity is sufficiently high, his relative consumer goods productivity is sufficiently low, and his marginal utility of food (at $F=0$) is low, then A will be a pure predator. Since $U_1(0,C)$ is likely to be large, pure predation is likely to be rare in a two-player Edgeworth box.

Derivation of Proposition 3:

$$(A12) \quad \frac{dU^A}{d\phi^A} = \frac{-w^A U_f^A}{w^A + w^E} + \frac{U_{w^A}^A w^E}{(w^A + w^E)^2} \geq 0 \text{ at } y^A = 1$$

$$(A13) \quad dU^E/dy^E = 0 \text{ for } 0 < y^E < 1$$

By Euler's theorem, substitute $U_1 f + U_2 c$ for U in (A12). Since $f(0)=0$, (A12) implies

$$\frac{U_1}{U_2} \leq \frac{c w^A w^E}{f w^A (w^A + w^E)}$$

$$(A13) \text{ implies } w^A + w^E = \frac{w^A + w^E}{c^2 w^E} c w^A w^E$$

Substituting the latter piece of information into the former yields the condition of proposition 3.

Proposition 4: Mutually beneficial exchange takes place instead of conflict if there exists a terms-of-trade p^* such that:

$$(A14) \quad \frac{(1-p^E)c}{P^E f} \leq p^* \leq \frac{P^A c}{(1-p^A) f}$$

where p^* is an equilibrium price in the Edgeworth-box. In some cases there may be multiple p^* 's that satisfy (A14) and are equilibria in the Edgeworth-box, so that p^* is a non-empty set of equilibrium prices in the Edgeworth-box and p^* is an element of p^* . If the equilibrium is unique, then p^* is a single price, p^* . For condition (A14) to hold it is necessary that $P^A/P^E \geq 1$, i.e., the offensive/defensive technology of conflict must favor the defense or be neutral.

Condition (A14) is sufficient for mutually beneficial trade to take place, but it is not necessary. In figure 3.A1 we assume that conflict technology favors the offense (i.e., $\beta > 1$ so that $P^A/P^E < 1$). The line running from the lower left to the upper right of the Edgeworth-box is the set of possible redistributions for $0 \leq \beta \leq \infty$; it is *not* a set of Pareto-optimal points. A gets a if he attacks and b if he defends; E gets b if she attacks and a if she defends. Since $\beta > 1$, a is to the right of b . Each side does better attacking than defending, and it seems that conflict is inevitable.

But each player has a better indifference curve in an exchange to e than the one they get when they attack.¹⁵

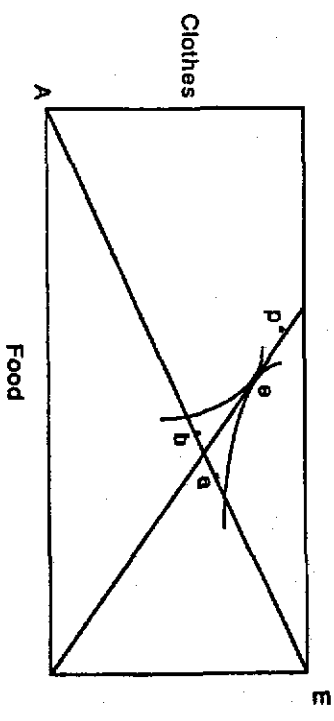


Figure 3.A1 Exchange instead of conflict when the offense is favored

When the technology of conflict favors the defense, conflict may still occur. In figure 3.A2, conflict technology favors the defense (a is to the left of b). If p^* is a unique Walrasian equilibrium, classically defined, then the economy of figure 3.A2 will not settle at a trade to e (i.e., it is not an equilibrium). E does better by initiating conflict. A, of course, prefers the trade along p^* , but E prefers the conflict ($U^2 > U^1$). Since it takes two to agree on an exchange, but only one to initiate conflict, the conflict occurs.¹⁶

Derivation of Proposition 4:

