

Trade in the Shadow of Power[†]

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1 Introduction

At least since Ricardo (1817), international trade theory has followed the traditional approach in economics of assuming that property rights on all goods and services are perfectly defined and costlessly enforced. Especially in the international context, however, where there is no overall authority as there is within individual states to either define or enforce property rights, this assumption is empirically untenable; and, as we argue in this chapter, the empirical failure of this assumption is not without consequences for theory. In particular, reasonable models that relax the assumption of perfect and costless enforcement yield different predictions and, in some cases, these predictions differ sharply from those obtained by traditional trade theory.

The absence of third-party enforcement implies the expenditure of significant resources by individual states in an effort to enforce property rights themselves. Military expenditures, representing one visible aspect of this costly self-enforcement, is nearly 2.5 percent of world GDP (SIPRI, 2008). Of course, states, organizations, and individuals incur other security and intelligence costs in the self-enforcement of property rights; although these costs are more difficult to estimate, they also contribute to changing the results of traditional models.

Ultimately, we argue that power matters for trade as critically as the traditional determinants of endowments, preferences, and technology. The type of power that we explore

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in this chapter is the one that is based on the use, or the threatened use, of violence that, in turn, depends on the military capabilities of states.

Trade has taken place in the shadow of power for all almost all of recorded human history. Each party faces not only the risk that the other party will fail to agree on a price; in addition, given the opportunity that comes with the threat—or exercise—of violence, each party faces the risk that the other party will take everything from him. Therefore, both sides in a trade under anarchy have to be prepared for the possibility of violence. Indeed, the history of Eurasia over the past millennium is full of examples of the dilemma of trade in the shadow of power.¹ As one Governor-General of the Dutch East India Company stated to the directors of his company upon taking office, “we cannot make war without trade nor trade without war” (Findlay and O’Rourke, 2007, p. 178). Similarly, the British Governor of Bombay Charles Boone commented in the eighteenth century: “If no Naval Force, no Trade” (Chaudhuri, 1985, p. 3). All other European powers in early modern times—the Spaniards, the Portuguese, the French, and the Russians—sought trade with the sword in hand and the cannon in support. Earlier, the Vikings, the Genoans, and the Venetians had also built their wealth on the twin enablers of trade and military might.

Trade in the shadow of power did not disappear with the industrial revolution and the rise of the modern nation-state. Indeed, one might argue that the British Industrial Revolution itself was underwritten by the British navy and the long-distance trade of the Empire. Furthermore, it is beyond dispute that the first modern era of globalization that preceded World War I was accompanied by an arms race among the Great Powers. And, it is difficult to deny the notion, even if rarely admitted among polite company or within much of economics, that in practice international trade today is taking place in the shadow of power.

Precisely how the shadow of power matters in trade depends on the particular setting. Our aim in this chapter is to examine how some of the main results in international trade theory fare when we allow for the exercise of power. We do this in the context of simplified versions of the 2-good, 2-country, Ricardian and Heckscher-Ohlin trade models, augmenting each with a nontraded good—namely “guns.” In the augmented Ricardian model, guns are used to capture some of the traded goods, whereas in the augmented Heckscher-Ohlin model guns are used to capture a contested resource, like oil.

In both models, the production of goods that are eventually traded depends not only on the endowments, technologies and preferences of the countries that are engaged in trade. It also depends on arming the takes scarce resources to produce. Consequently, prices in either domestic or international markets reflect arming and the power that comes from that, in addition to preferences, endowments or technologies of production. Of course,

¹See Findlay and O’Rourke (2007 and this volume).

arming is itself endogenous. And, as we show in the Ricardian context, those who hold the most socially valued goods need not have the advantage they would enjoy in a competitive economy with perfect security. For producing a good that is highly valued can induce a country to arm less and thus give them a “comparative *disadvantage*” in power.

In the Heckscher-Ohlin context, we examine the interaction of two small countries that compete for a resource and compare the outcomes when both countries are autarkic and when both countries engage in free trade, taking world prices as given. Arming under autarky and arming under free trade are typically not related, and we find that there exists a range of world prices under which both countries prefer autarky to free trade, despite the fact that both countries are small and thus have no effect on world prices. In particular, for this range of world prices, the gains from trade are swamped by the extra cost of arming under free trade. Moreover, for some range of prices, a country exports a different good when there are power considerations than when there are not as in the strictly neoclassical special case; thus, trade in the shadow of power can distort comparative advantage.

2 A Model with Insecure Outputs

Consider two countries, E (for England) and S (for Spain), having initial resources, R_E and R_S , respectively, and each one specializing in the production of a final good, cloth (c) and wine (w), respectively. Due to insecurity, both countries produce an additional good that we can call “guns.”² Letting g_E and g_S denote the amount of guns produced respectively by E and S , the production of final goods c and w are the following:

$$c = R_E - g_E \quad \text{and} \quad w = R_S - g_S. \tag{1}$$

Both countries have the same Cobb-Douglas utility function defined over the consumption of these two final goods, c_i and w_i :

$$U(c_i, w_i) = c_i^\alpha w_i^{1-\alpha}, \quad i = E, S, \tag{2}$$

where $\alpha \in (0, 1)$.

We suppose that the two countries first produce their guns. This choice, by equation

²We suppose throughout this section that, despite the problems created by insecurity, under free trade it does not “pay” for E to produce wine, nor for S to produce cloth. Specifically, we assume the technology for the good that each country has a comparative disadvantage in is extremely inefficient, so that we can essentially view the initial endowment R_E as being useful to produce only cloth and guns and the initial endowment R_S as being useful to produce only wine and guns. We note that this “augmented Ricardian” model coincides with the Armington model (Armington, 1969), in assuming that inputs (i.e., resource endowments) and thus outputs are nationally differentiated. Given our Cobb-Douglas specification for utility made below in equation (2), the model is a special case in which the elasticity of substitution equals 1.

(1), determines the output of cloth and wine. Each country then attempts to seize some of the other's output.³ Such a setting captures, for example, the interactions between Britain and Spain and between Britain and France in the Atlantic Ocean during the 17th and 18th centuries, when the navies and privateers of each of those countries captured merchants' ships and the cargo of one another.⁴ How much each country seizes of the other's output and how much it defends of its own output depend on two factors: (i) the general level of insecurity and (ii) the amount of guns that the two countries possess.

Let $\sigma \in [0, 1]$ denote the degree of security—that is, the fraction of each country's output that is not vulnerable to seizure by the other country. The remaining fraction of output, $1 - \sigma$, is subject to seizure, and divided among the two countries in shares that depend on the amount of guns in the two countries' possession. In particular, let $q(g_E, g_S)$ be country E 's share and $1 - q(g_E, g_S)$ be country S 's share. The function $q(g_E, g_S)$ is assumed to be differentiable, strictly increasing in g_E and strictly decreasing in g_S , and have other properties that we will specify below as needed. One particular form that we will employ is

$$q(g_E, g_S) = \begin{cases} \frac{g_E}{g_E + g_S} & \text{if } \sum_{i=E,S} g_i > 0; \\ \frac{1}{2} & \text{if } \sum_{i=E,S} g_i = 0. \end{cases} \quad (3)$$

The secure output of each country, σc for E and σw for S , is traded competitively by the large number of traders in each country. Of course, given the the Cobb-Douglas specification for utility (2), the competitive equilibrium allocations, the relative price of c to w , and the equilibrium payoff to each country would be the same if all output—secure as well as insecure—were traded competitively.

The sequence of events in the interaction between the two countries is as follows:

Stage 1. Arming levels g_E and g_S are chosen simultaneously. Given those choices, the outputs of c and w are determined by (1).

Stage 2. Arming levels determine how the insecure outputs of each country are divided. Country E keeps a $\sigma + (1 - \sigma)q(g_E, g_S)$ share of c and obtains a $(1 - \sigma)q(g_E, g_S)$ share of w , whereas country S obtains a $(1 - \sigma)[1 - q(g_E, g_S)]$ share of c and keeps a $\sigma + (1 - \sigma)[1 - q(g_E, g_S)]$ share of w .

Stage 3. The secure shares of c and w (or, equivalently, all shares of c and w) are traded competitively.

³Alternatively, the conflict between the two countries could be thought of as being driven by insecurity of intermediate goods. For this interpretation, equation (2) would be viewed as a production function, with c_i and w_i as intermediate goods; in this case, α and $1 - \alpha$ could be thought of as cost shares or elasticities of output.

⁴See Leeson (2009) for an overview of the historical evidence on privateers and Findlay and O'Rourke (2007) for many other examples.

