Trade, Size Asymmetry, and Militarized Conflict*

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Abstract

The article investigates the claim that symmetrical dependence on trade between two states is required for the trade bond to reduce the probability of interstate conflict. Since the degree of symmetry in a trade relationship is closely related to the degree of symmetry in in the military power of the two states, it is necessary to study the two types of symmetry simultaneously. The relationship between the two is explored in an expected utility model of trade, distribution of resources, and conflict. For the particular pacifying mechanisms of trade studied here, the model supports the view that trade most efficiently reduces the incentives for conflict in relatively symmetric dyads. The model also indicates that the most commonly used indicator of (trade) interdependence, the trade-to-GDP ratio, yields results that crucially depend on the degree of asymmetry in size. The implication of this is that the results of studies using this indicator to some extent is contaminated by realist variables as power preponderance. The hypotheses derived from the theoretical model are largely supported in a statistical analysis of directed dyads in the 1950-92 period.

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1 Motivation

Trade between two states is held to reduce the probability of militarized conflict between them (Polachek, 1980; Oneal et al., 1996; Oneal & Russett, 1997). A set of different causal mechanisms with this implication has been proposed. One of the most important of these is that the loss of trade associated with war increases the costs of war such that states are more likely to prefer negotiated solutions to a conflict. Another is that trade reduces the incentives for occupying another state's territory in order to secure access to resources important to the domestic economy, since the resources may be obtained by trade. Other mechanisms have been proposed, but I will limit the discussion to these two here.

States, however, vary greatly in the size of their economies. In terms of GDP size, the median economy, Cameroon, is ten times larger than the smallest country in the world, Sierra Leone (World Bank 2000:274-75). The US economy, in turn, is 1,000 times larger than Cameroon's. It is evident that changes in the trade flow between the US and Sierra Leone has fundamentally different implications for the economy of Sierra Leone than for the US. The asymmetry of size is likely to have implications for both of the mechanisms studied here.

Simultaneously, the likelihood of militarized conflict in a dyad is certainly also dependent on the size asymmetry. The USA is much more powerful than Cameroon partly because it is so much larger. The precise implication of such asymmetries is indeterminate (cf. Powell, 1996), but it is clear that it is impossible to discuss questions of war and peace between two states while ignoring issues of relative power.

A series of recent empirical studies have found statistical evidence for the 'peace through trade proposition' (Beck & Baum, 2000; Bennett & Stam, 2000; Hegre, 2000; Oneal et al., 1996; Oneal & Russett, 1997, 1999; Polachek 1980; Polachek, Robst & Chang 1999). A few studies find no relationship, or maybe even evidence for the opposite (Barbieri, 1996; Beck, Katz & Tucker, 1998). Most of all these operationalize the degree to which one country is dependent on trade with another country as the dollar value of the bilateral trade flow relative to the size of the economy, or as the value of the trade relative to the country's total trade. I will show below that this may be problematic, and suggest an alternative measure. Apart from Barbieri (1996) and Polachek, Robst & Chang (1999), these studies all assume that trade has the same impact on states' decisions to go to war independently of the relative size of their economies. All of them also ignore that their indicators of trade dependence are by definition heavily correlated with the same size asymmetry.

Many of these studies investigate the dyad as an entity, and aggregate the dependency scores for the two countries in the dyad to one value by using the lower of the two or by calculating the geometric mean. This is problematic, too, especially in an attempt to explore the importance of symmetry in the dyad, since the smaller state is likely to face different incentives than the larger state. In the theoretical discussion and empirical analysis presented below, I will disaggregate the dyad into the two 'directed dyads' – how state A relates to state B and how state B relates to state A.

In this paper, I formulate the relationship between trade, power, and militarized conflict in a expected utility model in order to explore these issues systematically. I will carefully discuss the implications of conceiving of trade dependence as a trade-to-GDP ratio, and suggest an alternative concept which bears some resemblance to the gravity model of trade. I will show that the two different concepts by construction yield completely different conclusion regarding the impact of size asymmetry, and argue that the gravity model-based measure is making more sense than the traditional measure. Finally, I will show that the propositions derived from the model are consistent with empirical data by analyzing data for most countries for the 1950–92 period. First, however, I will provide a brief overview of the most relevant contributions on the topic.

2 Empirical Studies of Trade, Asymmetry and Conflict

Barbieri (1996) was the first to test empirically hypotheses concerning trade asymmetry on a large historical dataset. She defines interdependence, or salience, as

$$Salience_{ij} = \sqrt{Trade\,Share_i \times Trade\,Share_j}$$

The trade shares are the values of the bilateral trade divided by state i and j's total trade. This measure automatically accounts for some asymmetry, since the product of a given sum of trade shares is the highest when these are equal.

In addition, Barbieri includes a measure of symmetry:

$$Symmetry_{ij} = 1 - |Trade\,Share_i - Trade\,Share_j|$$

This measure has a severe weakness, however, since the largest possible value for this measure depends on the magnitude of the trade shares. The difference between them will be larger, the larger $Trade\,Share_i$ is. To see this, consider a dyad where the bilateral trade makes up 0.40 and 0.50 of the two countries' total trade – both are heavily dependent on each other. Barbieri's symmetry measure is then 0.90. Then take a situation where the bilateral trade as share of total trade is 0.01 and 0.10 – two countries that are not very dependent on other, but the bilateral trade for one of the countries forms a 10 times larger share of the total trade than for the other. In this case, the symmetry measure will be 0.91 – more symmetric than the first case!

Barbieri also constructs an interaction term between Salience and Symmetry. Since the Symmetry variable varies between 0.85 and 1 and is negatively correlated with Salience, the interaction term introduces collinearity in the model. This makes it difficult to interpret the individual coefficients in her reported results. However, she also presents a plot of the estimated probabilities which indicates that moderately asymmetric dyads are the least conflict-prone, whereas the highly asymmetric and the completely symmetric dyads have the highest probabilities of dispute involvement. Her statistical model controls for asymmetries in power, but Barbieri makes no attempt to evaluate the extent to which the two variables depend on each other.