A geometric proof of Proposition 4 is given in figure 3.A3. The straight line running from the lower left to the upper right of the Edgeworth-box is the set of possible redistributions for $0 < \beta < \infty$; it is *not* a set of Pareto-optimal points. For example, if $P^E=0.6$ and $P^A=0.8$, then A gets $(1-0.6) = 0.4$ of the aggregate output when he attacks and E gets $(1-0.8) = 0.2$ of the aggregate output when she attacks. These are points a and b in the figure. Condition (A14) says that if a p^* exists that cuts in between what A and E can get as attackers, then mutually beneficial trade will take place. Given that p^* is an equilibrium price and indifference curves are convex, any separation of points a and b in figure 3.A3

must imply an exchange indifference curve for A that is above his indifference curve through a and an exchange indifference curve for E that is better than her

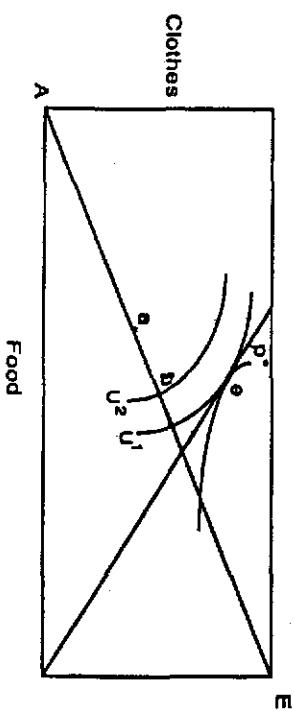


Figure 3.A2 Conflict instead of exchange when the defense is favored

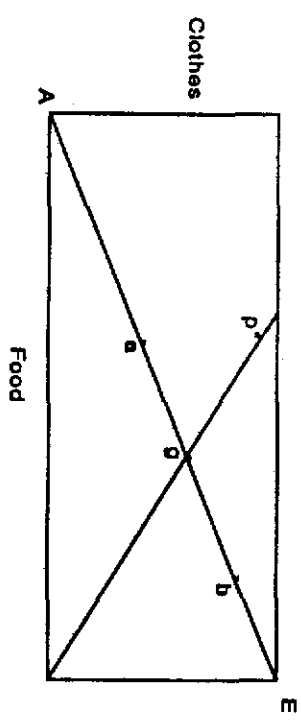


Figure 3.A3 Geometric proof of proposition 4

indifference curve through b . In the special case where a and b coincide at g and p^* cuts g , each player is indifferent between fighting and trading.