More formally, we define the outcome of stage 3 as follows:

Definition. A competitive equilibrium is an allocation $(c_E^*, w_E^*, c_S^*, w_S^*)$ and a relative price of c in terms of w , p^* , such that:

(i) For $i = E, S$, (c_i^*, w_i^*) maximizes (2) subject to $p^*c_i + w_i = m_i(p^*)$, where

$$\begin{aligned} m_E(p^*) &= p^*[\sigma + (1 - \sigma)q(g_E, g_S)]c + (1 - \sigma)q(g_E, g_S)w \\ m_S(p^*) &= p^*(1 - \sigma)(1 - q(g_E, g_S))c + [\sigma + (1 - \sigma)(1 - q(g_E, g_S))]w; \end{aligned}$$

and,

(ii) $c_E^* + c_S^* = c$ and $w_E^* + w_S^* = w$.

The first condition requires that each country choose its consumption to maximize utility subject to its budget constraint, with both expenditures and budget constraints evaluated at the competitive equilibrium price. The second condition requires that the markets for both goods clear.

Solving the model backwards starting with the third stage, it can be shown that, for any given choice of guns, the equilibrium relative price of c (i.e., the relative price that clears world markets) is the following:

$$p^* = \frac{\alpha}{1 - \alpha} \frac{w}{c} = \frac{\alpha}{1 - \alpha} \frac{R_S - g_S}{R_E - g_E}. \quad (4)$$

Note that this price depends not only on preferences (represented in this simple case by the parameter α) and endowments (R_E and R_S), but also on the amount of arming chosen by the two countries. An exogenous increase in arming by country E increases the scarcity and the relative price of the final good it produces, c ; by the same token, an increase in arming by country S increases the scarcity and the relative price of its produced final good, w .

The equilibrium price in (4), by definition, takes as the initial allocation the distribution of c and w across the two countries after each country has captured some of the other country's output—i.e., following stage 2 of the game. If, however, we were to consider as the “initial” allocations those after arming levels have been chosen in the first stage (1) and compare them to the final competitive equilibrium allocations, the implicit exchange ratio would generally differ from the price shown in (4). In particular, one can easily verify, using the definition of a competitive equilibrium above and equation (4), that country E 's and country S 's competitive equilibrium allocations, given g_E and g_S , satisfy respectively,

$$\frac{c_E}{c} = \frac{w_E}{w} = \sigma\alpha + (1 - \sigma)q(g_E, g_S) \quad (5a)$$

$$\frac{c_S}{c} = \frac{w_S}{w} = \sigma(1 - \alpha) + (1 - \sigma)(1 - q(g_E, g_S)). \quad (5b)$$

Thus, starting with initial endowments after arming choices have been made in stage 1, where country E owns all of its output of cloth, $c = R_E - g_E$, and country S owns all of its output of wine, $w = R_S - g_S$, the final allocations are as if E exchanged a $\sigma(1 - \alpha) + (1 - \sigma)(1 - q(g_E, g_S))$ fraction of its c for a $\sigma\alpha + (1 - \sigma)q(g_E, g_S)$ fraction of country S 's w . In fact, such an exchange that could be supported by each country's arming can be an alternative interpretation of the model. The resulting implicit or *effective* price of c in terms of w then is the following:

$$\bar{p} = \frac{\sigma\alpha + (1 - \sigma)q(g_E, g_S)}{\sigma(1 - \alpha) + (1 - \sigma)(1 - q(g_E, g_S))} \frac{R_S - g_S}{R_E - g_E}. \quad (6)$$

This price differs from p^* in (4) as two additional factors play a role in its determination: the degree of security, σ , and the appropriative shares, $q(g_E, g_S)$ and $1 - q(g_E, g_S)$.⁵ A higher degree of security σ implies that, other things being equal, \bar{p} is closer to p^* . (The two prices are equal only when there is perfect security, $\sigma = 1$.) The lower is the degree of security σ , the more prominent is the role played by the appropriative shares, $q(g_E, g_S)$ and $1 - q(g_E, g_S)$. Indeed, arming influences the effective price \bar{p} not only through its effect on output, $R_E - g_E$ and $R_S - g_S$, but also through its influence on these shares. Specifically, for country E , an increase in its arming increases its own share $q(g_E, g_S)$, decreases the share of country S $1 - q(g_E, g_S)$, and reduces its final output $c (= R_E - g_E)$. All these three effects of an increase in country E 's arming increase \bar{p} . Similarly, an increase in country S 's arming reduces the effective price \bar{p} . Thus, an increase in arming by one country (either E or S) unambiguously improves that country's terms of trade.

Of course, the choice of guns is endogenous, determined as a Nash equilibrium of the game described above. The relevant payoff functions for the two countries, given stages 2 and 3 where we take into account the competitive equilibrium (5) that is induced for any choice of guns in the first stage, can be shown to be the following:

$$V_E(g_E, g_S) = [\sigma\alpha + (1 - \sigma)q(g_E, g_S)](R_E - g_E)^\alpha (R_S - g_S)^{1-\alpha} \quad (7a)$$

$$V_S(g_E, g_S) = [\sigma(1 - \alpha) + (1 - \sigma)(1 - q(g_E, g_S))](R_E - g_E)^\alpha (R_S - g_S)^{1-\alpha}. \quad (7b)$$

Given that both countries have the same linearly homogeneous utility function (2), for any given choice of guns there is a total "surplus" (or transferable utility) that is divided among the two countries. It equals $(R_E - g_E)^\alpha (R_S - g_S)^{1-\alpha}$. The payoff functions in (7) indicate that each country's share of the surplus is a convex combination of the competitive and

⁵The difference between these two prices could be visualized within an Edgeworth box, depicting three points corresponding to the three stages: the final (stage 3) allocation, the initial (stage 1) allocation, and the interim (stage 2) allocation. The slope of the line connecting the interim (stage 2) allocation and the final allocation represents p^* , while the slope of the line connecting the initial (stage 1) allocation and the final allocation represents \bar{p} .

appropriative shares, with the weights determined by the security parameter σ . The larger is that security parameter, the more important are the competitive shares, α and $1 - \alpha$ respectively for countries E and S , and the less important are the appropriative shares, $q(g_E, g_S)$ and $1 - q(g_E, g_S)$ respectively for countries E and S , in determining the countries' shares of the surplus.

It is instructive to first examine the two limiting cases of perfect security ($\sigma = 1$) and perfect insecurity ($\sigma = 0$). We then turn to the intermediate case of partial security ($\sigma \in (0, 1)$).

2.1 Perfect security ($\sigma = 1$) as a benchmark

In the hypothetical case of perfect security, the payoff functions are those given in (7) with $\sigma = 1$:

$$V_E(g_E, g_S) = \alpha(R_E - g_E)^\alpha(R_S - g_S)^{1-\alpha} \quad (8a)$$

$$V_S(g_E, g_S) = (1 - \alpha)(R_E - g_E)^\alpha(R_S - g_S)^{1-\alpha}. \quad (8b)$$

Since arming is costly and provides no benefit in this case, neither country has an incentive to arm: $g_E^1 = g_S^1 = 0$, where the superscript 1 signifies that $\sigma = 1$. As such, the equilibrium allocations, prices, and utilities are the same as those that would obtain under competitive conditions in an economy with perfectly and costlessly enforced property rights. In particular, the equilibrium consumption levels, price, and payoffs are respectively the following:

$$\begin{aligned} c_E^1 &= \alpha R_E & \text{and} & & c_S^1 &= (1 - \alpha)R_E, \\ w_E^1 &= \alpha R_S & \text{and} & & w_S^1 &= (1 - \alpha)R_S, \\ p^{*1} &= \frac{\alpha R_S}{1 - \alpha R_E}, & & & & \\ V_E^1(0, 0) &= \alpha R_E^\alpha R_S^{1-\alpha} & \text{and} & & V_S^1(0, 0) &= (1 - \alpha)R_E^\alpha R_S^{1-\alpha}. \end{aligned} \quad (9)$$

The preference parameter α and the endowments R_E and R_S have the expected effects on equilibrium values. An increase, for example, in the relative value of the good produced by E (i.e., an increase in α) implies an advantage for that country in competitive trade. Furthermore, an increase in either country's initial endowment (R_E or R_S) increases the consumption (of c or w , respectively) of both countries and thus their payoffs.

2.2 Perfect insecurity ($\sigma = 0$)

Under perfect or complete insecurity, the payoff functions in (7) become:

$$V_E(g_E, g_S) = q(g_E, g_S)(R_E - g_E)^\alpha(R_S - g_S)^{1-\alpha} \quad (10a)$$

$$V_S(g_E, g_S) = (1 - q(g_E, g_S))(R_E - g_E)^\alpha(R_S - g_S)^{1-\alpha}. \quad (10b)$$

Our objective here is to characterize the unique interior Nash equilibrium (g_E^0, g_S^0) , which is known to exist.⁶ The equilibrium satisfies simultaneously the following first-order-conditions:

$$\begin{aligned} \frac{\partial V_E(g_E^0, g_S^0)}{\partial g_E} &= \frac{\partial q^0}{\partial g_E}(R_E - g_E^0)^\alpha(R_S - g_S^0)^{1-\alpha} \\ &\quad - \alpha q^0(R_E - g_E^0)^{\alpha-1}(R_S - g_S^0)^{1-\alpha} = 0 \end{aligned} \quad (11a)$$

$$\begin{aligned} \frac{\partial V_S(g_E^0, g_S^0)}{\partial g_S} &= -\frac{\partial q^0}{\partial g_S}(R_E - g_E^0)^\alpha(R_S - g_S^0)^{1-\alpha} \\ &\quad - (1 - \alpha)(1 - q^0)(R_E - g_E^0)^\alpha(R_S - g_S^0)^{-\alpha} = 0, \end{aligned} \quad (11b)$$

where $q^0 = q(g_E^0, g_S^0)$.