Polachek, Robst & Chang (1999) formulate an extension of an expected utility model (Polachek, 1980) where an actor country may derive positive utility from conflictual behavior towards a target country in addition to the utility of consumption of goods and services. Conflict, however, is assumed to decrease the actors' exports and imports. The country, then, faces a maximization problem where 'an actor country chooses the amount of conflict with country i so as to equate conflict's marginal costs ... and marginal benefits' (p. 408). The more conflict reduces trade, the less conflict will the actor state choose.

Polachek, Robst & Chang (1999: 414–416) proceed to explore the implications of varying country size in their model. They show that

> an increase in the price of exports to a larger country decreases conflict more than an increase in the price of exports to a smaller country. The logic is as follows: for both small and large target countries, an increase in the price of exports is assumed to increase the actor's gains from trade, which raises the cost of conflict. However, an improving trade relationship with a smaller country has little direct impact on the domestic economy, while it can markedly affect the domestic economy when trading with a larger country. (p. 415)

Polachek, Robst & Chang's model illustrates the difficulty in predicting the effect of trade in asymmetrical dyads for the probability of conflict in the dyad as a unity. With increasing difference in size, the model predicts that the smaller country will be more reluctant to initiate conflictual actions, but simultaneously the larger country will be less constrained from doing so. The net effect is indeterminate – it is necessary to study directed dyads. Polachek et al. also note that the larger actor is likely to have an military advantage over the small actor, which reinforces their hypothesis concerning trade asymmetry and conflict: Trade with a large target reduces conclict more than trade with a small target, and the military capability of a large target is more likely to deter conflict than a small target.

3 The Model

Dorussen (1999) proposes a model that explores the relationship between trade, power, and the incentives for militarized conflict simultaneously.[1] The model studies how the incentives for attempting conquest of resources in other countries varies with the number of countries, and with the trade openness in the system.

[1] His model, in turn, draws on Snidal (1991) and Wagner (2000). The model is extended in Dorussen & Hegre (2002).

In the model, all countries have equal size. Dorussen finds that trade reduces the incentives for conflict in the model.[2]

Here, I reformulate the model to address the incentives for two countries as a function of the distribution of resources between them and of the trade openness between them.[3] I introduce a few simplifications to the original model to facilitate the adaption of the model to my purposes. I also add a parameter modeling how much of the trade between the two countries that is lost during the war, which allows me to explore simultaneously the effects of trade losses (cf. Polachek, 1980) and of the incentives for occupation (cf. Rosecrance, 1986).

The model is an expected utility model, and disregards strategic interaction. The assumptions justifying this is that states always will go to war if they have an incentive to, there is no first-strike advantages that might induce weaker states to attack first to minimize losses in an unavoidable war, and that negotiated solutions of the conflict are unavailable (cf. Fearon, 1995, Powell, 1996).

3.1 Model of Production and Trade

There are two countries that split a territory between them such that country 1 controls a share s and country 2 controls the remainder $1 - s$. Production in country 1 is

$$P_1 = s, \tag{1}$$

and production in country 2 is

$$P_2 = (1 - s)\,. \tag{2}$$

There is constant returns to scale in production here. Henceforth, I will restrict the discussion to the expected utility of state 1.

Trade is a form for cooperation. Snidal (1991:714–15) formulates a model for the gains from cooperation between states of unequal size. He considers the states to be composed of different (integral) numbers of equal units. Cooperation between any pair of these identical uits yield identical net benefits. Assuming constant returns to scale, the total benefit of cooperation between the two groups of units is proportional to the number of cooperating dyads the two groups form, or to the product of the number of units in each group. Considering our two states as the two groups, s units are interacting with $1-s$ units, such that trade

[2] To keep the model simple, only the incentives for 'total conflict' are studied here – complete conquest of the opponent is the only possible outcome of the war. When relaxing this assumption, Dorussen (p. 453) generally finds a stronger effect of trade. When trade is asumed to revert to normal levels after the conflict, however, extensive trade may increase the incentives for conflcit over minor issues (Dorussen & Hegre, 2002:000). It is uncertain how this would affect the conclusions regarding asymmetry here.

[3] In Dorussen's model, there are N countries of equal size r. His model focuses only on one of these countries, which controls $\frac{r}{N}$ of the resources, while the remainder controls $\frac{(N-1)r}{N}$. I normalize the size of the system to $Nr = 1$, and define the size of country 1 to be s and the size of country 2 to be $1 - s$.

between the two states is proportional to the product of these: $T \vee s(1-s)$. Actual trade in the system is determined by a trade efficiency parameter λ, such that actual trade is $T = \lambda s(1-s)$.

Snidal (1991:714), furthermore, argues that the nominal gain from cooperation is split equally even when the states are of different size. This follows from the assumption of constant returns to scale. A state made up of p units interacts with the q units forming another state. The benefit from cooperation (or trade) is pq to both states, independently of the magnitude of p and q. Hence,

$$T_1 = \frac{1}{2}(\lambda s(1-s)) = \lambda s(1-s) \tag{3}$$

A similar relationship between size asymmetry and the volume of trade may also be derived from the gravity model of trade (Linneman, 1966; Anderson, 1979). The gravity equation is typically specified as

$$M_{12k} = \alpha_k Y_1^{\beta_k} Y_2^{\gamma_k} N_1^{\xi_k} N_2^{\epsilon_k} d^{\mu_k} U_{12k}$$

where M_{12k} is the dollar flow of good k from country 1 to country 2, Y_1 and Y_2 are incomes in 1 and 2, N_1 and N_2 are populations in 1 and 2, and d is the distance between 1 and 2. U_{12k} is a lognormally distributed error term with $E(\ln U_{12k}) = 0$ (Anderson , 1979: 106).To simplify, we may omit the population (N) terms, and aggregate all goods into one. The income elasticities β_k and γ_k are normally found to be not significantly different from 1 (Anderson 1979). I assume this to be the case here and omit them from the specification. I also abstract from distance and the error term. Income is assumed to be equal to production. Total production in the two countries is $Y_1 + Y_2 = Y$. Expressed in terms of the normalized parameters introduced above, production in the two countries is $Y(P_1 = P_2)$, such that $Y_1 = Ys$ and $Y_2 = Y(1-s)$. With these modifications, the gravity equation is $M_{ij} = \alpha Y^2 s(1-s)$. Normalizing such that $Y = 1$, the volume of trade predicted from the gravity model is $M_{ij} = \alpha s(1-s)$, which is identical to the model used here, with λ serving the same function as α. Anderson (1979) provides a theoretical justification for the gravity model.

