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A game-theoretic analysis of international trade and political conflict over external territories

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Abstract For analyzing conflict between two large open countries over external territories rich in natural resources, we develop a game-theoretic model of trade under resource appropriation possibilities. We show that greater trade openness (by lowering trade costs) reduces the overall intensity of arming when the adversary countries are symmetric in all dimensions. This finding is consistent with the liberal peace hypothesis that trade reduces conflict. We further analyze how equilibrium is affected by differences in national resource endowments. The resulting asymmetric equilibrium reveals that arming by the more endowed country exceeds that of the less endowed country and the two adversaries respond to lower trade costs differently: the more endowed country cuts back on its arming, whereas the less endowed country may increase it. Under resource endowment asymmetry, the aggregate arming allocations of the adversaries could increase despite greater trade openness.

Keywords Disputes over external territories · Trade openness · Conflict intensity

JEL Classification D30 · D74 · F10 · F51 · F52

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1 Introduction

How does greater trade openness affect the arming decisions of large open countries that have political disputes over external territories (e.g., overseas islands or fishing grounds near coastal waters) whose property rights are not well defined or enforced, especially when the territories have a rich abundance of natural resources? Viewed from a different angle, how do conflicts over external resource-rich territories affect the trading relationship between two adversaries? In this paper, we attempt to explore those questions by developing a game-theoretic model of trade wherein two adversaries may engage in armed confrontation over resources in external territories. The scenario characterized by both economic interdependence through trade and political disputes about overseas resources serves as a heuristic framework for investigating the liberal peace hypothesis that trade has pacifying effects on interstate conflicts.

The present study is motivated by the renewed interest in the trade-conflict nexus associated with recent (or historical) interstate disputes over the sovereignty of certain external or overseas territories. One recent case of interest concerns China and Vietnam. Vietnam's imports from China represent more than 30% of her total volume of imports. Also, China represents one of Vietnam's most important trading partners. Yet their dispute over the parcels of land in the South China Sea, which are rich in valuable resources such as minerals and fishing grounds, has been in the headlines of political discussions between the two countries' officials for decades. Another case of interest involves the political conflict between Japan and Russia in connection with the southern Kuril Islands, which are rich in natural resources and have a sizable source of income from tourism. Although Japan counts among the largest trading partners of Russia, their disputes over the islands have not yet been resolved. The third case is an historical one relating to the Falklands Conflict (also known as the Falklands War) between Argentina and the United Kingdom over British overseas territories in the South Atlantic. Those territories are rich in oil and gas, among other valuable resources. These three cases, despite their differences when viewed from the political perspectives of territorial expansion and geopolitics, share two things in common from the economic perspectives of resource appropriation and international trade. One issue concerns how conflicts over external territories affect the trading relationship between two adversary countries, and the other concerns how greater trade openness affects the intensity of conflict (measured as the aggregate expenditures on armaments) between the adversaries. We make no attempt to analyze the historical origins or specific causes of territorial and resource conflicts. Rather, we wish to identify conditions under which the liberal peace proposition is valid when trading nations have conflicts over external territories rich in natural resources.

The analysis with this paper can be viewed as a subset of the broader picture regarding how globalization fostered by lower trade costs (i.e., a greater degree of economic interdependence owing to trade) affects interstate armed conflicts.[1] Empirical research to study the correlation between international trade and political conflicts begins with Polachek (1980). Using panel data on 30 countries for a period of 10 years, the author shows that trade among nations significantly reduces the intensities of their conflicts. Following Polacheck's (1980) seminal work, numerous researchers have turned their attentions to

[1] See, e.g., Findlay and O'Rourke (2010), who discuss the general issues of natural resources, conflict and trade from an historical perspective. For other contributions that investigate resource-based disputes, see, e.g., Acemoglu et al. (2012), and Garfinkel et al. (2015).

analyzing the general validity of the liberal peace hypothesis.[2] The empirical findings in the literature do not reveal a high degree of consensus on the trade-conflict nexus, however.[3] As a theoretical underpinning, Skaperdas and Syropoulos (2001) develop a conflict model of trade when two small open countries have disputes over a valuable resource (e.g., oil) indispensable for producing tradable goods. The authors show that when international price of the contested resource exceeds its autarkic price, the opportunity cost of arming declines. In that case, bilateral trade prompts competition for the disputed resource, causing each contending country's arming to increase. Garfinkel et al. (2015) present a variant of the Heckscher–Ohlin model to analyze interstate disputes over resources. They find that if trade promotes adversary countries to export goods that are intensive in disputed-resource, it may intensify interstate conflict so much that autarky is preferable to free trade. In analyzing the trade causes of war, Martin et al. (2008, 2012) find that expanding the number of member countries within a regional trade bloc reduces the economic dependency between any pair of adversaries which, in turn, makes war between them more likely.

Starting with a conflict-theoretic framework of trade and external resource appropriation, we derive several new results that are summarized as follows. (1) For two large open countries that have disputes over external territories rich in natural resources, each country's arming has three different effects. The first is an export-revenue effect since arming causes export prices and revenue to go up. The resulting increase in export revenue reflects the marginal revenue (MR) of arming. The second is an import-expenditure effect since arming cause import prices and spending to increase. The third is an output-distortion effect which causes domestic production of consumption goods to fall. The aggregation of the second and third effects reflects the marginal cost (MC) of arming. In a conflict equilibrium, each country's arming is determined endogenously by equating marginal revenue (MR) with marginal cost (MC). (2) Based on the MR = MC conditions for determining the arming decisions of two resource-conflict countries, we show that greater trade openness (by lowering trade costs) reduces conflict intensity when the adversaries are symmetric in all dimensions (e.g., national endowments, production technology and consumer preferences). This finding provides a theoretical justification for the liberal peace hypothesis that trade reduces conflict. (3) For the case where there are differences in national resource endowments, we show the existence of an asymmetric equilibrium at which arming by the more endowed country exceeds that by the less endowed country. The two adversaries respond to lower trade costs differently: the more endowed country cuts back on arming, but the less endowed country may increase arming. We find that, under resource endowment asymmetry, the overall intensity of arming may increase despite greater trade openness.

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[2] For studies that present empirical evidence on the correlation between trade, conflict and related issues, see, e.g., Polachek (1992), Barbieri (1996), Barbieri and Levy (1999), Reuveny and Kang (1998), Polachek et al. (1999), Barbieri and Schneider (1999), Anderton and Carter (2001), Mansfield and Pollins (2001, 2003), Levy and Barbieri (2004), Kim and Rousseau (2005), and Glick and Taylor (2010).

[3] The book by Mansfield and Pollins (2003) contains studies of the trade and conflict debate. The contribution by Oneal and Russett (1999) supports Polachek (1980) and shows that strengthening the extent of trade openness between contending countries effectively can reduce their conflicts in terms of overall armament expenditures. Nevertheless, some studies (e.g., Kim and Rousseau 2005) find that the pacifying effect of greater trade openness can be neutral; other studies (e.g., Barbieri 1996) find that extensive trade linkages may increase the probability of armed conflicts. Barbieri and Levy (1999) show that war does not have significant impacts on trading relationships between adversaries.