The first term of each derivative represents the marginal benefit of a small increase in a country's own arming, and it equals the resulting small change in the share received times the size of the "surplus" that is contestable by the two countries. The second term of each derivative represents the marginal cost of a small increase in a country's own arming. That marginal cost equals the marginal utility of a country's own output (which is cloth for E and wine for S) times that country's appropriative share. Thus, other things being equal, a relatively greater valuation of one country's output (for example, c , if $\alpha > \frac{1}{2}$ so that $1 - \alpha < \frac{1}{2}$) would give, as noted above, an advantage to that country in the case of perfect security (see equation (9)), but would result in a disadvantage for that country under perfect insecurity.

To explore this issue further, note that the two first-order conditions in (11) can be simplified as follows:

$$\frac{\partial q^0}{\partial g_E}(R_E - g_E^0) = \alpha q^0 \quad (12a)$$

$$-\frac{\partial q^0}{\partial g_S}(R_S - g_S^0) = (1 - \alpha)(1 - q^0). \quad (12b)$$

⁶The proofs can be found in Skaperdas and Syropoulos (1997), who analyze the more general case where the utility function is linearly homogeneous. Skaperdas (1992) presents and analyzes a similar model where $R_E = R_S$.

Combining these two expressions and rearranging yields:

$$\frac{\frac{\partial q^0}{\partial g_E}/q^0}{-\frac{\partial q^0}{\partial g_S}/(1-q^0)} = \frac{\alpha(R_S - g_S^0)}{(1-\alpha)(R_E - g_E^0)}. \quad (13)$$

Note that if $q(g_E, g_S)$ is symmetrically defined in its two arguments, and is a concave function of its first argument, then $\frac{\partial q^0}{\partial g_E}$ and $-\frac{\partial q^0}{\partial g_S}$ are decreasing in g_E and g_S respectively. Thus, $\frac{\partial q^0}{\partial g_E} < -\frac{\partial q^0}{\partial g_S}$ holds if and only if $g_E^0 > g_S^0$ holds. It follows, then, that the left hand side (LHS) of (13) is less than 1 if and only if $g_E^0 > g_S^0$. Now consider the case where $R_E = R_S$ and suppose, without loss of generality, that $g_E^0 > g_S^0$. Since the LHS of (13) is then less than 1, we must have $(1-\alpha)(R_E - g_E^0) > \alpha(R_S - g_S^0) = \alpha(R_E - g_S^0) > \alpha(R_E - g_E^0)$, which is possible only if $\alpha < \frac{1}{2} < 1 - \alpha$, or cloth is relatively less valuable than wine. In other words, provided $R_E = R_S$, country E is more powerful than country S and receives a greater share of the total surplus if and only if the good that it produces, cloth, is less valuable relative to the good that country S produces. This result, which stands in sharp contrast to what would occur under perfect competition and perfect security as shown in (9), emerges because the production of a good that is relatively more valuable in consumption implies a greater opportunity cost in arming, to put the country producing that good at a relative disadvantage in the conflict. It is worth noting that this result remains intact for fairly general specifications of $q(g_E, g_S)$ (i.e., other than that shown in (3)) and of utility functions (see Skaperdas, 1992; Skaperdas and Syropoulos, 1997).

More generally, and for any combination of initial resources R_E and R_S , an increase in the relative preference for cloth α decreases the equilibrium level of arming by country E , increases that by country S , and therefore unambiguously reduces E 's equilibrium share and increases that of country S (see Proposition 3 in Skaperdas and Syropoulos, 1997; and the Appendix to this chapter). We summarize the main comparative static results of this subsection in the following proposition.

Proposition 1. *Suppose there is perfect insecurity ($\sigma = 0$).*

- (i) *Let $R_E = R_S$. Then, the following conditions are equivalent: (a) $\alpha < 1 - \alpha$; (b) $g_E^0 > g_S^0$; and, (c) $q^0 > 1/2$.*
- (ii) *For any combination of R_E and R_S , an increase in α induces a reduction in g_E^0 and an increase in g_S^0 , and therefore a reduction in q^0 .*

Thus, an exogenous increase in the intrinsic valuation of a good that a country specializes in reduces the country's arming, power, and share of the total surplus that it receives in equilibrium. This finding might sound extreme, but note that the conditions under which it holds are extreme as well. That is, there is perfect insecurity and the terms of trade

are solely determined by the relative amounts of arming. However, the result is indicative of the overall role that higher relative valuations and scarcity for some goods can play in determining their producer's welfare, as shown in the next subsection that considers a less extreme case.

2.3 Partial security ($0 < \sigma < 1$)

The relevant payoff functions in the intermediate case of imperfect (or partial) security are the general ones in (7). The Nash equilibrium (g_E^*, g_S^*) can be derived from conditions analogous to (12). In particular, the equilibrium conditions imply (where an “*” indicates evaluation at the equilibrium point):

$$(1 - \sigma) \frac{\partial q^*}{\partial g_E} (R_E - g_E^*) = \alpha [\sigma \alpha + (1 - \sigma) q^*] \quad (14a)$$

$$(1 - \sigma) \left(-\frac{\partial q^*}{\partial g_S}\right) (R_S - g_S^*) = (1 - \alpha) [\sigma(1 - \alpha) + (1 - \sigma)(1 - q^*)]. \quad (14b)$$

As in the case of perfect insecurity in (12), the LHS of each equation is proportional to the marginal benefit of arming and the right hand side (RHS) of each equation is proportional to the marginal cost of arming. Each LHS of (14) equals that of (12) multiplied by $1 - \sigma$, the degree of insecurity. Not surprisingly, the marginal benefit of arming is lower the greater is security. Each RHS of (14) differs from that in (12) only in that q^0 is replaced by $\sigma \alpha + (1 - \sigma) q^*$ for E and $1 - q^0$ is replaced by $\sigma(1 - \alpha) + (1 - \sigma)(1 - q^*)$ for S . Given that α is a determinant of the marginal cost of arming for E and $1 - \alpha$ is a determinant of the marginal cost of arming for S , the preferences parameter α plays a similar role that it plays in the case of perfect insecurity.

In fact, we can show, based on a similar line of reasoning similar used above to analyze (13), that when $R_E = R_S$, $g_E^* > g_S^*$ if and only if $\alpha < 1 - \alpha$. Thus, as in the case with perfect insecurity when $R_E = R_S$, other things being equal, the country that specializes in the production of the good that is valued by less also arms more than its adversary and receives a greater share of the insecure output. However, the total share of each final good received by this country need not be greater than the total share received the other country that tends to arm less. For the final shares are determined both by guns and by the competitive share (α for E and $1 - \alpha$ for S). A larger α implies a greater share for England that comes from the secure part of its endowment but it also implies a smaller share that comes from the insecure part. Which effect dominates obviously depends on the level of security σ .

As in the case of complete insecurity, for any combination of endowments R_E and R_S , an increase in α reduces the level of arming for country E relative to that of country S ,

and therefore reduces q^* . More importantly, a reduction in the level of security, σ , increases arming by both countries. The following proposition, shown in the Appendix, summarizes these findings:

Proposition 2. *Suppose there is partial security ($\sigma \in (0, 1)$).*

- (i) *Let $R_E = R_S$. Then, the following conditions are equivalent: (a) $\alpha < 1 - \alpha$; (b) $g_E^* > g_S^*$; and, (c) $q^* > 1/2$.*
- (ii) *For any combination of R_E and R_S , an increase in α induces a reduction in g_E^* relative to g_S^* , and therefore a reduction in q^* .*
- (iii) *For any combination of R_E and R_S , an increase in σ induces a reduction in both g_E^* and g_S^* .*

It is worth noting that for a sufficiently low level of security, or small σ , an increase in α implies a lower g_E^* and a higher g_S^* , consistent with the result of Proposition 1(ii), which focuses on the case of complete insecurity. For higher levels of security, however, the effects of an increase in α on equilibrium arming by the two countries is ambiguous. Nevertheless, regardless of the level of security ($\sigma \in [0, 1)$), an increase in the social value of the good in which one country specializes reduces that country's comparative advantage in conflict over insecure output.