3.2 Time Model

Total income per period I_1 is the sum of production and trade:

$$I_1 = P_1 + T_1 = s + \lambda s(1-s) = s(1 + \lambda(1-s)).$$

Production and trade continues in perpetuity. However, the actors are likely to prefer gains now to similar gains later: Future payoffs are both perceived to be more uncertain (the payoff stream may end for some unforeseen reason), and actors are likely to be impatient. Hence, the gains are discounted over time. This is incorporated into the model by the discount factor δ (cf. Dorussen, 1999:446). Assuming an infinite time horizon, the discounted benefits to the two states of peaceful trade and production are

$$I_1 = \frac{P_1 + T_1}{1-\delta} = \frac{s\,(1+\lambda\,(1-s))}{1-\delta}.$$

3.3 The Utility of War

Dorussen (1999: 457–458) also develops an expression for the utility of war. In the simplest version of this model, the state winning a war gains control over all resources, such that the per-period production after victory in war is $P_V = 1$. The defeated state loses all, such that per-period income after war is $P_D = 0$. Trade is not relevant after a war since all production is controlled by one state. Total income after a war is therefore $I_V = P_V = 1$ and $I_D = P_D = 0$. V and D refers to victory and defeat, respectively. Dorussen's model operates with two cost terms: Firstly, all gains from production and trade are spent for the war effort during the conflict which may last several periods (Dorussen, 1999: 446). Secondly, a constant per-period cost c runs on top of that. The cost term is expressed as a share of total per-period production in the two countries, and may exceed 1. The probability of victory to state 1 and defeat to state 2 in a given period is denoted as p_1, the probability of victory to state 2 and defeat to state 1 is p_2, and the probability of stalemate is p_0. Given this, Dorussen derives the expected utility of war:

$$W_1 = \frac{p_1\,(I_V) + p_2\,(I_D) - c_1}{(1-p_0)\,(1-\delta)^2} = \frac{p_1 - c_1}{(1-p_0)\,(1-\delta)^2} \tag{4}$$

The utility of war W_1 to state 1 is increasing in the probability p_1 of that state winning the war. It is decreasing in the per-period costs of war c – states are more likely to prefer war to peace if the war entails small costs. If $p_1 < c_1$, the utility of war is negative and will never be preferred to peaceful production and trade. If $p_1 > c_1$, W_1 is positive, and decreasing in the probability p_0 of running into a stalemate. Finally, the expected payoff of war is increasing in δ: War is more useful the more patient is the actor, since the long-term gains from gaining control over the other territory is more likely to outweigh the short-term costs and losses of production and trade during the war the more the actor values the future relative to the present.

The three probabilities p_1, p_2, and p_0 may be derived from a standard ratio-form contest success function, abbreviated CSF (cf. Hirshleifer, 2000:775). The standard CSF assigns a probability p of victory and a probability $1-p$ of defeat to the fighting efforts of the two sides.[4] I extend this model to also yield a probability of stalemate by assuming that each period consists of two battles: One battle where the two possible outcomes are victory for side 1 (defeat to side 2) or victory for neither, and a second battle where the two possible outcomes are victory for side 2 (defeat to side 1) or victory for neither. Assuming a particular value for the decisiveness parameter, and that each side have equal

[4] A version of the standard CSF is used in Hegre (2001) and Dorussen & Hegre (2002).

battle effectiveness and spend the same share of its resources in the contest, the three probabilities are expressed in terms of the asymmetry parameter s as

$$p_1 = s^2 \tag{5}$$

$$p_2 = (1-s)^2 \tag{6}$$

$$p_0 = 2s(1-s) \tag{7}$$

The complete derivation of the probabilities is given in Appendix A.1.[5]

3.3.1 Per-period cost of war

The probabilities of victory and stalemate derived above models both that a large state is more likely to win a military contest and that contests between two states of equal size are more likely to be stalemated. Stalemated contests last longer, and with a constant per-period cost of war, will be more costly.

I will model the per-period cost as consisting of two components: A variable γ represents the destruction of production in the two states per period of fighting. The costs are represented as a share of total production in the two countries.[6]

Another component τ in the cost function represents the fraction of the trade between the two states that is lost during the war. Substituting from (1) and (3) yields the cost function for State 1:

$$c_1 = \gamma + \tau\lambda s(1-s) \tag{8}$$

The nominal per-period cost of war is equal for the each state, since it is assumed that destruction is equal on both sides, and that trade gains and losses are divided equally between the two.

Substituting the expressions for the probabilities of the three outcomes (5), (6), and (7), and for the war costs (8) into (4) yields:

$$\begin{aligned} W_1 &= \frac{p_1 \cdot 1 + p_2 \cdot 0 - c_1}{(1-p_0)(1-\delta)^2} = \frac{p_1 - c_1}{(1-p_0)(1-\delta)^2} \\ &= \frac{s^2 - \gamma - \tau\lambda s(1-s)}{(1-2s(1-s))(1-\delta)^2} \end{aligned}$$

[5] The CSF is derived from production P only. It would be more realistic to use $P + T$ instead of P only, but for low λ this works as an approximation.

[6] The costs of war here are independent of the asymmetry in the dyad. An alternative model would be to model the costs of war as proportional to the number of pairs engaged in fighting, e.g. $\gamma = \zeta s(1-s)$, and to express the threshold derived below in terms of this per-fighting pair cost ζ. This would affect the results obtained later. There are certain disadvantages to this alternative, however. Firstly, the total cost of conflict is already modeled as a function of size asymmetry through the outcome probabilities, since symmetrical dyads have the longest conflicts. Secondly, the model chosen may later be extended to model the per-period cost as an outcome of an allocation decision for the two states' fighting efforts.