The remainder of the paper is organized as follows. Section 2 presents a conflict-theoretic model of trade between two countries having disputes over an external territory rich in resource inputs. We determine equilibrium arming for each country under symmetry in all aspects. In Sect. 3, we characterize trade and conflict equilibrium when two adversaries are different in terms of national resource endowments. We then study how the resulting asymmetric equilibrium is affected by greater trade openness. Section 4 concludes.

2 The analytical framework

2.1 Basic assumptions

We consider a world of two countries (denoted A and B) having disputes over the property rights of a territory, which is located outside their respective national boundaries. The territory is either an island, a parcel of external land, or a newly discovered maritime fishing ground. This external territory is rich in valuable natural resource (e.g., minerals, fish and wildlife, natural gas, or oil), which can be used as an intermediate input by each country to produce a country-specific final good for domestic consumption or for exportation. We assume that the "undetermined" status of the external territory constitutes the primary cause of conflict between the two large open countries. Our aim is to see how the adversaries determine their productive and appropriative activities, as well as the relationship between conflict and trade.

Owing to their political disputes over the undetermined territory, country A (respectively, country B) chooses to produce G_A (respectively, G_B) guns for occupying the territory and, hence, obtaining the resource input for final good production. In the event of appropriation, the probability that country $i (i = A, B)$ is able to obtain the contested resource is represented by a canonical "contest success function" (CSF) that reflects the technology of conflict (see Tullock 1980; Hirshleifer 1989; Skaperdas 1996) as follows:

$$\Psi_i = \frac{G_i}{G_A + G_B} \text{ for } G_A + G_B > 0; \quad \Psi_A = \Psi_B = \frac{1}{2} \text{ for } G_A = G_B = 0. \tag{1}$$

Let the amount of natural resource endowment possessed by country $i (i = A, B)$ be given as R_i, which is inalienable. Assume that the total amount of resource input in the external territory is $Z(>0)$. That resource input can be used by country A to produce a consumption good, denoted as X; on the other hand, the resource input can be used by country B to produce a different consumption good, denoted as Y. In other words, either A or B can utilize the external resource as an intermediate input in producing a country-specific product. The setup is analogous to the Ricardian world in which a single resource input is used by two countries to produce different tradable goods.

For analytical simplicity and tractability, we assume that one unit of each country's resource endowment is required to produce either one unit of its consumption good or one unit of armaments. In addition, one unit of the resource input is able to produce one unit of a country-specific final good. Given the CSF in (1) and in the event of fighting to acquire Z, country A's total production of final good X is:

$$X_A = R_A - G_A + \left(\frac{G_A}{G_A + G_B}\right)Z, \tag{2a}$$

where the last term measures the amount of the good produced from the appropriated resource input. Given the CSF in (1), country B's total output of final good Y is:

$$Y_B = R_B - G_B + \left(\frac{G_B}{G_A + G_B}\right)Z, \tag{2b}$$

where the last term is the amount of the good produced from the appropriated resource input.

As for consumer preferences in country A, we consider a symmetric quadratic utility function: $U(D_X, M_Y) = \alpha(D_X + M_Y) - (D_X^2 + M_Y^2)/2$, where D_X is consumption of the final good X produced domestically and M_Y is consumption of the final good Y imported from country B. Corresponding to the quadratic preferences, market demands for the domestic good X and the imported good Y in country A are:

$$D_X = \alpha - P_X \text{ and } M_Y = \alpha - P_Y, \tag{3a}$$

where $\alpha(>0)$ is the quantity intercept, and P_X and P_Y are, respectively, the domestic prices of final goods X and Y in the country. We assume that α is greater than the quantity of the endowed resource R_A when market prices are zero, that is, $\alpha > R_A$.

Likewise, we consider a symmetric quadratic utility function for country B as $V(D_Y, M_X) = \alpha(D_Y + M_X) - (D_Y^2 + M_X^2)/2$, where D_Y is consumption of the final good Y produced domestically and M_X is consumption of the final good X imported from country A. Corresponding to the quadratic preferences, market demands for the domestic good Y and for the imported good X in country B are:

$$D_Y = \alpha - H_Y \text{ and } M_X = \alpha - H_X, \tag{3b}$$

where α is the quantity intercept, and H_Y and H_X are, respectively, the domestic prices of goods Y and X in the country. We again assume that α is greater than the quantity of the endowed resource R_B when market prices are zero, that is, $\alpha > R_B$.

Based on the market demands in (3a) and (3b), we calculate benefits to consumers in the two countries in terms of consumer surplus as follows:

$$CS_A = \frac{1}{2}(D_X^2 + M_Y^2) \text{ and } CS_B = \frac{1}{2}(D_Y^2 + M_X^2). \tag{4}$$

Producer surplus in country A (respectively, country B) is measured by the total value of final good production, $P_X X_A$ (respectively, $P_Y Y_B$). We have from X_A in (2a) and Y_B in (2b) that

$$PS_A = P_X\left[R_A - G_A + \left(\frac{G_A}{G_A + G_B}\right)Z\right] \text{ and } PS_B = P_Y\left[R_B - G_B + \left(\frac{G_B}{G_A + G_B}\right)Z\right]. \tag{5}$$

With resource appropriation possibilities, country $i(i = A, B)$ determines an arming allocation G_i to maximize its aggregate payoff (Π_i), which is specified as

$$\Pi_i = CS_i + PS_i, \tag{6}$$

where CS_i and PS_i (for $i = A, B$) are given in (4) and (5).[4] We consider a simultaneous-move game in which countries A and B independently determine their arming allocations G_A and G_B.

2.2 Trade and conflict equilibrium under symmetry

We proceed to characterize trade equilibrium in the presence of conflict over the external territory where resource Z is located. In the analysis, we incorporate the CSFs as specified in (1) into the Bagwell and Staiger (1997) framework of international trade between two large open economies.[5]

For country A, the production of good X, X_A, minus domestic consumption, D_X, yields the amount of the good that country B imports, M_X. It follows from (2a), (3a) and (3b) that

$$\left[R_A - G_A + \left(\frac{G_A}{G_A + G_B}\right)Z\right] - (\alpha - P_X) = (\alpha - H_X). \tag{7}$$

For country B, the total production of good Y, Y_B, minus domestic consumption, D_Y, yields the amount of the good that country A imports, M_Y. It follows from (2b), (3a) and (3b) that

$$[R_B - G_B + (\frac{G_A}{G_A + G_B})Z] - (\alpha - H_Y) = (\alpha - P_Y). \tag{8}$$

Denote t_i as trade cost (per unit of output) that country i $(i = A, B)$ incurs when exporting a final good to the market in its rival.[6] To maintain the trade patterns as described, we note the comparative advantage principle that a country exports a good whose price in its own domestic market plus unit trade cost can never exceed the good's price in an importing country's market. To satisfy this principle, we follow Bagwell and Staiger (1997) to impose the non-arbitrage conditions for trade in final goods X and Y:

[4] Conflicts between nations for valuable resources reflect international competition for rents through *non-market means*. We hypothesize that each nation has an aggregate payoff function and devotes efforts or resources into international rent-seeking activities (i.e., fighting) for more resources. We abstract our analysis from destruction costs. For studies on conflict that takes into account the endogeneity of destruction costs see, e.g., Sanders and Walia (2014), and Chang et al. (2015), and Chang and Luo (2017).