Finally, we consider some of the welfare implications of insecurity. As a starting point, consider the benchmark case where the two countries have identical resource endowments (i.e., $R_E = R_S$) and consumers in both countries value wine and cloth equally (i.e., $\alpha = \frac{1}{2}$). Since in the presence of insecurity the two countries produce positive and equal quantities of guns—and thus share the surplus equally—both must find the equilibrium under perfect security, where no guns are produced, more appealing. In other words, in this benchmark case where the two countries are identical and the two goods are equally valued, conflict has the features of a prisoner's dilemma. Moreover, because under partial insecurity an increase in the degree of security (σ) induces both countries to produce less arms (Proposition 2(iii)), each country's welfare must be monotonically increasing in σ .

These findings, however, need not remain intact when we allow for asymmetries: $R_E \neq R_S$ and $\alpha \neq \frac{1}{2}$. Even when $R_E = R_S$, country E for example prefers conflict as long as α is sufficiently small. For in this case, as noted earlier, while a smaller α implies a smaller share of the total surplus for country E that comes from the secure part of its endowment, it also implies a larger share that comes from the insecure part. Given some degree of insecurity ($\sigma \in [0, 1)$), if α is sufficiently small, the latter effect dominates such that country E receives a greater total share of the surplus, and these gains to E swamp the increased costs of arming reflected in a smaller total surplus, relative to the case of complete

security.⁷ By the same token, if α is sufficiently large, country S will prefer some degree of insecurity $\sigma \in [0, 1)$ to none at all. The logic follows more generally when $R_E \neq R_S$. Not surprisingly, then, an increase in security need not be welfare-improving for country E if α is sufficiently small or for country S if α is sufficiently large. The following proposition summarizes these results, which are shown in the Appendix:

Proposition 3. *For any combination of R_E and R_S ,*

- (i) *country $i = E$ ($i = S$) will prefer some conflict to none if α is sufficiently small (large); and*
- (ii) *if α is sufficiently small (large) then the welfare of country $i = E$ ($i = S$) need not be monotonically increasing in the degree of security σ .*

For most of human history, long-distance trade has been taking place in the face of high insecurity. Both the level of insecurity and the attempts by each country to mitigate the level of insecurity, primarily through arming, can only have economic consequences in ways not predicted by traditional models. Production of goods is endogenous to arming decisions, and preferences have unexpected and seemingly perverse effects on what each country receives in the end. Market prices or shadow prices reflect not only the effect of arming to divert endowments away from the production of final consumption goods, but also the influence of arming along with insecurity in the determination of how much each side receives.⁸

Of course, given the structure of this model consisting of only two countries, one might naturally attribute the distortions induced by conflict to terms of trade effects. However, as shown in the next section, the distortionary influence of conflict on equilibrium outcomes does not hinge on such effects.

⁷Indeed, in the case of partial security ($\sigma \in [0, 1)$), country E 's share of the total surplus and thus its welfare is strictly positive as α approaches to zero; by contrast, in the case of complete security ($\sigma = 1$), E 's share of the surplus vanishes and thus its welfare approaches zero.

⁸One might view the model of this section as having no relevance to the modern world; however, the following statement by former President of Germany Koehler suggests otherwise:

“A country of our size, with its focus on exports and thus reliance on foreign trade, must be aware that military deployments are necessary in an emergency to protect our interests, for example, when it comes to trade routes, for example, when it comes to preventing regional instabilities that could negatively influence our trade, jobs and incomes.” Horst Köhler, former President of Germany (NY Times, May 31, 2010)

It is interesting to add that, almost immediately after having made this statement, former President Koehler felt compelled to resign, not because the statement is untrue, but probably because of its bluntness. The apparent taboo in politics of even uttering statements like that quoted above might have its counterpart within economics, making research and models that allow for the interdependence of security and trade policies rare.

3 A Model with Insecure Resources

Whereas the model of the previous section can be considered Ricardian in its emphasis on differences in technologies across countries, in this section we turn to a model that is an outgrowth of the Heckscher-Ohlin model of trade that assumes identical technologies. One other difference is that, in the model of this section insecurity is confined to one input. Furthermore, whereas the model of the last section considered two “large” countries, the model of this section consists of two “small” countries; their arming decisions influence autarkic prices, but not world prices.

The model is that found in Skaperdas and Syropoulos (2001) and is a special case of Garfinkel et al. (2010). Consider two countries, with each country $i = E, S$ possessing T_i units of secure land and L_i units of secure labor. There are, in addition, T_0 units of insecure land that the two countries contest. Land is valuable because it contains *oil* (or water, minerals, and any other valuable resource). One unit of land produces one unit of oil, and there is no alternative use. In contrast, labor can be used to produce on a one-to-one basis *guns* and/or *butter*. Then, letting g_i denote the quantity of guns under country i 's control, the maximal production of butter in country i is $L_i - g_i$.

As in the previous section, consumers in both countries have preferences defined over the two final goods—oil and butter; and, these preference take the Cobb-Douglas form:

$$U_i(O_i, B_i) = O_i^\alpha B_i^{1-\alpha}, \quad (15)$$

where $\alpha \in (0, 1)$ and O_i and B_i are the aggregate quantities of oil and butter respectively consumed in country $i = E, S$.

Arming determines the division of the disputed land T_0 (and the associated quantity of oil) between the two countries. Following the strategy of the previous section, we suppose that the share going to each country i , $q(g_E, g_S)$ for $i = E$ and $1 - q(g_E, g_S)$ for $i = S$, depends on the arming by both countries. But, here we use the particular specification in (3). Thus, we write the share going to country $i = E, S$ as $q_i = \frac{g_i}{g_E + g_S}$.

The stages of interactions between the two countries are also analogous to those in the previous section:

Stage 1. Arming levels g_E and g_S are chosen simultaneously. These choices determine the production of butter in the two countries (i.e., $B_i = L_i - g_i$).

Stage 2. Arming levels also determine how the insecure land is distributed. Country E ends up with total endowment of land that equals $T_E + q_E T_0$ and country S ends up with an endowment of $T_S + q_S T_0$. Those endowments of land also equal the production of oil in each country.

Stage 3. Butter and oil are traded competitively either (i) domestically within each country under autarky or (ii) internationally with each country taking world prices as given.

Let p_i denote the price of oil (and land) in country i relative to butter (as well as relative to guns and labor). Then, for any given choice of guns, the value of country i 's income or revenue is

$$R_i = p_i(T_i + q_i T_0) + (L_i - g_i), \quad i = E, S. \quad (16)$$

Note that a larger level of arming chosen by one country, g_i given g_j for $j \neq i$, has two opposing effects on that country's income. It raises the country's income R_i because it increases the country's share of the contested oil T_0 , but also reduces the country's income because less labor is available for the production of butter.

Solving the consumer's problem of maximizing the utility function in (15) subject to the budget constraint that the country's aggregate expenditure is equal to the value of its income in (16) yields the following indirect utility functions:

$$V_i = \gamma p_i^{-\alpha} R_i = \gamma p_i^{-\alpha} [p_i(T_i + q_i T_0) + (L_i - g_i)], \quad (17)$$

where $\gamma \equiv \alpha^\alpha (1 - \alpha)^{1-\alpha}$ for $i = E, S$. The term $\gamma p_i^{-\alpha}$ represents the marginal utility of income for country $i = E, S$. As one can verify, country i 's demand and supply of oil, given the countries' arming choices and the outcome of the conflict, are respectively $\alpha R_i / p_i$ and $T_i + q_i T_0$. Therefore, country i 's excess demand for oil, contingent on the conflict outcome, is

$$M_i = \frac{\alpha R_i}{p_i} - [T_i + q_i T_0], \quad (18)$$

which is positive when the country imports oil and negative when the country exports oil.

The effect of arming on a country's welfare need not be confined to its effect on income. In addition, particularly in the case of autarky, arming can influence welfare through its effect on prices. We next explore the implications for arming and welfare for the two countries under *autarky* and under completely *free trade* with both countries being small in world markets and therefore taking the world price of oil as given. To simplify, let $L_i = L$ for both $i = E, S$. Furthermore, let T denote the whole supply of land and let $T_i = \frac{\sigma}{2} T$ for both $i = E, S$, where σ denotes the fraction of all land that is secure and non-contested. It then follows that $T_0 = (1 - \sigma)T$.

3.1 Autarky

In the case of autarky, individuals in each country consume only the quantities that are produced domestically. Letting superscript A identify variables in an autarkic equilibrium, this restriction implies that $M_i^A = 0$ for $i = E, S$. Then, from (18) with (16), one can easily verify that, for any given choices of arming by the two countries, the market clearing relative price of oil (and, consequently, of the relative price of land) in country i is given by

$$p_i^A = \frac{\alpha}{1 - \alpha} \left[\frac{L_i - g_i}{T_i + q_i T_0} \right] = \frac{\alpha}{1 - \alpha} \left[\frac{L - g_i}{T[\frac{1}{2}\sigma + q_i(1 - \sigma)]} \right], \quad i = E, S. \quad (19)$$

Despite the absence of international trade, this expression is analogous to the price in (4), with preferences (as reflected in the parameter α) and relative endowments of labor and land determining the price. Here, an exogenous change in a country's arms has an unambiguous effect on the autarkic price. Specifically, an increase in country i 's gun production reduces the domestic supply of butter and, as a result of the increased share of contested land, increases the domestic supply of oil; thus, an increase in country i 's gun production reduces the autarkic price.