For notational convenience, I will henceforth in many places replace $1 - p_0$ with $p_E = (1 - 2s(1 - s))$, or the probality of war ending (through victory to either part). The utility of war is then $W_1 = \frac{s^2 - (\gamma + \tau\lambda) s (1-s)}{p_E (1-\delta)^2}$. The probality of a war decision is a parabola which approaches 1 as s approaches 0 or 1, and has its minimum of $\frac{1}{2}$ for $s = \frac{1}{2}$.

The state will prefer war to peace if the discounted expected utility of war W_1 exceeds the discounted income from production and trade with the initial distribution of resources I_1. It is useful to express this criterion as thresholds for the costs of war γ for each of the two states (equation 9). If the per-period cost of war is higher than this threshold, the state will prefer peaceful production and trade to war, and the state will not have an incentive to attempt conquest of the other.

$$\begin{aligned} W_1 &> I_1 \\ \Leftrightarrow& \frac{s^2 - \gamma - \tau\lambda s (1-s)}{p_E (1-\delta)^2} > \frac{s (1 + \lambda (1-s))}{1-\delta} \\ \Leftrightarrow& s^2 - \gamma - \tau\lambda s (1-s) > s (1 + \lambda (1-s)) p_E (1-\delta) \\ \Leftrightarrow& \gamma < s^2 - s (1 + \lambda (1-s)) p_E (1-\delta) - \tau\lambda s (1-s) \\ \Leftrightarrow& \gamma < s (s - p_E (1-\delta)) - \lambda s (1-s) (p_E (1-\delta) + \tau) \equiv \underline{\gamma}_1 \end{aligned} \tag{9}$$

3.4 Exploring the Effect of Size Asymmetry

The focus of this article is on the relationship between trade and conflict. Still, it is necessary to discuss briefly the implications of the model for the relationship between size asymmetry and the incentives for conflict. This is the topic of an extensive and unresolved debate between the balance-of-power school that argues that an even distribution of power is most stable, and the preponderance-of-power school that argues that a preponderance of power is most stable (cf. Powell, 1996 for a brief discussion of the debate and an interesting extension to it).

The model supports neither or both of these positions.[7] The solid black and gray lines in Figure 1 plot the threshold $\underline{\gamma}_1$ for $\delta = 0.1$ and $\delta = 0.9$, respectively, in a situation of no trade. If the per-period cost γ is lower than the value indicated by the lines, state 1 has an incentive to go to war. If we think of γ as having an unknown distribution, the probability that the costs exceed the threshold is increasing when the threshold is increasing. Figure 1 may then be read as representing the probability of war. The figure shows that if the state is very patient ($\delta = 0.9$, gray line), the war cost required to maintain peace – or the probability of war – is monotonically increasing in the country's size s (i.e., its power relative to the opponent). If patient, the long-term gain from

[7] In contrast to Fearon (1995) and Powell (1996), the model developed here excludes any negotiated solutions, disregards information deficiencies, and has only a rudimentary model of strategic interaction. This limits its relevance to the power asymmetry debate.

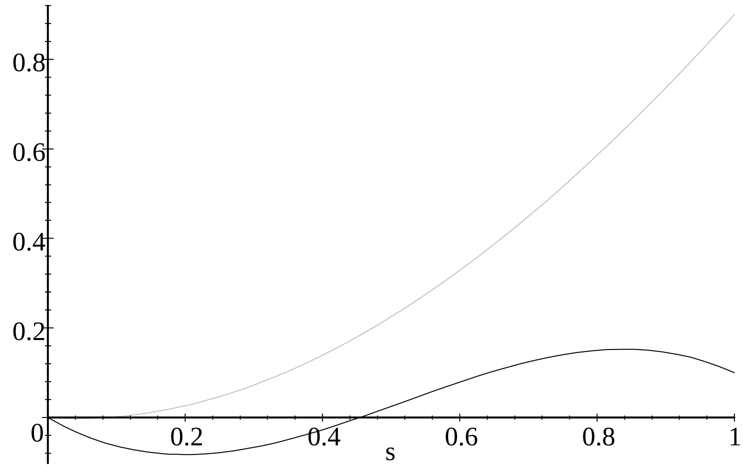

Figure 1: $\underline{\gamma}$ threshold by s for $\delta = 0.1$ (black line) and $\delta = 0.9$ (gray line)

conquest more easily exceeds the short-term cost of war for a large state with a high probability of success. This is consistent with the implications of the balance-of-power hypothesis. For lower δ, however, Figure 1 shows the opposite relationship: The threshold is increasing in s up to a certain level, and then decreasing. When the immediate future is relatively more important, the cost of war tends to outweigh the benefit of conquest. Since the model assumes that all production is spent for the war effort[8], and the war will last for at least one period, the conquest of a very small country will not pay. This prediction is in line with the power-preponderance hypothesis.

The figure shows that the model yields no prediction as to the relationship between power symmetry and the probability of conflict, since how the incentives for a state's use of military force vary with its size relative to the other is dependent on the discount factor. Although this inconclusiveness may not be entirely desirable, it has one advantage in this context: the propositions derived below are not dependent on resolving this question, since they are independent on the discount factor δ which accounts for the different results concerning this question.

[8]That assumption is admittedly quite unrealistic. Still, some war costs are independent of the relative size of the opponent, such as problems with legitimating hostile actions when faced with domestic opposition or international reactions.