[5] The modeling approach herein thus stands in contrast to the traditional assumption of "small open economies" in neoclassical international trade analysis, wherein trading nations accept the prices of tradable goods in their world markets under perfect competition.

[6] We thank an anonymous referee for valuable suggestions to consider reinforcement of borders as part of arming expenditures. This makes trade costs to be determined endogenously determined by arming choices. To focus on disputes over an external territory, our analysis abstracts from conflict over national endowments, which are taken to be secured. That is, the analysis abstracts from border issues of the contending countries. Our simple analysis considers arming expenditures by each country as the number of guns required for occupying the territory so as to acquire its valuable resource or intermediate input for final good production. The term "trade costs" refers to the purely economic costs of engaging in bilateral trade according to the traditional international economics analysis. One advantage of this traditional treatment of trade costs is to see how economic decisions (in exporting and importing different final goods) affects military decisions (in terms of conflict-related resources allocated to armaments production). For ease of showing the relationship between trade decisions and military decisions, we consider trade costs to be exogenous in the analysis. The endogeneity of trade costs would add analytical complexity. We wish to pursuit this interesting extension in our future research.

$$P_X + t_X \leq H_X \text{ and } H_Y + t_Y \leq P_Y. \tag{9\&10}$$

Making use of (7)–(10) and considering the equality conditions in (9) & (10) along with the symmetric assumption that $t_X = t_Y = t$, we solve for the equilibrium prices of the final goods:

$$H_X = \frac{2\alpha - X_A + t}{2}, \quad P_X = \frac{2\alpha - X_A - t}{2}, \quad H_Y = \frac{2\alpha - Y_B - t}{2}, \quad P_Y = \frac{2\alpha - Y_B + t}{2}, \tag{11}$$

where X_A and Y_B are given in (2a) and (2b). As shown in Appendix 1, we can further derive the equilibrium prices of the final goods, consumer surplus, and producer surplus in terms of arming by the two countries, G_A and G_B.

Substituting the market price P_X from (11) back into the market demand D_X in (3a) and making use of X_A in (2a), we calculate country A's domestic consumption of good X:

$$D_X = \alpha - \left(\frac{2\alpha - X_A - t}{2}\right) = \frac{X_A}{2} + \frac{t}{2} = \frac{1}{2}\left[R_A + \left(\frac{G_A}{G_A + G_B}\right)Z - G_A\right] + \frac{t}{2}.$$

It follows that

$$\frac{\partial D_X}{\partial G_A} = -\frac{(G_A + G_B)^2 - G_B Z}{2(G_A + G_B)^2} < 0 \quad \text{if } Z < \frac{(G_A + G_B)^2}{G_B}. \tag{12}$$

Equation (12) shows that country A's arming has a negative effect on domestic consumption of good X, under the inequality condition that $Z < (G_A + G_B)^2 / G_B$. It is plausible to assume that this inequality holds.[7] The economic reason why the derivative $\partial D_X / \partial G_A$ has a negative sign should be explained. When country A allocates more resources to arming, it has fewer resources available for producing good X. A reduction in the production of good X causes the good's market price to go up. Country A's consumption of good X thus declines along with its arming.

Substituting the market price P_Y from (11) into the demand function $M_Y = \alpha - P_Y$ in (3a), making use of Y_B in (2b), we calculate country A's import demand for good Y:

$$M_Y = \alpha - \left(\frac{2\alpha - Y_B + t}{2}\right) = \frac{1}{2}Y_B - \frac{t}{2} = \frac{1}{2}\left[R_B + \left(\frac{G_A}{G_A + G_B}\right)Z - G_B\right] - \frac{t}{2}.$$

It follows that

$$\frac{\partial M_Y}{\partial G_A} = -\frac{\partial P_Y}{\partial G_A} = -\frac{G_B Z}{2(G_A + G_B)^2} < 0. \tag{13}$$

Equation (13) indicates that country A's arming negatively affects the consumption of good Y imported from its adversary. The economic reason is as follows. An increase in arming by country A forces country B to increase its arming. Country B then has fewer resources with which to produce its final good Y. The price of good Y will increase to

[7] For the case of symmetry in all dimensions that shall be discussed in the latter part of this section, we see that this inequality condition implies that $Z < 4G$, where $G = G_A = G_B$. The inequality condition then indicates that $G > Z/4$. That is, each country's arming is strictly greater than a quarter of its national resource endowment.

reflect its scarcity. As a result, country A's import demand for good Y falls, explaining why A's arming affects its import demand negatively.

Following CS_A in (4), we see that the effect of country A's arming on consumer surplus is:

$$\frac{\partial CS_A}{\partial G_A} = D_X \frac{\partial D_X}{\partial G_A} + M_Y \frac{\partial M_Y}{\partial G_A} < 0, \tag{14}$$

where the negative sign in (14) follows directly from (12) and (13). The result in (14) implies that A's arming affects domestic consumers negatively.

As for the effect of A's arming on domestic producers, we have from PS_A in (5) that

$$\frac{\partial PS_A}{\partial G_A} = P_X \frac{\partial X_A}{\partial G_A} + X_A \frac{\partial P_X}{\partial G_A}, \tag{15}$$

where

$$\begin{aligned} &\frac{\partial X_A}{\partial G_A} = -\frac{(G_A+G_B)^2 - G_B Z}{(G_A+G_B)^2} < 0 \text{ and } \frac{\partial P_X}{\partial G_A} = \frac{(G_A+G_B)^2 - G_B Z}{2(G_A+G_B)^2} > 0 \\ &\quad \text{if } Z < \frac{(G_A+G_B)^2}{G_B}. \end{aligned} \tag{16}$$

When allocating more resources to arming, country A has fewer resources available for producing good X. The export price of good X will rise owing to its scarcity. The two derivatives in (16) are opposite in sign, causing the derivative $\partial PS_A/\partial G_A$ in (15) to be indeterminate. We cannot conclude unambiguously how domestic producers in country A is affected by its arming.

2.3 Decomposing the impact of a country's arming

We proceed to analyze how arming affects the aggregate payoff for each country. We look at country A first. Making use of $\partial CS_A/\partial G_A$ in (14) and $\partial PS_A/\partial G_A$ in (15), we show in Appendix 2 the detailed derivation for the impact of country A's arming on its aggregate payoff (Π_A) and record the result as follows:

$$\frac{\partial \Pi_A}{\partial G_A} = \underbrace{E_X \frac{\partial P_X}{\partial G_A}}_{\substack{\text{Export-revenue effect} \\ \text{of arming} \\ (+)}} + \underbrace{M_Y\left(-\frac{\partial P_Y}{\partial G_A}\right)}_{\substack{\text{Import-expenditure effect} \\ \text{of arming} \\ (-)}} + \underbrace{P_X \frac{\partial X_A}{\partial G_A}}_{\substack{\text{Output-distortion effect} \\ \text{of arming} \\ (-)}} \tag{17}$$

where $E_X \equiv (X_A - D_X)$ is the amount of the final good X exported from A to B.