By substituting (19) into (17) or, equivalently, by simply substituting the country's endowments after arming into the utility function (15), we obtain the relevant payoff function for each country (at the beginning of stage 1). It can be shown that each country's optimizing choice of guns (g_E^A, g_S^A) in an autarkic equilibrium satisfies

$$p_i^A(1 - \sigma)T \frac{\partial q_i^A}{\partial g_i} - 1 = 0, \quad i = E, S. \quad (20)$$

The first term represents the marginal benefit of guns and equals the value of the additional land (or oil) obtained by increasing arms by one unit. The second term consists only of the price of guns.⁹ Using (19) and (20) with (3), we find that the Nash equilibrium is symmetric, with both countries choosing the following level of arming:

$$g^A = \frac{1}{4}p^A(1 - \sigma)T = \frac{\alpha(1 - \sigma)}{2(1 - \alpha) + \alpha(1 - \sigma)}L. \quad (21)$$

As shown in this solution, arming under autarky is proportional to labor L , increasing in the relative importance of oil in consumption (α), and increasing in the proportion of land that is insecure ($1 - \sigma$). By substituting (21) in (19) we obtain the equilibrium autarkic

⁹As suggested by the earlier discussion, each country's choice of arms influences its own autarkic price. However, the effect of this influence on the optimizing choice of guns vanishes due to the equilibrium requirement that the excess demand for oil be equal to zero under autarky (i.e., $M_i^A = 0$ for $i = E, S$).

price in each country:

$$p^A = \frac{\alpha}{1-\alpha} \frac{2L}{T} \left[\frac{2(1-\alpha)}{2(1-\alpha) + \alpha(1-\sigma)} \right]. \quad (22)$$

Note that the term inside the brackets in (22) is maximized at 1 when security problems are absent ($\sigma = 1$). Hence, some insecurity ($\sigma < 1$) drives a wedge between the resulting equilibrium price p^A and that which would emerge in the hypothetical case of perfect security (denoted by p^{A1}). This wedge, which implies that $p^A < p^{A1}$, arises as insecurity induces the countries to arm, thereby diverting labor resources away from the production of butter. The greater is the degree of insecurity (i.e., the smaller is σ), the greater is the wedge, and thus the lower is p^A relative to p^{A1} .

This same bracketed term also appears in the equilibrium payoff for each country:

$$V_i^A = V^A = \left[\frac{2(1-\alpha)}{2(1-\alpha) + \alpha(1-\sigma)} \right]^{1-\alpha} (T/2)^\alpha L^{1-\alpha} \quad i = E, S. \quad (23)$$

Thus, equilibrium payoffs under autarky are decreasing in the level of insecurity as well. We summarize the equilibrium outcome under autarky in the following:

Proposition 4. *Under Autarky where the two contending countries are identical,*

- (i) *the equilibrium domestic price (p^A) is strictly increasing in the degree of security σ and, therefore, is lower than the domestic autarkic price that obtains when security is perfect (p^{A1}); and,*
- (ii) *equilibrium welfare (V^A) is strictly increasing in the degree of security σ and, therefore, is lower than the level of welfare that obtains when security is perfect (V^{A1}).*

3.2 Free trade

Suppose now that in stage 3 both countries participate in the world market with oil and butter traded freely at a relative price p for oil. Since the two countries are small, they take this world price as given. Country i 's payoff function $V_i^F(g_E, g_S)$ under trade can be obtained from (17) by replacing p_i with p . With these payoffs, we can now determine the two countries' equilibrium arming levels, denoted by (g_E^F, g_S^F) . The equilibrium conditions have a seemingly strong resemblance to those in the case of autarky in (20):

$$p(1-\sigma)T \frac{\partial q_i^F}{\partial g_i} - 1 = 0, \quad i = E, S. \quad (24)$$

Nevertheless, because p is now exogenous, whereas the price in the case of autarky was endogenous to arming, the resulting equilibrium does not have to be similar to the one

under autarky. Under free trade as in the case of autarky, the marginal cost of guns is identical for the two countries; however, in the case of free trade, an important component of the marginal benefit of guns—namely, the price of oil and land—is also identical for the two countries. These two forces work together to “*level the playing field*,” as they equalize arming across the two countries.¹⁰

Specifically, assuming that the labor constraint is not binding for either economy (i.e., $g_i < L$), the Nash equilibrium choices of guns for the two countries under free trade are identical and equal to the following:

$$g^F = \frac{1}{4}p(1 - \sigma)T, \quad i = E, S. \quad (25)$$

This level of arming under free trade is proportional to size and price of the contested land, in contrast to the level of arming under autarky, which is proportional to the labor endowment. Of course, when the world price of oil and the size of the contested resource—which also depends on the degree of security—are sufficiently large, the labor constraint is binding. For simplicity, we maintain the assumption that the labor constraint is non-binding so that $L > \frac{1}{4}p(1 - \sigma)T$. Then, the equilibrium payoffs under free trade are:

$$V_i^F(p) = V^F(p) = \gamma p^{-\alpha} \left(\frac{1}{4}pT(1 + \sigma) + L \right) \quad i = E, S. \quad (26)$$

Clearly, this equilibrium payoff, like that under autarky, is strictly increasing in the degree of security σ .

When all factors and goods are perfectly secure, welfare is a strictly quasi-convex function of the world price p , attaining its minimum at the autarkic price, $p = p^A$. Hence, under perfect security, trade at any world price other than the autarkic price implies an increase in welfare, reflecting the familiar gains from trade. In the presence of insecurity, however, the endogeneity of arming implies that factor endowments available for the production of goods that can be traded are also endogenous; and, in general, welfare need not be minimized at the autarkic price. In fact, it can be verified from (26) that $V^F(p)$ is minimized at

$$p^{\min} = \frac{\alpha}{1 - \alpha} \frac{2L}{T} \frac{2}{1 + \sigma}. \quad (27)$$

Given some degree of insecurity (i.e., any $\sigma < 1$), this critical price is strictly greater than the autarkic price p^A shown in (22). The importance of this point will become apparent

¹⁰This effect emerges under free trade even when the secure endowments of land (T_i) and labor (L_i) are asymmetrically distributed across the two countries; by contrast, the symmetric equilibrium emerges under autarky only if the countries have identical secure land and labor endowments. Garfinkel et al. (2010) show under more general production structures, where both land and labor are used to produce both consumption goods and arms, and under a more general specification for utility that free trade induces a greater tendency for arms equalization than does autarky.

shortly when we compare the welfare levels that countries attain under autarky and trade, to which we turn in the next subsection. First, we summarize the main findings of this subsection.

Proposition 5. *Under Free Trade where the two contending countries are identical,*

- (i) *the welfare minimizing world price (p^{\min}) is strictly decreasing in the degree of security σ and is strictly greater than the equilibrium domestic autarkic price (p^A); and*
- (ii) *equilibrium welfare (V^F) is strictly increasing in the degree of security σ and, therefore, is lower than the level of welfare that obtains when security is perfect (V^{F1}).*

But, before turning to our comparison of the outcomes under the two trade regimes, we consider one more implication of conflict for free trade—namely, comparative advantage. Combining equation (18) with the conflict technology (3), the expression for income (16) under the assumption that the two countries have identical secure resource endowments and the solution for arming (25), we can write country i 's net imports of oil as

$$M_i^F = -\frac{1}{4}T[2(1 - \alpha) + \alpha(1 - \sigma)] + \frac{\alpha}{p}L \quad i = E, S. \quad (28)$$

One can easily verify from this expression that the two countries will be net exporters of oil when $p > p^A$ where p^A is as shown in (22), and net importers otherwise. Using equation (28) with $\sigma = 1$, we can also find the level of oil imports in the hypothetical case of no conflict:

$$M_i^{F1} = -\frac{1}{2}T(1 - \alpha) + \frac{\alpha}{p}L \quad i = E, S. \quad (29)$$

In this case, the two countries will be net exporters of oil when $p > p^{A1}$ where p^{A1} is as shown in (22) with $\sigma = 1$, and net importers otherwise. But, as established in Proposition 4(i), the autarkic price with some degree of insecurity is strictly less than the autarkic price under perfect security: $p^A < p^{A1}$. Thus, there exists a range of world prices, $p \in (p^A, p^{A1})$, under which the contending countries export oil, but would be importing oil if resources were perfectly secure.¹¹ Thus, the shadow of power can distort the countries' apparent comparative advantage. But, also note from (28) that, for any given world price, the greater is the degree of insecurity (i.e., the lower is σ), the smaller is the country's net imports of oil. As such, the shadow of power more generally distorts trade flows.