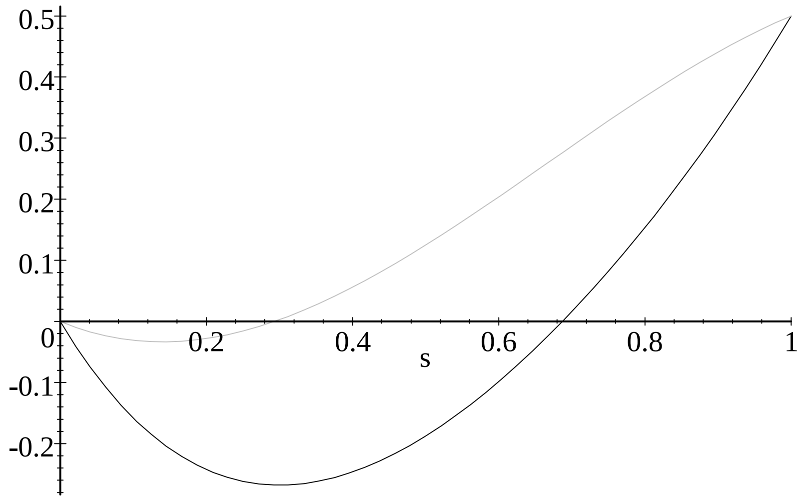

Figure 2: $\underline{\gamma}$ treshold by s for $\lambda = \tau = 1$, (black line) and $\lambda = \tau = 0$ (gray line), $\delta = 0.5$

3.5 Propositions

We do not have any information on the actual magnitude of the per-period cost of war, γ.[9] However, the probability that a given unobserved value γ^* is below the threshold $\underline{\gamma}$ is larger the higher the threshold is. Hence, the probability of war predicted from the model is increasing monotonically in the threshold $\underline{\gamma}_1$. Given this, we may formulate a set of probabilistic hypotheses from the model on the basis of a set of propositions in terms of the $\underline{\gamma}_1$ threshold. Throughout, I restrict the attention to state 1. Corresponding propositions for state 2 may be derived by replacing s with $(1 - s)$ in the expressions below.

3.5.1 The relationship between trade and conflict in terms of λ

Figure 2 plots the cost threshold as a function of s for a situation with no trade (gray line), and one with extensive trade and maximum loss of trade during war; $\lambda = \tau = 1$. For these particular values for λ and τ, increasing trade efficiency reduces the incentives for conflict for state 1. This is not surprising, of course, since the model assumes that some trade is lost as a result of the war, and that trade by assumption is an alternative way to get hold of resources in the other

[9] Although they are probably increasing in the distance between the two states, the degree to which they are industrialized, and the degree to which they are democratized. These factors will be controlled for in the empirical analysis reported below.

country needed for own production. The exception to this is when State 1 is extremely small relative to state 2 ($s \rightarrow 0$) or when it is extremely large ($s \rightarrow 1$). Trade has maximum effect in the model for perfectly symmetric dyads.[10]

The intuition behind this result is the following: For low s, state 1 has little interest in attempting conquest of state 2 since the probability of succeeding is very small. Increased trade does little to change this despite the high value to state 1 of the trade with the much larger state 2. When s is increasing, the chances of winning increases, such that there is a considerable incentive for attempting conquest that trade might do something about. At the same, however, the value of the trade diminishes. Around $s = 0.7$, the value to state 1 of the trade relationship is sufficiently large to have a significant effect at the same time as the incentives for war (in the absence of trade) are substantial.

Propositions 1–3 states that this holds for all relevant values for s, δ, and τ. The propositions are proved in Appendix A.2.

Proposition 1 The $\underline{\gamma}$ threshold is decreasing in λ: $\frac{\partial \underline{\gamma}_1}{\partial \lambda} < 0$ for all relevant s, δ, and τ

Proposition 2 The $\underline{\gamma}_i$ threshold is decreasing most strongly in λ when $s = \frac{1}{2}$ for all relevant s, δ, and τ.

Proposition 3 The $\underline{\gamma}_i$ threshold is decreasing in λ only for moderately symmetric dyads: $\frac{\partial \underline{\gamma}_1}{\partial \lambda} \rightarrow 0$ when $s \rightarrow 1$ and when $s \rightarrow 0$ for all relevant s, δ, and τ

3.5.2 The relationship between trade and conflict in terms of $\mathbf{D}_i$

Trade's importance to production in country 1 is measured by dividing trade by production for the two states:[11]

$$
\begin{aligned}
D_1 &= \frac{T_1}{P_1} = \frac{\lambda s (1-s)}{s} = \lambda (1-s) \qquad (10)\\
&\Leftrightarrow \lambda = \frac{D_1}{(1-s)}
\end{aligned}
$$

Proposition 4 The dyadic trade-to-production ratio D_1 is inversely related to the size of State 1 relative to the other state in the dyad

Proposition 4 is seen directly in equation (10): the bilateral trade by definition is relatively less important the larger is State 1: D_1 is decreasing in the

[10] In a model more closely based on Dorussen's original model, Hegre (2001) obtains a different result. There, the derivative of the cost parameter with respect to λ decreases monotonically with increasing N. This corresponds to decreasing monotonically with increasing $1 - s$ in the model presented here.

[11] For simplicity, trade is divided by production P_1 and not by total income $I_1 = P_1 + T_1$. Although dividing by I_1 would render the indicator more closely analogous to the trade-to-GDP ratio used in the empirical analysis, the formulation in (10) is a good approximation as long as λ is small.

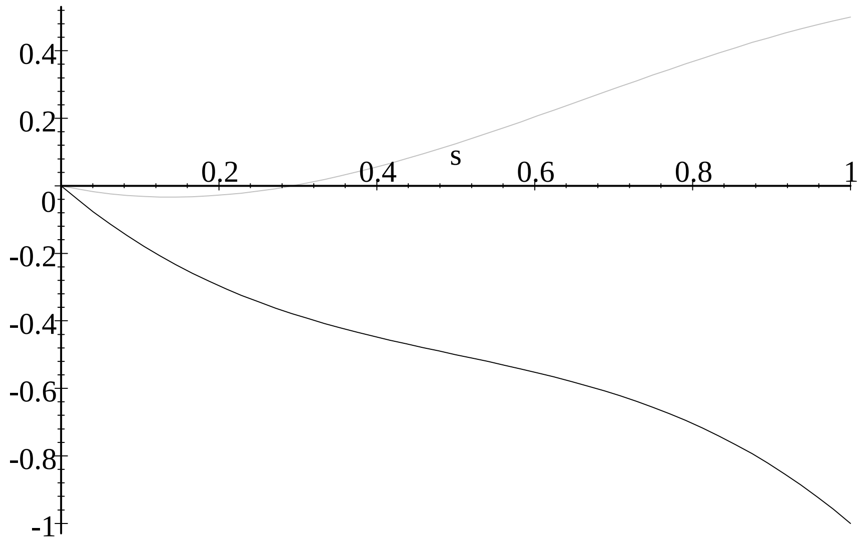

Figure 3: $\underline{\gamma}$ threshold by s for $D_1 = \tau = 1$ (black line) and $D_1 = \tau = 1$ (gray line), $\delta = 0.5$