Following from (17), we find that a country's arming contains three different terms. (1) The first term shows that country A's arming increases its export revenue since $E_X = (X_A - D_X) > 0$ and $\partial P_X/\partial G_A > 0$. This first term measures the marginal revenue of arming. (2) The second term shows that country A's arming increases its expenditure on imports from the rival country since the import price increases, $\partial P_Y/\partial G_A > 0$. (3) The third term shows that country A's arming reduces final good production since $\partial X_A/\partial G_A < 0$. The aggregation of the last two terms (in absolute value) measures the marginal cost of arming. We thus have

Proposition 1 *For the case of bilateral trade and conflict over an external territory rich in a valuable resource input, the impact of a country's arming contains three separate effects. The first is an export-revenue effect since arming causes export prices and revenue to go up. This effect constitutes the marginal revenue of arming* (MR_i^{Arms}). *The second is an import-expenditure effect since arming causes export prices and spending to increase. The third is an output-distortion effect since arming reduces domestic production of consumption goods. The last two effects constitute the marginal cost of arming* (MC_i^{Arms}).

Proposition 1 indicates that arming by each contending country to maximize its aggregate payoff is determined where marginal revenue equals marginal cost. That is, $MR_i^{Arms} = MC_i^{Arms}$. It is straightforward to see the following corollary:

Corollary 1 *For two adversaries, the best option is not to fight over an external territory if arming is such that* $MR_i^{Arms} < MC_i^{Arms}$. *The result is a corner solution with* $G_A = G_B = 0$. *This corner solution arises when the export-revenue effect is more than offset by the import-expenditure effect plus the output-distortion effect.*

Proof See Appendix 3. □

The implication of Corollary 1 is as follows. Under the circumstances where $MR_i^{Arms} < MC_i^{Arms}$, the best strategy for two adversary countries is to maintain the "status quo" without claiming the property rights of an external territory and its resources. This may help explain why not all disputes over external territories (with undetermined property rights) give rise to militarized interstate conflicts.

We consider the case of symmetry in endowed resources $(R_A = R_B = R)$ and trade costs $(t_A = t_B = t)$ when there is an interior solution for arming. Using the FOCs for countries A and B and the $MR_i^{Arms} = MC_i^{Arms}$ conditions (see Appendix 2), we solve for the Nash equilibrium level of arming for each country under symmetry $(G_A = G_B = G)$. This exercise yields

$$G^* = \frac{6R + 5Z - 8\alpha + 2t + \sqrt{K}}{12}, \tag{18}$$

where $K = 36R^2 + 12RZ + 24Rt - 96R\alpha + Z^2 + 20Zt - 32Z\alpha + 4t^2 - 32t\alpha + 64\alpha^2$. It can be verified that $G^* > 0$ if $2R + Z > 2\alpha$, which implies that $R > \alpha - Z/2$. We assume that this inequality condition holds.[8]

2.4 Comparative statics of the equilibrium arming under symmetry

It is instructive to see how each country's equilibrium arming is affected by exogenous changes in the values of Z, R, and t. Making use of G^* in (18), we show the following results (see detailed derivatives in Appendix 4):

$$\frac{\partial G^*}{\partial Z} > 0, \frac{\partial G^*}{\partial R} > 0, \text{ and } \frac{\partial G^*}{\partial t} > 0.$$

The economic implications of the derivatives are summarized in the second proposition:

[8] That condition guarantees that the equilibrium prices and quantities of the final goods are positive under symmetry.

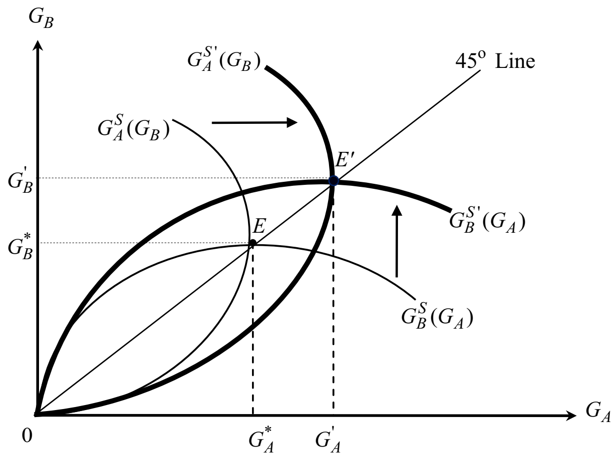


Fig. 1 An external territory with a greater amount of resource causes each country's arming to increase under symmetry

Proposition 2 *Under symmetry, the equilibrium arming by each contending country increases with the amount of the contested resource in an external territory, increases with each country's national endowment, but decreases with the size of trade costs.*

Given trade costs, we see from Fig. 1 that point E is the intersection of country A's arming reaction curve, denoted as $G_A^S(G_B)$, and country B's arming reaction curve, denoted as $G_B^S(G_A)$.[9] The symmetric arming equilibrium occurs at point E, $\{G_A^*, G_B^*\}$, which is lying on the 45-degree degree line. An exogenous increase in the amount of the contested resource Z causes country A's arming reaction curve to shift outward and country B's arming reaction curve to shift upward. In equilibrium, the contending countries increase their arming allocations, i.e., $G_A^{'} > G_A^*$ and $G_B^{'} > G_B^*$.

Figure 2 presents a graphical interpretation of the result that decreases in trade costs reduce the intensity of conflict. When trade costs are lower, A's arming reaction curve shifts leftward and B's arming reaction curve shifts download. The equilibrium arming allocations of the two adversaries are such that $G_A'' < G_A^*$ and $G_B'' < G_B^*$. These results suggest that the equilibrium arming allocations under symmetry are fundamentally "strategic complements" in response to lower trade costs.[10] Figure 2 thus illustrates the validly of the liberal peace proposition that greater trade openness reduces conflict intensity and hence promotes peace.

3 Trade and conflict under asymmetry in national resource endowments

No countries are identical in terms of national resource endowments. In this section, we analyze the more general case where two adversaries fighting for an external resource-rich territory differ in their endowments of resources. In terms of the notations in our analysis,

[9] Note that country A's arming reaction curve, $G_A^S(G_B)$, is implicitly defined by its FOC that $\partial \Pi_A / \partial G_A = 0$ and country B's arming reaction curve, $G_B^S(G_A)$, is implicitly defined by its FOC that $\partial \Pi_B / \partial G_B = 0$.

[10] We thank an anonymous referee for valuable suggestions to discuss whether the arming levels are strategic substitutes or strategic complements. We find that they are strategic complements under symmetry. For the case in which there is asymmetry in national endowments, the arming levels may be strategic substitutes. We present the case of asymmetry in Sect. 3.