¹¹See also Dal Bo and Dal Bo (2004 and this volume), as well as Garfinkel, et al. (2008), who find a similar result in the context of domestic insecurity and free trade.

3.3 Comparing autarky with free trade

Given our characterization above of the equilibrium outcomes under autarky and free trade, we now turn to compare them in terms of arming and welfare. We start with the level of arming. As shown earlier, the level of arming under autarky (21) depends only on endowments and the other parameters of the model. By contrast, the level of arming under free trade (25) depends critically on the world price and positively so. Then, using (21) and (25) with the solution for the equilibrium price under autarky (22), one can show that

$$g^F \begin{matrix} \geq \\ \leq \end{matrix} g^A \text{ if and only if } p \begin{matrix} \geq \\ \leq \end{matrix} p^A. \quad (30)$$

When the world price of oil is relatively high, land and the oil it contains are relatively more valuable so as to induce greater arming by both countries. To be more precise, for world prices above p^A implying the countries export oil, their incentive to arm is greater than that under autarky; and, for world prices below p^A implying that the countries import oil, their incentive to arm is less than that under autarky.¹²

We now turn to the welfare comparison under the two trade regimes. As this comparison reveals, there are two critical forces at work here. First, as noted above in section 3.2, we have the well known gains from trade that favor trade over autarky. Second, as we have just seen, trade influences the countries' incentive to contest the insecure resource; whether this effect favors trade over autarky depends on whether the world price is less than or greater than the autarkic price.

To proceed, note first that the payoffs under free trade are identical to those under autarky when the world price equals the autarkic price: $V^F(p^A) = V^A$. Furthermore, recall that $V^F(p)$ is a strictly quasi-convex function of the world price, reaching its minimum at p^{\min} . This strict quasi-convexity implies that there exists another price $p' > p^{\min}$, uniquely defined by the condition $V^F(p') = V^A$. Since p^{\min} as shown in (27) is greater than p^A (Proposition 5(i)), there exists a range of world prices under which autarky dominates free trade for both countries—namely, $p \in (p^A, p')$ —as illustrated in Figure 1. For world prices within this range, the payoffs for both countries under autarky are strictly greater than the payoffs they enjoy under free trade; for world prices outside that range, $p \leq p^A$ or $p \geq p'$, the payoffs for both countries under free trade are at least as high as the payoffs under autarky.¹³ These findings are summarized in the following proposition:

¹²Dal Bo and Dal Bo (2004 and this volume) and Garfinkel et al. (2008) yield an analogous finding in a setting with domestic insecurity.

¹³One can show further that the range of world prices under which autarky strictly dominates trade is increasing in the degree of insecurity. The proof is similar to that of an analogous result shown Garfinkel et al. (2008), who consider among other things the effects of *domestic* conflict on the relative appeal of free trade.

Proposition 6. *When the world price of oil is between p^A and p' , welfare under autarky is higher than welfare under free trade; otherwise, welfare under free trade is higher.*

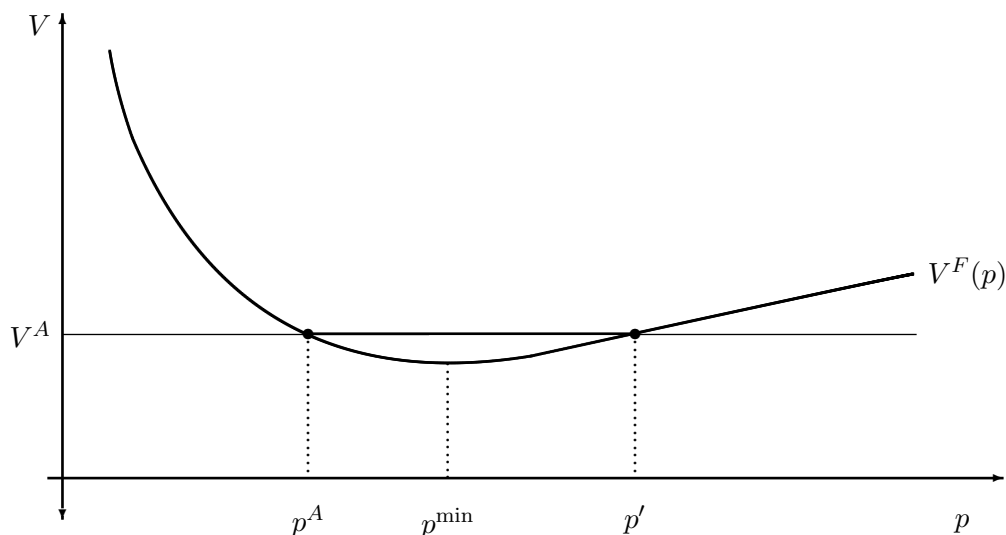


Figure 1: Welfare comparison

The intuition for these findings draws on the two key forces noted above: (i) the familiar gains from trade and (ii) the induced (strategic) effects on arming and the associated costs of insecurity. When the world price for oil (p) is less than the autarkic price (p^A), the production of guns under trade is lower. In this case, switching from an autarkic regime to a free trade regime reduces each country's incentive to contest the disputed resource. This strategic effect represents a benefit that reinforces the familiar gains from trade to make welfare unambiguously higher in a free-trade regime than that under autarky. However, as the world price of oil rises and approaches p^A , the conflict between the two nations intensifies and the strategic benefit falls, as do the gains from trade. At the autarkic price, the costs of insecurity are just as large under free trade as they are under autarky, so that the strategic benefit from trade goes to zero along with the gains from trade. Thus, at $p = p^A$, welfare under autarky equals welfare under free trade, as shown in Figure 1.

As the world price rises above the autarkic level, the conflict between the two countries intensifies further, implying that the strategic effect of trade generates a welfare cost relative to the outcome under autarky (i.e., a higher burden of guns). Of course, at the same time, the gains from trade rise above zero. However, these gains are swamped by the higher burden of guns; thus, as the world price of oil rises above the autarkic price, welfare under free trade falls below its autarkic level. Yet, as Proposition 6 indicates, when the world price of oil becomes sufficiently high ($p > p'$), the gains from winning the valuable land and selling the oil in the global marketplace become very large and outweigh the welfare cost of

guns.

4 Concluding Remarks

Throughout most of human history, trade has taken place within insecure environments, where property rights are not well defined or enforced—in both domestic and international settings. While the costs borne by states, organizations, and individuals in trying to self-enforce property rights are substantial, such costs and more generally the shadow of power have not been formally incorporated into traditional economic thinking.

In this chapter, we have explored the robustness of some of the central results of traditional trade theory to power considerations between nations. The analysis has shown that prices depend on arming and more generally power. This dependence implies in the context of the augmented Ricardian model, contrary to traditional theory where power considerations are ignored, that the country producing the more socially valued good faces a higher opportunity cost of arming and thus a comparative disadvantage in power. In the context of the augmented Heckscher-Ohlin model, this dependence has implications for the appeal of free trade relative to that of autarky. Indeed, for some range of world prices, autarky will be dominated by free trade. The analysis has shown further that, depending on the world price, a country's comparative advantage in the presence of insecurity might be opposite to that predicted by the traditional theory that abstracts from insecurity.

Key to the analysis of both models is the level of security, represented by σ —a parameter that we have treated as exogenous. An obviously important issue is what determines the level of security. The continual fighting between England and France during the 18th century took place mostly in the high seas and in their respective colonies. As such, only trade of goods and resources that did not have to be transported by ship to-and-from the colonies could be considered secure. The long nineteenth century that ended with the First World War was relatively peaceful among the European powers. However, most international trade then was taking place within each European power's sphere of influence, and thus security was not necessarily much greater than it had been in the 18th century. To be sure, not many wars broke out during this period; but, there was considerable arming that accelerated during the last two decades of that era. The gradual expansion of formal diplomacy, the marriages and blood relations among European royalty, and perhaps emerging norms of international conduct served as checks on the insecurity that existed then. After the Second World War, these emerging norms along with the dismal experience of warfare crystallized into a number of international organizations and institutions that significantly increased perceived security in interstate relations. With the creation of the United Nations and the collective security norms that developed, it became considerably harder for one country to attack another, possibly resulting in a lower level of arming than what might have occurred

otherwise. The creation of the Steel and Coal Union that evolved into the current European Union is another example of the organizations and institutions that dramatically increased the level of security among some formerly mortal enemies. Whereas France and Germany were such enemies before World War II, now there is no visible insecurity in any of the resources and goods traded between them.

The level of security, then, depends on international institutions and norms that prevail in any particular era. But security can also be expected to depend partly on the actions of the states themselves vis-à-vis one another. By maintaining embassies, for example, in each others' capital, states can reduce the chance of accidental wars, and engage in confidence-building measures that increase the perceived security of trade across them. The institution-building that France and Germany and other European countries undertook after World War II is an even more obvious example of the endogeneity of the level of security to the actions of states. The process is not dissimilar to state-building by different factions within countries as modeled by McBride et al. (2010).