state's size s. Below, I will refer to λ as a trade flow parameter, and to D_i as a trade dependence parameters.To explore whether it makes any difference to measure trade in terms of the trade-to-production ratio D_i, I will derive the equivalents to Propositions 1, 2, and 3 in terms of D_1.

The first thing to do is to derive the $\underline{\gamma}$ threshold in terms of D_1. This is most easily done by substituting $\frac{D_1}{(1-s)}$ (cf. expr.10) for λ in (9):

$$
\begin{aligned}
W_1 &> I_1 \\
&\Leftrightarrow \frac{s^2 - \gamma - \tau \frac{D_1}{(1-s)} s (1-s)}{p_E (1-\delta)^2} > \frac{s\left(1 + \frac{D_1}{(1-s)} (1-s)\right)}{1-\delta} \\
&\Leftrightarrow \gamma < s (s - p_E (1-\delta)) - D_1 s (p_E (1-\delta) + \tau) \equiv \underline{\gamma}_1 \qquad (11)
\end{aligned}
$$

Figure 3 plots the cost threshold as a function of s for a situation with no trade (gray line), and one with extensive trade and maximum loss of trade during war; $\lambda = \tau = 1$ (black line). The gray line is identical to the gray line in Figure 2, since there is no trade to make any difference. The black line shows another relationship between trade and the incentives for conflict than Figure 2, however. At least for these particular values for λ and τ, increasing trade dependence reduces the incentives for conflict for State 1 more the larger it is relative to State 2. The reason is simply that a trade-to-production ratio of 1 for State 1 represents much larger gains from trade relative to the potential utility of conquest the larger the state is relative to State 2, since a small State 2 is not much to conquer. However, viewing the relationship between trade, asymmetry and conflict through the trade-to-production ratio disregards that the trade relationship with State 2 becomes less useful to State 1 the smaller State 2 is relative to State 1, as argued above, in Snidal (1991), and as follows from the gravity model of trade. The trade-to-production ratio is by construction inseparable from size asymmetry. This has implications for the theoretical understanding of the relationship between trade and conflict that we cannot ignore, and has equally important implications for the empirical testing of this relationship as will be demonstrated below.

Propositions 5–7 states that the relationship depicted in Figure 3 holds for all relevant combinations of s, δ, and τ. The propositions are proved in Appendix A.2.

Proposition 5 The $\underline{\gamma}_i$ threshold is decreasing in D_i: $\frac{\partial \underline{\gamma}_1}{\partial D_i} < 0$ for all relevant s, δ, and τ

Proposition 6 The $\underline{\gamma}_i$ threshold is decreasing most strongly in D_i when $s = 1$.

Proposition 7 The $\underline{\gamma}_1$ threshold is not decreasing in D_1 for a small state 1: $\frac{\partial \underline{\gamma}_1}{\partial D_1} \rightarrow 0$ when $s \rightarrow 0$ for all relevant s, δ, and τ

3.6 Hypotheses to Test

The per-period cost variable γ may be seen as exogeneously given and unrelated to the other variables in the model. The cost is unknown, but has a probability distribution such that the probability that the actual cost is lower than any given value (e.g. the threshold derived) is increasing monotonically with this value. Since conflict occurs if the actual costs are below the threshold, this means that the probability of conflict is increasingly monotonically with the threshold. This allows a straightforward translation of the propositions stated to statistically testable hypotheses: Variables that decreases the threshold when they increase, decreases the probability of conflict when increased. Below the seven propositions are reformulated as probabilistic hypotheses, which will be tested on a historical data set in section 5.

1. The trade flow indicator λ is negatively related to the probability of an actor state using military force against a potential target
2. The estimated coefficient for the trade flow indicator λ is largest for actor states that are 2–3 times larger than the potential target
3. The estimated coefficient for the trade flow indicator λ is lowest for actor states that are very small or very large relative to the potential target

4. An actor state's trade-to-GDP ratio D_1 is negatively correlated with its size s relative to a potential target
5. The trade dependence indicator D_i is negatively related to the probability of an actor state using military force against a potential target
6. The estimated coefficient for the trade dependence indicator D_1 is largest for actor states that are infinitely larger than the potential target
7. The estimated coefficient for the trade dependence indicator D_1 is smallest for actor states that are very small relative to the potential target

4 Statistical Model

4.1 Directed Dyads

The dependent variable in a directed-dyad analysis of militarized conflict is the carrying out of a militarized action towards another country that leads to casualties – a 'fatal militarized action'.[12] The variable is constructed from a subset of the Militarized Interstate Disputes (MID) compiled by the Correlates of War Project (Jones, Bremer & Singer, 1996). I use the dyadic version of the dataset compiled by Maoz, which eliminates a number of anomalies that appear when using the original MID data set in a dyadic analysis. I restrict the analysis to 'fatal actions', implying that only disputes where at least one of the two states in the dyad experienced at least one fatality resulting from the dispute were included. Actions that lead to battle deaths are more clear-cut examples of militarized actions and probably require taking a much more difficult decision than those not involving fatalities (i.e., threats and displays of force). Moreover, there is reason to suspect that militarized disputes between rich democracies are over-reported in the MID dataset (cf. Gasiorowski, 1986:29).