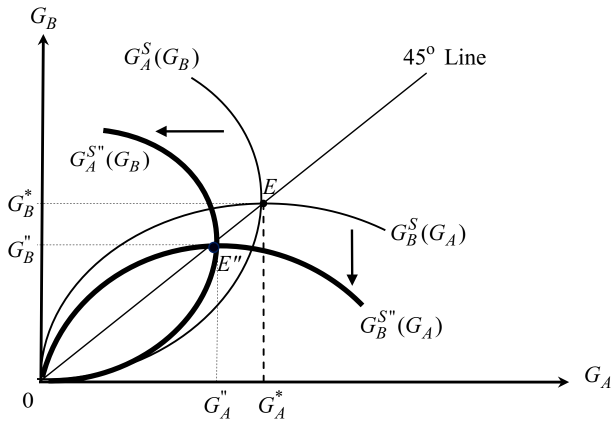


Fig. 2 Decreases in trade costs cause each country's arming to decline under symmetry

we have $R_A \neq R_B$. Two questions we wish to answer: one is how the resource endowment asymmetry affects the arming decisions of two adversary countries, the other is how the resulting equilibrium is affected by greater trade openness owing to lower trade costs. Answers to these questions have implications for whether the liberal peace proposition continues to hold under asymmetry in national resource endowments.

3.1 Effects of resource endowment asymmetry on arming and conflict intensity

Without lost of generality, we introduce a new parameter δ by assuming that $R_A = (R_o + \delta)$ and $R_B = (R_o - \delta)$, where R_o denotes the average endowment of the two-country world and $\delta(>0)$. The difference between R_A and R_B is then given as $R_A - R_B = 2\delta > 0$, which implies the assumption that country A is relatively more endowed country B.[11] An increase in the value of $\delta(>0)$ reflects that the degree of endowment asymmetry increases.

As in Sect. 2, we continue to assume that the adversary countries engage in trade. Substituting the conditions that $R_A = (R_o + \delta)$ and $R_B = (R_o - \delta)$ into the consumer and producer surplus functions of the two countries (see Eqs. 28 and 29 in Appendix 1), we show in Appendix 5 their aggregate payoff functions: $\Pi_A(G_A, G_B; \delta)$ and $\Pi_B(G_A, G_B; \delta)$. The countries determine arming levels to maximize their respective aggregate payoff functions. The FOCs are:

$$\frac{\partial \Pi_A(G_A, G_B; \delta)}{\partial G_A} = 0 \text{ and } \frac{\partial \Pi_B(G_A, G_B; \delta)}{\partial G_B} = 0. \tag{19a\&19b}$$

The FOC in (19a) defines A's arming reaction function to the arming level chosen by B, that is, $G_A = G_A(G_B; \delta)$. The FOC in (19b) defines B's arming reaction function to the arming level chosen by A, that is, $G_B = G_B(G_A; \delta)$. Given the value of δ, the two reaction functions determine the equilibrium arming allocations, $\{\tilde{G}_A, \tilde{G}_B\}$, of countries A and B under asymmetry.

[11] The parameter δ may be used to represent the country size differential between A and B in that the higher the value of δ the greater the size of country A relative to country B.

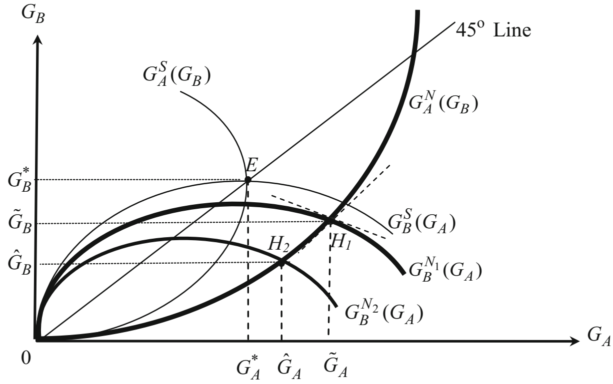


Fig. 3 Conflict intensity may increase under national endowment asymmetry

Next, we evaluate the asymmetric equilibrium, $\{\tilde{G}_A, \tilde{G}_B\}$, using the symmetric equilibrium as the baseline. This is due to the analytical intractability of finding the reduced-form solutions for $\tilde{G}_A$ and $\tilde{G}_B$. For δ being equal to zero such that $R_A = R_B = R_o$, we have the symmetric arming allocations chosen by A and B, $\{G_A^*, G_B^*\}$, where $G_A^* = G_B^*$. Fig. 3 illustrates this symmetric equilibrium at point E which lies on the 45-degree degree line. Point E is the intersection of A's arming reaction curve, $G_A^S(G_B)$, and B's arming reaction curve, $G_B^S(G_A)$.

Under resource endowment asymmetry ($\delta > 0$), we need to determine what effects an exogenous increase in δ have on the signs of the two derivatives: $\partial \Pi_A(G_A, G_B; \delta)/\partial G_A$ and $\partial \Pi_B(G_A, G_B; \delta)/\partial G_B$. Making use of $\Pi_A(G_A, G_B; \delta)$ in Appendix 5, we find that

$$\frac{\partial}{\partial \delta}\left(\frac{\partial \Pi_A(G_A, G_B; \delta)}{\partial G_A}\right) = \frac{3(G_A + G_B)^2 - 2G_B Z}{4(G_A + G_B)^2} > 0. \tag{20}$$

The positive sign in (20) indicates that country A's marginal benefit of arming, $\partial \Pi_A(G_A, G_B; \delta)/\partial G_A$, increases with δ. Country A is thus better off by increasing arming when the degree of endowment asymmetry increases, given the arming level chosen by its rival. As illustrated in Fig. 3, an increase in the degree of endowment asymmetry causes country A's arming reaction curve to move rightward to the one as shown by $G_A^N(G_B)$.

On the other hand, making use of $\Pi_B(G_A, G_B; \delta)$ in Appendix 5, we find that

$$\frac{\partial}{\partial \delta}\left(\frac{\partial \Pi_B(G_A, G_B; \delta)}{\partial G_B}\right) = -\frac{3[(G_A + G_B)^2 - G_A Z]}{4(G_A + G_B)^2} < 0. \tag{21}$$

The negative sign in (21) indicates that country B's marginal benefit of arming, $\partial \Pi_B(G_A, G_B; \delta)/\partial G_B$, decreases with δ. Country B is then better off by reducing arming when the degree of endowment asymmetry increases, given the arming level chosen by its rival. As can be seen from Fig. 3, an exogenous increase in δ causes country B's arming reaction curve to move downward to the one as shown by either $G_B^{N_1}(G_A)$ or $G_B^{N_2}(G_A)$.

There are two interesting possibilities for the asymmetric equilibrium, depending on the relative shifts of the two countries' arming reaction curves. For illustration, we assume that A's arming reaction curve is given by $G_A^N(G_B)$. The two possible cases of interest are:

Case 1 The asymmetry equilibrium occurs at point H_1, which is the intersection of $G_A^N(G_B)$ and $G_B^{N_1}(G_A)$. This implies that $\tilde{G}_A > G_A^*$, $\tilde{G}_B < G_B^*$, and $\tilde{G}_A + \tilde{G}_B > G_A^* + G_B^*$.

Case 2 The asymmetry equilibrium occurs at point H_2, which is the intersection of $G_A^N(G_B)$ and $G_B^{N_2}(G_A)$. This implies that $\hat{G}_A > G_A^*$, $\hat{G}_B < G_B^*$, and $\hat{G}_A + \hat{G}_B < G_A^* + G_B^*$.