Another type of state action, however, that can be deleterious to the security of any two given states is the influence of third parties, usually states that can be considered great powers. European countries that previously had high levels of contact and security in their dealings before World War II, suddenly became enemies after the war because they fell on either side of the divide created by the Cold War. That is not an historically atypical condition. Before World War II, for example, smaller states in the periphery of the European Great powers had to choose which Great power with whom to ally, a choice that automatically implied that they would become enemies with neighbors who chose to ally with a rival power.

More generally, even without consideration of third party intervention, alliance formation would seem to matter for security. As surveyed by Bloch (this volume), a number of scholars have examined the determinants of alliances formation, but have not considered explicitly the role of trade. We conjecture that different trade regimes imply potentially different sets of stable alliances of countries, which is an important topic for future research.

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A Appendix

Proof of proposition 1. Part (i) was established in the text, and part (ii) has been shown in Skaperdas and Syropoulos (1997). However, we also prove part (ii) below in the proof to the next proposition, as a special case.

Proof of proposition 2.

Part i. Suppose that $R_E = R_S$. Combining the two expressions in (14), we obtain the following:

$$\begin{aligned} \frac{\partial q^*}{\partial g_E} (R_E - g_E^*) (1 - \alpha) [\sigma(1 - \alpha) + (1 - \sigma)(1 - q^*)] \\ = -\frac{\partial q^*}{\partial g_S} (R_S - g_S^*) \alpha [\sigma\alpha + (1 - \sigma)q^*]. \end{aligned} \quad (\text{A.1})$$

Now suppose that $g_E^* > g_S^*$. Then we have the following:

- $q^* > \frac{1}{2} > 1 - q^*$;
- $\frac{\partial q^*}{\partial g_E} < -\frac{\partial q^*}{\partial g_S}$, when $q(g_E, g_S)$ is concave (convex) in its first (second) argument, as is the case with the Tullock form of the contest success function (3); and,
- $R_E - g_E^* < R_S - g_S^*$.

These three inequalities imply

$$\begin{aligned} \frac{\partial q^*}{\partial g_E} (R_E - g_E^*) (1 - \alpha) [\sigma(1 - \alpha) + (1 - \sigma)(1 - q^*)] \\ < -\frac{\partial q^*}{\partial g_S} (R_S - g_S^*) (1 - \alpha) [\sigma(1 - \alpha) + (1 - \sigma)q^*]. \end{aligned} \quad (\text{A.2})$$

But, (A.1) and (A.2) together imply,

$$\begin{aligned} -\frac{\partial q^*}{\partial g_S} (R_S - g_S^*) (1 - \alpha) [\sigma(1 - \alpha) + (1 - \sigma)q^*] \\ > -\frac{\partial q^*}{\partial g_S} (R_S - g_S^*) \alpha [\sigma\alpha + (1 - \sigma)q^*]. \end{aligned} \quad (\text{A.3})$$

Since $-\partial q^*/\partial g_S > 0$, this expression can hold if and only if

$$\begin{aligned} (1 - \alpha) [\sigma(1 - \alpha) + (1 - \sigma)q^*] &> \alpha [\sigma\alpha + (1 - \sigma)q^*] \Leftrightarrow \\ (1 - \alpha)^2 \sigma + (1 - \alpha)(1 - \sigma)q^* &> \alpha^2 \sigma + \alpha(1 - \sigma)q^* \Leftrightarrow \\ (1 - 2\alpha)(1 - \sigma)q^* &> [\alpha^2 - (1 - \alpha)^2] \sigma. \end{aligned}$$

This last inequality is only possible if $\alpha < \frac{1}{2}$; otherwise, the LHS would be non-positive and the RHS would be non-negative, thus negating the strict inequality.

Parts ii and iii. For notational convenience, let $V_i \equiv V_i(g_E, g_S)$ for $i = E, S$ and $\beta \equiv \sigma/(1 - \sigma)$. In what follows, we sometimes omit the equilibrium symbol “*” to avoid clutter, but one should keep in mind that functions are to be evaluated at the Nash equilibrium. The optimizing choices of g_E and g_S must satisfy respectively the following conditions:

$$\frac{\partial V_E}{\partial g_E} = V_E \left[\frac{\frac{\partial q}{\partial g_E}}{\beta\alpha + q} - \frac{\alpha}{R_E - g_E} \right] = 0 \quad (\text{A.4a})$$

$$\frac{\partial V_S}{\partial g_S} = V_S \left[\frac{-\frac{\partial q}{\partial g_S}}{\beta(1 - \alpha) + (1 - q)} - \frac{1 - \alpha}{R_S - g_S} \right] = 0. \quad (\text{A.4b})$$

Using the specification of the CSF shown in (3) and letting $\bar{G} = g_E + g_S$,¹⁴ we can rewrite g_E and g_S as $g_E = q\bar{G}$ and $g_S = (1 - q)\bar{G}$, respectively. Furthermore, the specification in (3) implies that $\partial q/\partial g_E = (1 - q)/\bar{G}$ and $\partial q/\partial g_S = -q/\bar{G}$. Substituting these relationships into (A.4a) and (A.4b) yields the following:

$$\frac{(1 - q)/\bar{G}}{\beta\alpha + q} - \frac{\alpha}{R_E - q\bar{G}} = 0 \quad (\text{A.5a})$$

$$\frac{q/\bar{G}}{\beta(1 - \alpha) + 1 - q} - \frac{1 - \alpha}{R_S - (1 - q)\bar{G}} = 0. \quad (\text{A.5b})$$

Now solve (A.5a) and (A.5b) for \bar{G} and label the resulting solutions \bar{G}_E and \bar{G}_S , respectively. Then, for given factor endowments R_E and R_S , define

$$\begin{aligned} \Phi(q, \alpha, \beta) &\equiv \bar{G}_E - \bar{G}_S \\ &= \frac{(1 - q)R_E}{q(\alpha + 1 - q) + \alpha^2\beta} - \frac{qR_S}{(1 - q)(1 - \alpha + q) + (1 - \alpha)^2\beta}. \end{aligned} \quad (\text{A.6})$$

Φ is continuous in q , $\lim_{q \rightarrow 0} \Phi = R_E/(\alpha^2\beta) > 0$, and $\lim_{q \rightarrow 1} \Phi = -R_S/[(1 - \alpha)^2\beta] < 0$; therefore, by the implicit function theorem, there exists a $q^* = q^*(\alpha, \beta)$ such that $\Phi(q^*, \alpha, \beta) = 0$.

¹⁴We use this particular specification to keep matters as simple as possible; however, the results hold more generally.

Differentiating Φ with respect to q , α and β gives respectively,

$$\Phi_q = - \left\{ \frac{R_E [\alpha + \alpha^2\beta + (1-q)^2]}{[q(\alpha + 1 - q) + \alpha^2\beta]^2} + \frac{R_S [1 - \alpha + (1 - \alpha)^2\beta + q^2]}{[(1-q)(1 - \alpha + q) + (1 - \alpha)^2\beta]^2} \right\} \quad (\text{A.7a})$$

$$\Phi_\alpha = - \left\{ \frac{R_E(1-q)(q + 2\alpha\beta)}{[q(\alpha + 1 - q) + \alpha^2\beta]^2} + \frac{R_S q [1 - \alpha + 2(1 - \alpha)\beta]}{[(1-q)(1 - \alpha + q) + (1 - \alpha)^2\beta]^2} \right\} \quad (\text{A.7b})$$

$$\Phi_\beta = - \frac{R_E \alpha^2 (1-q)}{[q(\alpha + 1 - q) + \alpha^2\beta]^2} + \frac{R_S (1 - \alpha)^2 q}{[(1-q)(1 - \alpha + q) + (1 - \alpha)^2\beta]^2}. \quad (\text{A.7c})$$

Notice that the sign of Φ_β is ambiguous, whereas the signs of Φ_q and Φ_α are both negative. Moreover, since $\Phi_q < 0$, the equilibrium share q^* is unique.

Now, consider how q^* responds to an exogenous increase in α . By the implicit function theorem, we have $dq^*/d\alpha = -\Phi_\alpha/\Phi_q$. Since Φ_α and Φ_q are both negative, $dq^*/d\alpha < 0$ for all $\alpha \in (0, 1)$, which establishes part (ii) of the proposition, and suggests that g_E^* falls relative to g_S^* as α rises.