In the models derived above, it matters which of the two states in the dyad initiates the violence. To test the hypotheses formulated, it is necessary to distinguish between the actor initiating the action and the target of the action. A number of recent studies (e.g., Beck et al., 2000; Bennett & Stam, 2000) models this by sampling each dyad twice for each year: Once for actions directed from country a toward country b, and once for actions in the opposite direction. The model thus estimates the probability that a specified state (called the actor when observed at time t) directs a 'fatal action' towards another specified state (called the target). This directed action may be a reciprocation of a similar action recently (at time $t - \epsilon$) directed by the state labeled target at t towards the actor at t. A reciprocation obviously is dependent on the initation act. This is modeled by means of a 'Proximity of hostile action by target towards actor' described below.

[12] Ideally, the dependent variable should be the carrying out of an action that was expected to lead to fatalities, since the outcome of an action is unknown when the decision to act is made. Such expectations are unobservable, of course, such that the observation of actual 'fatal militarized actions' is the best approximation.

4.2 Cox Regression

Raknerud & Hegre (1997) suggested using Cox (1972) regression to model the outbreak of interstate war. The details of the model may be found there. Cox regression models the hazard $h(t)$ of a transition – from peace to a directing a 'fatal action' in this application. $h(t)\,\Delta t$ is approximately the probability of a transition in the 'small' time interval $(t, t + \Delta t)$). The hazard function is factorized into a parametric function of time-dependent explanatory variables and a non-parametric baseline hazard function $\alpha(t)$ of time itself. The time-varying baseline hazard accounts for system-wide fluctuations in the probability of interstate conflict. The model allows coding the values for the explanatory variables at the precise time of war outbreaks. The values for each dyad are coded for each time there is an outbreak of conflict in the system. This allows, for instance, the modeling of swift succession of events as the state A's inititation of hostilities towards state B, and state B's response to that. In a dyad-year model it is not possible to model explicitly the dependence between the actions of an initiator and a target in a militarized conflict in this way since the time unit is fixed and large. The Cox regression model also solves problems with time dependence pointed out by Beck, Katz & Tucker (1998) since series of consequtive peace observations are disregarded in parametric part of the model.

The results presented below are still quite preliminary. They are estimated using a crude form for retrospective sampling (King & Zeng, 2001), where 5% of the non-dispute observations were sampled and entered into the estimation with a weight of 20. The foundation for this approach admittedly has a weak foundation in statistical theory.

4.3 Operationalizing the Variables in the Model

4.3.1 s

The share of resources for the actor state s was operationalized as the GDP of that country divided by the sum of the two countries' GDP. The data for GDP were taken from Penn World Tables Mark 5.6 (Summers & Heston, 1991)[13]. Figures for current US dollars were obtained by multiplicating the POP and CGDP variables.

The variable was lagged with one year, such that 1950 data were used for observations in 1951.

4.3.2 D_1

D_1 is the trade-to-GDP ratio. The trade data were taken from Gleditsch (2000)[14]. This dataset is in a dyad-year format, and improves the International Monetary Fund (1997) Direction of Trade dataset by replacing missing observations with estimates based on related observations. Gleditsch' data set reports both imports from A to B and exports from A to B, and the same two

[13] The data are available from http://pwt.econ.upenn.edu/.
[14] The data are available from http://k-gleditsch.socsci.gla.ac.uk/projects.html.

entities in the opposite direction. I summed the four figures for each observation and divided by two to get the average imports and exports in each dyad. The trade figures are in current US dollars.

The variable was lagged with one year.

4.3.3 λ

The λ variable was constructed from the trade-to-GDP ratio data using (10): $\lambda = \frac{D_1}{(1-s)}$. Since D_1 is operationalized as $\frac{\text{Dyadic trade}}{\text{GDP actor}}$ and $(1-s)$ is operationalized as $\frac{\text{GDP target}}{\text{GDP actor + GDP target}}$, this means that

$$\lambda = \frac{\frac{\text{Dyadic trade}}{\text{GDP actor}}}{\frac{\text{GDP target}}{\text{GDP actor + GDP target}}} = \frac{(\text{GDP actor + GDP target})(\text{Dyadic trade})}{(\text{GDP target})(\text{GDP actor})}$$

The validity of this measure of trade interdependence rests largely on the validity of the model stated in Section 3.

4.4 Control Variables

4.4.1 Modeling Temporal Dependence

To control for how militarized actions are dependent of previous actions, the action history of the dyad three variables were coded in three variables. All variables are defined as decaying functions of time since the previous event of that type: Prox(event) = exp(-days since event/α). This function has the value 1 if the event is very recent, and 0 if the event is very distant. The half-life of the decaying function is given by the α parameter.

Proximity of independence This variable is a function of the time elapsed since the youngest state gained its independence. α were set to 3,162, implying a half-life of 6 years.

Proximity of hostile action by actor towards target This variable is a function of the time elapsed since the last fatal military action by the actor state towards the target.For instance, 11 February 1990 1,851 days had passed since Pakistan carried out a military action towards India. α were set to 3,162, implying a half-life of 6 years

Proximity of hostile action by target towards actor As mentioned, the directed dyad setup introduces time dependence beyond that found in non-directed dyad setups. Fortunately, the continuous-time Cox regression model allows the solution of these problems. The iniating side is assumed to move first, and the target side afterwards. If the MID data set codes the dispute to start at time t, the initiator is coded as starting hostilities at t, and the target at $t+\varepsilon$ where ε is a small positive number. To denote whether any hostile act has been targeted toward a country a at time $t+\varepsilon$, I include a variable called 'Proximity of hostile action by target towards actor'. This variable is a function of the time elapsed since the last fatal military action by the target state towards the actor. This variable models the reciprocation of military actions. α were set to 100, implying a half-life of approximately two months.