It follows that conflict intensity is relatively lower in case 2, but is relatively higher in case 1. Note that, irrespective of the possible outcomes, the asymmetric equilibrium always occurs at a point below the 45-degree line such that $\tilde{G}_A > \tilde{G}_B$ and $\hat{G}_A > \hat{G}_B$. We thus have

Proposition 3 *Under asymmetry in national resource endowments between two adversaries, all else being equal, equilibrium arming is greater for the more-endowed country than for the less-endowed country. The overall conflict intensity under asymmetry is greater than that under symmetry, provided that the increase in arming by the more-endowment country outweighs the decrease in arming by the less-endowment country.*

Proposition 3 implies that national endowment asymmetry does not necessarily lower the intensity of conflict. This suggests that, other things being equal, whether a world with two asymmetric adversaries is "safer" than a world with two symmetric adversaries cannot be determined unambiguously.

3.2 Effects of greater trade openness under endowment asymmetry

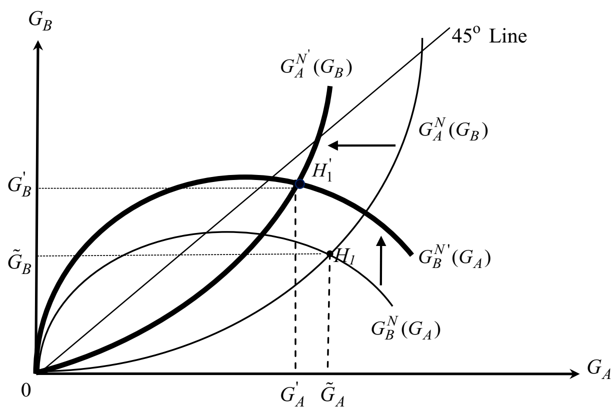
We are in a position to analyze how the asymmetric equilibrium is affected when trade costs are lower. First, we calculate the derivative of $\partial \Pi_A(G_A, G_B; \delta)/\partial G_A$ with respect to t:

$$\frac{\partial}{\partial t}\left(\frac{\partial \Pi_A(G_A, G_B; \delta)}{\partial G_A}\right) = \underbrace{-\frac{(G_A + G_B)^2 - G_B Z}{4(G_A + G_B)^2}}_{\substack{\text{Export-revenue effect} \\ \text{of arming as } t \text{ decreases} \\ (-)}} + \underbrace{\frac{G_B Z}{4(G_A + G_B)^2}}_{\substack{\text{Import-expenditure effect} \\ \text{of arming as } t \text{ decreases} \\ (+)}} + \underbrace{\frac{(G_A + G_B)^2 - G_B Z}{2(G_A + G_B)^2}}_{\substack{\text{Output-distortion effect} \\ \text{of arming as } t \text{ decreases} \\ (+)}}, \tag{22a}$$

where $\Pi_A(G_A, G_B; \delta)$ is given in Appendix 5. Combining the terms on the RHS of (22a) yields

$$\frac{\partial}{\partial t}\left(\frac{\partial \Pi_A(G_A, G_B; \delta)}{\partial G_A}\right) = \frac{1}{4} > 0. \tag{22b}$$

Fig. 4 Greater trade openness may increase conflict intensity under national endowment asymmetry



It follows from (22b) that the marginal benefit of arming for country A decreases as t decreases. This implies that, when trade costs are lower, the export-revenue effect is dominated by the aggregation of the import-expenditure effect and the output-distortion effect. Namely, the marginal revenue of arming decreases relative to the marginal cost, causing country A's arming incentive to decline. In Fig. 4, country A's arming reduction is illustrated by a leftward shift of its reaction curve from $G_A^N(G_B)$ to $G_A^{N'}(G_B)$.

Second, we examine how country B's arming affects its aggregate payoff when trade costs are lower. We calculate the derivative of $\partial \Pi_B(G_A, G_B; \delta)/\partial G_B$ with respect to t:

$$\frac{\partial}{\partial t}\left(\frac{\partial \Pi_B(G_A, G_B; \delta)}{\partial G_B}\right) = \underbrace{-\frac{(G_A + G_B)^2 - G_A Z}{4(G_A + G_B)^2}}_{\substack{\text{Export-revenue effect} \\ \text{of arming as } t \text{ decreases} \\ (-)}} + \underbrace{\frac{G_A Z}{4(G_A + G_B)^2}}_{\substack{\text{Import-expenditure effect} \\ \text{of arming as } t \text{ decreases} \\ (+)}} \underbrace{-\frac{(G_A + G_B)^2 - G_A Z}{2(G_A + G_B)^2}}_{\substack{\text{Output-distortion effect} \\ \text{of arming as } t \text{ decreases} \\ (-)}}. \tag{23a}$$

where $\Pi_B(G_A, G_B; \delta)$ is given in Appendix 5. Combining the terms on the RHS of (23a) yields

$$\frac{\partial}{\partial t}\left(\frac{\partial \Pi_B(G_A, G_B; \delta)}{\partial G_B}\right) = -\frac{3(G_A + G_B)^2 - 4G_A Z}{4(G_A + G_B)^2} > (=)(<)\, 0. \tag{23b}$$

It follows from (23b) that the sign of the derivative is indeterminate. When trade costs are lower, we cannot rule out the possibility that the export-revenue effect dominates the aggregation of the export-revenue effect and the output-distortion effect. This possibility arises when the increase in marginal revenue of arming exceeds the marginal cost, causing country B's arming incentive to go up. Figure 4 illustrates this case that country B's arming reaction curve shifts upward from $G_B^N(G_A)$ to $G_B^{N'}(G_A)$. The reaction curves $G_A^{N'}(G_B)$ and $G_B^{N'}(G_A)$ determine the new asymmetric equilibrium at a point like H_1'. Comparing H_1' to the original equilibrium at H_1, we see that

$$G_A^{'} < \tilde{G}_A, G_B^{'} > \tilde{G}_B, \text{ and } G_A^{'} + G_B^{'} > \tilde{G}_A + \tilde{G}_B.$$

This indicates that country A reduces arming whereas country B increases it. Moreover, the intensity of conflict increases when trade costs are lower. There is a decrease in arming by A (the more endowed country), but it continues to arm more than B (the less endowed country). We, therefore, have

Proposition 4 *Under asymmetry in national resource endowments, greater trade openness resulting from lower trade costs causes the more endowed country (A) to cut back on its arming. But the effect on the arming level of the less endowed country (B) can be positive, zero, or negative. The impact of greater trade openness on conflict intensity is then indeterminate.*

The economic implications of Proposition 4 is as follows. In a world where conflicting countries differ in their resource endowments, they respond to lower trade costs differently. The more abundant country finds it optimal to reduce arming. But the less abundant country may increase it when lower trade costs cause the marginal cost of arming to be lower than the marginal revenue. Under this circumstance, the overall conflict intensity could increase despite greater trade openness. The liberal peace hypothesis that trade reduces conflict may not be observed under resource endowment asymmetry.