This finding, however, does not necessarily imply that g_E^* is decreasing or that g_S^* is increasing in α . Consider the influence of an exogenous increase in α on g_E^* , for example, noting that $\bar{G}^* = \bar{G}^{E*}$, which implies $g_E^* = q^* \bar{G}^{E*}$. Differentiation of $g_E^* = q^* \bar{G}^{E*}$ appropriately yields the following:

$$\begin{aligned} \frac{dg_E^*}{d\alpha} &= q \frac{d\bar{G}^*}{d\alpha} + \left(\bar{G}^* + q \frac{d\bar{G}^*}{dq} \right) \frac{dq^*}{d\alpha} = q \frac{d\bar{G}^*}{d\alpha} + \left(\bar{G}^* + q \frac{d\bar{G}^*}{dq} \right) \left[-\frac{\Phi_\alpha}{\Phi_q} \right] \\ &= -\frac{R_E q (1-q)(q + 2\alpha\beta)}{[q(\alpha + 1 - q) + \alpha^2\beta]^2} + \frac{R_E \alpha [q^2 + (2q - 1)\alpha\beta]}{[q(\alpha + 1 - q) + \alpha^2\beta]^2} \left[\frac{\Phi_\alpha}{\Phi_q} \right]. \end{aligned}$$

Generally, this expression cannot be signed. However, it is worth considering what happens in the case of complete insecurity, where $\sigma = 0$ and thus $\beta = 0$ (Proposition 2(ii)). In this case, the expression above simplifies as follows:

$$\begin{aligned} \left. \frac{dg_E^*}{d\alpha} \right|_{\beta=0} &= -\frac{R_E(1-q)}{(\alpha + 1 - q)^2} + \frac{R_E \alpha}{(\alpha + 1 - q)^2} \left[\frac{\frac{R_E(1-q)}{q(\alpha+1-q)^2} + \frac{R_S q}{(1-q)(1-\alpha+q)^2}}{\frac{R_E[\alpha+(1-q)^2]}{q^2(\alpha+1-q)^2} + \frac{R_S[1-\alpha+q^2]}{(1-q)^2(1-\alpha+q)^2}} \right] \\ &= -\frac{R_E \Theta}{(\alpha + 1 - q)^2 \Phi_q}, \end{aligned} \quad (\text{A.8})$$

where¹⁵

$$\Theta = - \left[\frac{R_E(1-q)^2}{q^2(\alpha + 1 - q)} - \frac{R_S(1 - \alpha - \alpha q + q^2)}{(1-q)(1 - \alpha + q)^2} \right] = -\frac{2(1 - \alpha)\bar{G}}{q(1 - \alpha + q)} < 0.$$

¹⁵The second equality below can be verified by using the definitions of \bar{G}^{E*} and \bar{G}^{S*} (both of which equal \bar{G}^* in equilibrium) given in connection with (A.6) to eliminate R_E and R_S .

Since $-\Phi_q > 0$ and $q \leq 1$, the sign of the expression in (A.8) equals the sign of Θ , which is negative as indicated above. Thus, when $\sigma = 0$, an increase in α implies a decrease in g_E^* . Analogous calculations show that an increase in α implies an increase in g_S^* . Hence, an exogenous increase in α induces a decrease in q^* .

Turning to the effects of a change in security σ and thus $\beta = \sigma/(1 - \sigma)$, first note that, since the sign of Φ_β is ambiguous, we cannot sign $dq^*/d\beta = -\Phi_\beta/\Phi_q$. However, we can sign the effect of an exogenous change in security on arming by both countries. To proceed, recall that $\bar{G}^* = \bar{G}^{E*}$, which implies $g_E^* = q^*\bar{G}^{E*}$. Now differentiate the latter expression to obtain

$$\begin{aligned} \frac{dg_E^*}{d\beta} &= q \frac{d\bar{G}^*}{d\beta} + \left(\bar{G}^* + \frac{d\bar{G}^*}{dq} \right) \frac{dq^*}{d\beta} = q \frac{d\bar{G}^*}{d\beta} + \left(\bar{G}^* + \frac{d\bar{G}^*}{dq} \right) \left[-\frac{\Phi_\beta}{\Phi_q} \right] \\ &= -\frac{R_E \alpha^2 q (1-q)}{[q(\alpha+1-q) + \alpha^2 \beta]^2} - \frac{R_E \alpha [q^2 + \alpha(2q-1)\beta]}{[q(\alpha+1-q) + \alpha^2 \beta]^2} \left[\frac{\Phi_\beta}{\Phi_q} \right]. \end{aligned}$$

Simplifying leads us to conclude that $\text{sign}(dg_E^*/d\beta) = -\text{sign}(\Omega)$, where

$$\Omega \equiv \frac{R_E \alpha (1-q)^2}{q(\alpha+1-q) + \alpha^2 \beta} + \frac{R_S q [(1-\alpha)^2 q (q + \alpha\beta) + \alpha(1-\alpha+q^2)(1-q)]}{[(1-q)(1-\alpha+q) + (1-\alpha)^2 \beta]^2} > 0.$$

It follows that $dg_E^*/d\beta < 0$. Similar calculations show that $dg_S^*/d\beta < 0$. Hence, an increase in security (σ and thus β) unambiguously reduces arming by both countries, as claimed in part (iii) in the proposition.

Proof of Proposition 3.

Part i: Let $Z^k \equiv (R_E - g_E)^\alpha (R_S - g_S)^{1-\alpha}$ denote the total surplus under security regime k ($= 1, *$) and observe that, from Proposition 2(iii), $Z^* < Z^1$. Focusing on $i = E$, to prove the first point, it is sufficient to show that, for any $\sigma \in [0, 1)$, $\lim_{\alpha \rightarrow 0} V_E^* > \lim_{\alpha \rightarrow 0} V_E^1$. This sufficiency is so for the following reason. Since, as was noted in the text above, $V_E^* < V_E^1$ for $\alpha = \frac{1}{2}$ and equilibrium payoffs are continuous in α , the inequality implies that there will exist an $\tilde{\alpha} \in (0, \frac{1}{2})$ such that $V_E^* = V_E^1$ for $\alpha = \tilde{\alpha}$ and $V_E^* > V_E^1$ for all $\alpha \in [0, \tilde{\alpha})$. Furthermore, since $Z^k = V_E^k + V_S^k$ and $Z^* < Z^1$, it follows that $V_S^* < V_S^1$ for all $\alpha \in [0, \tilde{\alpha})$. By the same logic, we also can establish the existence of an $\tilde{\alpha} \in (\frac{1}{2}, 1)$ such that $V_S^* = V_S^1$ for $\alpha = \tilde{\alpha}$, with $V_S^* > V_S^1$ and $V_E^* < V_E^1$ for all $\alpha \in (\tilde{\alpha}, 1]$.

To proceed, let $b_S(g_E)$ and $b_E(g_S)$ denote the best-response functions of countries S and E , respectively. It is straightforward to verify from (14) that, as $\alpha \rightarrow 0$, the functions

satisfy the following

$$b_S(g_E) = \max(0, \sqrt{(1-\sigma)g_E(g_E + R_S)} - g_E)$$

whereas $b_E(g_S) = R_E$ for $g_S > 0$ and $b_E(0)$ equals any $g_E \in (0, R_E]$.¹⁶ One can verify now that the Nash equilibrium in guns is given by:

$$(g_E^*, g_S^*) = \begin{cases} (R_E, \sqrt{(1-\sigma)R_E(R_E + R_S)} - R_E) & \text{if } \sigma \in \left[0, \frac{R_S}{R_E + R_S}\right]; \\ \left(\frac{1-\sigma}{\sigma}R_S, 0\right) & \text{if } \sigma \in \left(\frac{R_S}{R_E + R_S}, 1\right). \end{cases} \quad (\text{A.9})$$

Substituting these values into (7a) with $\alpha = 0$ yields the following equilibrium welfare value for country $i = E$:

$$\lim_{\alpha \rightarrow 0} V_E^* = \begin{cases} R_E(1-\sigma) \left(\sqrt{\frac{R_E + R_S}{R_E(1-\sigma)}} - 1 \right) & \text{if } \sigma \in \left[0, \frac{R_S}{R_E + R_S}\right]; \\ R_S(1-\sigma) & \text{if } \sigma \in \left(\frac{R_S}{R_E + R_S}, 1\right). \end{cases} \quad (\text{A.10})$$

Notice that $\lim_{\alpha \rightarrow 0} V_E^* > 0$ for all resource endowments and $\sigma \in [0, 1)$. By contrast, from (8a) with $\alpha = 0$, $\lim_{\alpha \rightarrow 0} V_E^1 = 0$. Thus, $\lim_{\alpha \rightarrow 0} V_E^* > \lim_{\alpha \rightarrow 0} V_E^1$ for $\sigma \in [0, 1)$.

Part ii: That V_E^* is not necessarily increasing in security (σ) follows from inspection of the first part of (A.10), which reveals that, in the neighborhood of $\alpha = 0$, V_E^* could be decreasing, increasing or non-monotonic in σ for $\sigma \leq \frac{R_S}{R_E + R_S}$.

¹⁶Recalling that $\beta \equiv \sigma/(1-\sigma)$, the definition of $b_S(g_E)$ reveals that $b_S(g_E) > 0$ for all $g_E \in (0, R_S/\beta)$ and $b_S(g_E) = 0$ for all other g_E values.