1. Partial analysis has its virtues. For example, the pure exchange model highlights the mutually beneficial character of exchange based on differences in tastes or endowments. Nevertheless, the gains from trade can be even larger once production is added. By adding production, one of the great concepts in all of economics is revealed: comparative advantage.
 2. Nation-state conflict occupied the attention of many economists of earlier eras (e.g. Smith, Ricardo, Mill, Edgeworth, Clark, Cliffe Leslie, Cairnes, Bagehot, Senior, Cobden, Veblen, Pareto, and Pigou). See Goodwin (1979) for a summary of many of the earlier economists' views.
 3. See, for example, Boulding (1978), Brito (1972), Brito and Intriligator (1985), Dumas (1979), Garfinkel (1990), Hirao (1994), Isard (1988), Kuenne (1992), Polachek (1992), Radner (1989), Sandler and Hartley (1995), Seigle (1992, 1993), Sen (1992), Shubik (1987), Simaan and Cruz (1975), Tinbergen (1990), Vickrey (1978), Witman (1979), and Wolfson (1992).
 4. See, for example, Ayanian (1992), Conybeare, et al. (1994), Enders, et al. (1992), Hansen, et al. (1990), Hilton and Vu (1991), Jones (1992), MacNair, et al. (1995), McGuire (1990), Sandler and Cauley (1975), Sandler (1977, 1992), Sandler and Forbes (1980), Murdoch and Sandler (1984), and Wong (1991).
 5. See, for example, Usher (1989) on dynamic cycles, Grossman (1991, 1992) on insurrections, and Gupta (1990) on revolution. See also Paul and Whitte (1990) on revolution, warfare, and their relationship to the rent-seeking literature. On narcotics traffic and guerrilla warfare, see Brito and Intriligator (1992).
 6. See, for example, Cauley and Sandler (1988), Lee and Sandler (1989), and Lapan and Sandler (1988).
 7. See Grossman and Noh (1990, 1994), Olson (1994a, 1994b), and Murrell and Olson (1991).
 8. For related literature, see Akerlof and Yellen (1994), Becker and Landes (1974), Brown and Reynolds (1973), Eide (1994), Heineke (1975),
9. Shavell (1987), Polinsky and Shavell (1984), and Posner (1985).
 10. An extensive bibliography of economic and political models of conflict is provided by Lichbach (1992). See also Hartley and Sandler (1995) for readings and bibliographies in defense and peace economics. Hirschleifer's model generally applies in a world of no property rights. One of his income distribution equations, however, allows for protected fractions of income that can be viewed as representing partial property rights.
 11. Skaperdas (1992, footnote 1) points out that recent work in neoclassical economics has moved away from the assumption of complete property rights. He cites the literature on transactions-cost economics, the principal-agent problem, and the theory of incomplete contracts and missing markets.
 12. Rider (1993) comes closest to being an exception to this statement. He develops a two-good infinitely repeated game theory model of the emergence of private property or balanced power from a Hobbesian world of conflict. The equilibrium utilities could, and presumably do, involve mutually beneficial exchange of goods, but Rider "did not show market trading in this new equilibrium ..." (Rider, 1993, p. 155). Rider's model is also quite restrictive. For example, the players must allocate zero percent, fifty percent, or one-hundred percent of their labor to conflict; other allocations, which vary with underlying production and conflict technologies, are excluded. Nevertheless, Rider fully captures the theme that production, conflict, and exchange are intertwined: "Economic and power relations are enmeshed" (p. 155).
- Other contributions that come close to being an exception to our statement are the Bush-Buchanan model and the work of Solomon Polachek (1980, 1992). In the Bush-Buchanan model, when and if a disarmament of appropriations occurs, mutually beneficial production and exchange can then take place in a traditional neoclassical world. Polachek theoretically and empirically investigates the relation between international trade and nation-state conflict. His major purpose is to study the "trade leads to peace" thesis, rather than extend the neoclassical model into the domain of conflict and endogenous property and exchange institutions.

13. We could assume that Adam and Eve can produce both goods and that Adam has a comparative advantage in food. Assuming incomplete specialization, the production point would be interior to the box as in figure 3.1. Our more restrictive assumption aids in the tractability of the formal model in the appendix.
14. Our initial one man/one woman model can apply to individuals, but also to organizations, even nations. The model is designed to be a metaphor of conflict in general, even though there are important differences in behavior between individuals and organizations (Olson, 1965). Our approach is analogous to international trade theory where players are typically nations, but the theory could apply to production and trade between individuals. If the players in figure 3.3 are nations, it could be viewed as a simple international trade model where the nations are potential combatants but they might trade instead.
15. Figure 3.A1 shows that the lower the elasticity of substitution and the further e is from the redistribution line, the greater the potential for exchange to replace conflict in an environment where both parties do better attacking than defending. For some utility functions (e.g., Cobb-Douglas with equal exponents), the locus of indifference curve tangencies is linear and runs from A's origin to E's origin. Under these conditions, (A14) is necessary for mutually beneficial trade to take place.
16. Figure 3.A2 ignores strategic play by A to induce E to exchange. An A indifference curve through point b gives rise to a region of mutual gain to the northwest of b . A could propose an exchange in that region that would make A and E better off than they are at b . The terms-of-trade that would emerge as the equilibrium p^* would not be Walrasian p^* (because excess demands would exist). The equilibrium p^* is influenced by potential conflict. The excess demands that persist provide incentives for institutional formation.

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