4 Concluding remarks

In this paper, we present an economic analysis of international rent-seeking activities through non-market means. Specifically, we develop a game-theoretic model to investigate how political disputes over an external territory affects the trading relationship between two resource-conflict countries and how greater trade openness affects the intensity of arming. Instead of imposing the small-open-economy assumption, we consider trade between two large open economies under resource conflict when terms of trade are endogenously affected by their arming decisions. We show that a country's arming raises its revenue from exports, increases its spending on imports, and lowers the production of civilian goods for domestic consumption. These three different effects of arming jointly determine how resource conflict affects the equilibrium volumes of imports and exports between two adversaries, and how greater trade openness affects their optimal arming choices. For the case in which two adversaries are symmetric in all aspects, our analysis demonstrates the validly of the liberal peace proposition that trade reduces conflict.

We further analyze how conflict equilibrium is affected by differences in national resource endowments. The result is an asymmetric equilibrium such that the more endowed country arms more than the less endowed country. But the two adversaries respond to lower trade costs differently: the more endowed country is interested in arms reduction, whereas the less-endowed country may be interested in arms buildup. Under endowment asymmetry, conflict intensity could increase despite greater trade openness.

It should be mentioned that the analysis with this paper is a subset of the broader issues concerning how the economic forces of globalization through trade affect interstate conflicts. In our model, we look at the effect that conflict over external territories has on trade in final goods between two adversaries, without considering the possibility of trade in resources or intermediate inputs. This research question remains open for future investigation. The present model of conflict and trade adopts the simple assumption that one unit of resource or intermediate input is required to make one unit of a country-specific final product. In reality, two contending countries may not have the same capacity to utilize resource. Admittedly, we focus our analysis only on the case of endowment asymmetry without considering the aspect of capacity asymmetry. One interesting extension is to see how differences in the capacity of resource utilization would affect the validity of the liberal peace hypothesis.[12] Another dimension we ignore is the strategic intervention of a third country into the two-country trade and conflict over external resources.[13] We wish to pursue all these issues in our future research.

Acknowledgements We are indebted to William F. Shughart II, the Editor in Chief, and two anonymous reviewers for insightful comments and valuable suggestions, which have significantly improved the paper. An earlier version of this paper was presented in the conflict/security sessions at the International

[12] We owe thanks to an anonymous referee in providing us this important point for further study.

[13] Garfinkel and Syropoulos (2017) examine the case where two adversaries do not trade with each other but do engage in trade with a third country. For issues on how the equilibrium outcome of a two-party conflict is altered by the strategic involvement of an outside party, see Chang et al. (2007), Chang and Sanders (2009), Sanders and Walia (2014). But these three studies do not consider the possibility of bilateral trade between adversaries.

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Appendix

Appendix 1: Equilibrium prices, consumer surplus, and producer surplus

After substituting X_A from (2a) and Y_B from (2b) into the final good prices in (11), we have:

$$P_X = \frac{G_A(G_A + G_B - Z) + (2\alpha - R_A - t)(G_A + G_B)}{2(G_A + G_B)}, \tag{24}$$

$$P_Y = \frac{G_B(G_A + G_B - Z) + (2\alpha - R_B + t)(G_A + G_B)}{2(G_A + G_B)}. \tag{25}$$

$$H_X = \frac{G_A(G_A + G_B - Z) + (2\alpha - R_A + t)(G_A + G_B)}{2(G_A + G_B)}, \tag{26}$$

$$H_Y = \frac{G_B(G_A + G_B - Z) + (2\alpha - R_B - t)(G_A + G_B)}{2(G_A + G_B)}, \tag{27}$$

Substituting these equilibrium prices into the demand equations in (3), we then use Eqs. (4) and (5) to calculate consumer and producer surplus. For country A, we have

$$\begin{aligned} CS_A &= \frac{1}{2}\left[\frac{G_A(Z - G_A - G_B) + (R_A + t)(G_A + G_B)}{2(G_A + G_B)}\right]^2 \\ &\quad + \frac{1}{2}\left[\frac{G_B(Z - G_B - G_A) + (R_A - t)(G_A + G_B)}{2(G_A + G_B)}\right]^2, \\ PS_A &= \left(\frac{(2\alpha - R_A - t)(G_A + G_B) - G_A(Z - G_A - G_B)}{2(G_A + G_B)}\right) \\ &\quad \times \left[R_A - G_A + \left(\frac{G_A}{G_A + G_B}\right)Z\right]. \end{aligned} \tag{28}$$

For country B, we have

$$\begin{aligned} CS_B &= \frac{1}{2}\left[\frac{G_B(Z - G_B - G_A) + (R_B + t)(G_A + G_B)}{2(G_A + G_B)}\right]^2 \\ &\quad + \frac{1}{2}\left[\frac{G_A(Z - G_A - G_B) + (R_A - t)(G_A + G_B)}{2(G_A + G_B)}\right]^2, \\ PS_B &= \left(\frac{(2\alpha - R_B + t)(G_A + G_B) - G_B(Z - G_A - G_B)}{2(G_A + G_B)}\right)\left[R_B - G_B + \left(\frac{G_B}{G_A + G_B}\right)Z\right]. \end{aligned} \tag{29}$$

Appendix 2: Decomposing the effect of country A's arming

Making use of $\partial CS_A/\partial G_A$ in (14) and $\partial PS_A/\partial G_A$ in (15), the effect of country A's arming on its aggregate payoff is calculated as follows:

$$\begin{aligned}\frac{\partial \Pi_A}{\partial G_A} &= \frac{\partial CS_A}{\partial G_A} + \frac{\partial PS_A}{\partial G_A} = \left(D_X \frac{\partial D_X}{\partial G_A} + M_Y \frac{\partial M_Y}{\partial G_A}\right) + \left(P_X \frac{\partial X_A}{\partial G_A} + X_A \frac{\partial P_X}{\partial G_A}\right)\\ &= D_X \frac{\partial D_X}{\partial G_A} + M_Y \frac{\partial M_Y}{\partial G_A} + P_X \frac{\partial X_A}{\partial G_A} + X_A\left(-\frac{\partial D_X}{\partial G_A}\right)\\ &= \left[-(X_A - D_X)\frac{\partial C_X}{\partial G_A}\right] + M_Y\left(\frac{\partial M_Y}{\partial G_A}\right) + P_X \frac{\partial X_A}{\partial G_A} \quad \left(\text{noting that } \frac{\partial M_Y}{\partial G_A} = -\frac{\partial P_Y}{\partial G_A}\right)\\ &= (X_A - D_X)\frac{\partial P_X}{\partial G_A} + \left[M_Y\left(-\frac{\partial P_Y}{\partial G_A}\right)\right] + P_X \frac{\partial X_A}{\partial G_A}\end{aligned}$$

The above derivative can further be re-written as $\frac{\partial \Pi_A}{\partial G_A} = E_X \frac{\partial P_X}{\partial G_A} + M_Y\left(-\frac{\partial P_Y}{\partial G_A}\right) + P_X \frac{\partial X_A}{\partial G_A}$. Similarly, country B determines an arming allocation G_B that solves the following maximization problem: $\underset{\{G_B\}}{\text{Max}}\, \Pi_B = CS_B + PS_B$, where CS_B and PS_B are consumer and producer surplus as given in Appendix 1. We decompose the effect of country B's arming into three separate terms:

$$\frac{\partial \Pi_B}{\partial G_B} = \underbrace{E_Y \frac{\partial P_Y}{\partial G_B}}_{\substack{\text{Export-revenue effect}\\ \text{of arming}\\ (+)}} + \underbrace{M_X\left(-\frac{\partial P_X}{\partial G_B}\right)}_{\substack{\text{Import-expenditure effect}\\ \text{of arming}\\ (-)}} + \underbrace{P_Y \frac{\partial Y_B}{\partial G_B}}_{\substack{\text{Output-distortion effect}\\ \text{of arming}\\ (-)}}$$

where $E_Y \equiv (Y_B - D_Y)$ is the amount of the final good Y exported from B to A.

Alternatively, we can use (14)–(16) to decompose the effect of country A's arming into three separate terms explicitly in terms of G_A and G_B as follows:

$$\begin{aligned}\frac{\partial \Pi_A}{\partial G_A} &= \frac{\partial CS_A}{\partial G_A} + \frac{\partial PS_A}{\partial G_A}\\ &= \left(D_X \frac{\partial D_X}{\partial G_A} + M_Y \frac{\partial M_Y}{\partial G_A}\right) + \left(P_X \frac{\partial X_A}{\partial G_A} + X_A \frac{\partial P_X}{\partial G_A}\right)\\ &= D_X\left(-\frac{(G_A+G_B)^2 - G_B Z}{2(G_A+G_B)^2}\right) + M_Y\left(-\frac{G_B Z}{2(G_A+G_B)^2}\right)\\ &\quad + P_X\left(-\frac{(G_A+G_B)^2 - G_B Z}{(G_A+G_B)^2}\right) + X_A\left(\frac{(G_A+G_B)^2 - G_B Z}{2(G_A+G_B)^2}\right)\\ &= \underbrace{(X_A - D_X)\left[\frac{(G_A+G_B)^2 - G_B Z}{2(G_A+G_B)^2}\right]}_{\substack{\text{Export-revenue effect}\\ \text{of arming}\\ (+)}} \underbrace{-M_Y \frac{G_B Z}{2(G_A+G_B)^2}}_{\substack{\text{Import-expenditure effect}\\ \text{of arming}\\ (-)}} \underbrace{-P_X\left[\frac{(G_A+G_B)^2 - G_B Z}{(G_A+G_B)^2}\right]}_{\substack{\text{Output-distortion effect}\\ \text{of arming}\\ (-)}},\end{aligned}$$

where X_A, D_X,M_Y, and P_X are functions of G_A and G_B. That expression implies that country A increases its arming up to where marginal benefit equals marginal cost, that is,

$$\underbrace{(X_A - D_X)\left[\frac{(G_A + G_B)^2 - G_B Z}{2(G_A + G_B)^2}\right]}_{\text{A's marginal revenue of arming}} = \underbrace{M_Y \frac{G_B Z}{2(G_A + G_B)^2} + P_X \left[\frac{(G_A + G_B)^2 - G_B Z}{(G_A + G_B)^2}\right]}_{\text{A's maerginal cost of arming}}.$$

As for country B, we have the following FOC:

$$\frac{\partial \Pi_B}{\partial G_B} = \underbrace{(Y_B - D_Y)\left[\frac{(G_A + G_B)^2 - G_A Z}{2(G_A + G_B)^2}\right]}_{(+)} \underbrace{-M_X \frac{G_A Z}{2(G_A + G_B)^2}}_{(-)} \underbrace{-P_Y \left[\frac{(G_A + G_B)^2 - G_A Z}{(G_A + G_B)^2}\right]}_{(-)} = 0.$$

Country B's arming likewise is chosen where marginal benefit equals marginal cost, namely,

$$\underbrace{(Y_B - D_Y)\left[\frac{(G_A + G_B)^2 - G_A Z}{2(G_A + G_B)^2}\right]}_{\text{B's marginal revenue of arming}} = \underbrace{M_X \frac{G_A Z}{2(G_A + G_B)^2} + P_Y \left[\frac{(G_A + G_B)^2 - G_A Z}{(G_A + G_B)^2}\right]}_{\text{B's marginal cost of arming}}.$$

Appendix 3: Proof of Lemma 1

For country A, $\partial \Pi_A / \partial G_A < 0$ when $E_X(\partial P_X / \partial G_A)$ is less than the sum of $M_Y(-\partial P_Y / \partial G_A)$ and $P_X(\partial X_A / \partial G_A)$ in absolute value. That is, $MR_A^{Arms} < MC_A^{Arms}$. Similarly, $\partial \Pi_B / \partial G_B < 0$ when $MR_B^{Arms} < MC_B^{Arms}$. As a result, we have $G_A = G_B = 0$. □

Appendix 4: Comparative statics of the equilibrium arming under symmetry

Taking the derivative of G^* (18) with respect to Z, R, and t, respectively, we have the following derivatives:

$$\frac{\partial G^*}{\partial Z} = \frac{6R + Z - 16\alpha + 10t + 5\sqrt{K}}{12\sqrt{K}} > 0, \frac{\partial G^*}{\partial R} = \frac{6R + Z - 8\alpha + 2t + \sqrt{K}}{2\sqrt{K}} > 0,$$
$$\frac{\partial G^*}{\partial t} = \frac{(6R + 5Z - 8\alpha + 2t + \sqrt{K})}{6\sqrt{K}} > 0.$$

Appendix 5: Aggregate payoff functions under asymmetry in national endowments

Substituting $R_A = (R_o + \delta)$ and $R_B = (R_o - \delta)$ into (28) and (29) in Appendix 1, we have the following aggregate payoff functions for countries A and B:

$$
\begin{aligned}
&\Pi_A(G_A, G_B; \delta) \\
&= CS_A(G_A, G_B; \delta) + PS_A(G_A, G_B; \delta) \\
&= \frac{1}{2}\left(\frac{G_A(Z - G_A - G_B) + (R_o + \delta + t)(G_A + G_B)}{2(G_A + G_B)}\right)^2 + \frac{1}{2}\left(\frac{G_B(Z - G_B - G_A) + (R_o - \delta - t)(G_A + G_B)}{2(G_A + G_B)}\right)^2 \\
&\quad + \left(\frac{(2\alpha - R_o - \delta - t)(G_A + G_B) - G_A(Z - G_A - G_B)}{2\beta(G_A + G_B)}\right)\left[(R_o + \delta) - G_A + \left(\frac{G_A}{G_A + G_B}\right)Z\right]
\end{aligned}
$$

and

$$
\begin{aligned}
&\Pi_B(G_A, G_B; \delta) \\
&= CS_B(G_A, G_B; \delta) + PS_B(G_A, G_B; \delta) \\
&= \frac{1}{2}\left(\frac{G_B(Z - G_A - G_B) + (R_o - \delta + t)(G_A + G_B)}{2(G_A + G_B)}\right)^2 + \frac{1}{2}\left(\frac{G_A(Z - G_A - G_B) + (R_o - t)(G_A + G_B)}{2(G_A + G_B)}\right)^2 \\
&\quad + \left(\frac{(2\alpha - R_o + \delta + t)(G_A + G_B) - G_B(Z - G_A - G_B)}{2\beta(G_A + G_B)}\right)\left[(R_o - \delta) - G_B + \left(\frac{G_B}{G_A + G_B}\right)Z\right].
\end{aligned}
$$

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