4.4.2 Democracy actor and target

The Polity democracy index (Jaggers & Gurr, 1995) ranges from 0 (non-democratic) to 10 (democratic). The data were taken from the Polity IIId data set (McLaughlin et al., 1998) to ensure that the coded regime type is the one in effect at the day of the dispute action. The Polity scores were coded for the actor and for the target. The interaction between actor and target democracy scores were also included in the models to capture the dyadic nature of the democratic peace hypothesis. Both the Democracy Actor and the Democracy Target variables were centered to minimize problems with collinearity when creating the interaction term.

4.4.3 Development actor and target

Hegre (2000) found high development, measured as GDP per capita, to be associated with a lower probability of conflict. Moreover, the conflict-reducing effect of trade seemed to be contingent on the level of development. To control for this, the actor's and target's GDP per capita were included. The Penn World Tables RGDPCH variable was used to code GDP per capita for the actor and the target This variable reports real GDP per capita in US dollars calculated using the Chain index with 1985 as base year.

The variables are lagged with one year.

4.4.4 Contiguity

The directed dyad was coded as contiguous if the two states share a land border or have less than 25 nautical miles of water between them. Contiguity through colonies was not coded as contiguity here.

4.4.5 Distance

The distance variable is the distance between the capitals of the two states.

4.4.6 Dyad size

Dyad size was defined as $\ln(GDP\text{ actor } + GDP\text{ target})$. The variable replaces the major/minor power variable routinely included in comparable models (e.g., Oneal & Russett, 1997; Bennett & Stam, 2000).

Variable	Model I	
	β	s.e.
Democracy Actor	-0.021	0.016
Democracy Target	-0.013	0.015
Democracy Int.	-0.018	0.0030***
GDP/cap. Actor	-0.25	0.069***
GDP/cap. Target	-0.21	0.070***
Distance	-0.63	0.063***
Contiguity	2.47	0.20***
Dyad Size	0.35	0.046***
Prx(independence)	0.091	0.28
Prx(actor action)	3.43	0.17***
Prx(target action)	6.55	0.90***
Log likelihood	-3147.15	
No. of failures	438	
LL null model	-4462.24	
$^{*}: p < 0.10, ^{**}: p < 0.05, ^{***}: p < 0.01$		

Table 1: Control variables

5 Results

Table 1 reports the results from estimating the model $h(t) = \alpha(t) \exp(\boldsymbol{\beta}\mathsf{X}(t))$ where $\boldsymbol{\beta}\mathsf{X}(t)$ is the set of control variables with corresponding coefficients. The set of regime type variables are consistent with the democratic peace hypothesis: the interaction term between Democracy Actor and Democracy Target is negative and clearly significant. Both Democracy Actor and Democracy Target are negative (although not statistically significant).[15] The development indicators, Actor's and Target's GDP per capita, are negative and significant. This is consistent with the statistical results in Hegre (2000), and with an argument found in Rosecrance (1986): Industrialized states are likely to perceive the costs of war to be higher than non-industrialized states, and will therefore less seldom have an incentive to go to war. The coefficient for Distance is negative and statistically significant: The longer the distance between two states, the lower the risk of militarized conflict. This holds even with Contiguity in the model, which is positive and equally significant. Dyad size is positive and significant: the larger the two states are, the more likely are they to get into conflict. This variable partly captures the difference in conflict behavior between major and minor powers, but also account for the fact that large minor powers have a larger interaction capacity than small minor powers, such that conflicts between them are more likely to escalate beyond the 1 battle death threshold. Most of these results are consistent with what found in Bennett & Stam (2000: 682–683) and

[15] Democracy Actor and Democracy Target are negative and significant if the control for the Actor's and Target's GDP per caput is omitted. This is not strange given the high correlation between democracy and development (cf. Burkhart & Lewis-Beck, 1994).

Variable	Model II		Model III	
	$\hat{\beta}$	s.e.	$\hat{\beta}$	s.e.
s	-0.055	0.20	-0.28	0.21
s^2	-2.640	0.70^{***}	-2.89	0.74^{**}
λ	-68.8	20.0^{***}		
λs	-1.9	6.2		
λs^2	317.8	86.5^{***}		
D_1			-63.5	19.1^{***}
$D_1 s$			-84.6	51.0^{*}
$D_1 s^2$			105.3	92.8
Democracy Actor	-0.013	0.016	-0.013	0.016
Democracy Target	-0.006	0.014	-0.005	.014
Democracy Int.	-0.014	0.0032^{***}	-0.014	$.0032^{***}$
GDP/cap. Actor	-0.25	0.073^{***}	-0.24	0.073^{***}
GDP/cap. Target	-0.22	0.077^{***}	-0.22	0.077
Distance	-0.70	0.059^{***}	-0.70	0.060^{***}
Contiguity	2.39	0.19^{***}	2.40	0.19^{***}
Dyad Size	0.44	0.050^{***}	0.44	0.050^{***}
Prx(independence)	0.21	0.28	0.21	0.28
Prx(actor action)	3.20	0.18^{***}	3.20	0.18^{***}
Prx(target action)	7.04	0.71^{***}	7.03	0.73^{***}
Log likelihood	-3130.16		-3130.76	
No. of failures	438		438	
LL null model	-4462.24		-4462.24	
$^{*}: p < 0.10, ^{**}: p < 0.05, ^{***}: p < 0.01$				

Table 2: Trade and size variables

in dyad-year analyses of interstate conflict, although differences in operationalizations inhibits a precise comparison.

The temporal dependence controls have signs in the expected direction: Proximity of independence is positive although not significant: New states are not significantly more prone to interstate conflicts than established states. Proximity of actor action is positive and clearly significant: Hostile actions are much more frequently targeted towards previous enemies in militarized conflicts than towards states that never have been enemies. Likewise, the Proximity of target action variable is positive and significant: A state is much more likely to use military force against another state if they have initiated a militarized conflict towards them – militarized disputes rarely escalate to a level where lives are lost without the target state performing a reciprocal act.

The tables do not report the N of the analyses, only that the dataset contains 438 'failures' or initiation of fatal militarized actions. The significance levels obtained in a survival analysis are primarily dependent on this figure, rather than the total number of dyads or the total time of observation or the product of these (cf. Collett, 1994:254–265).

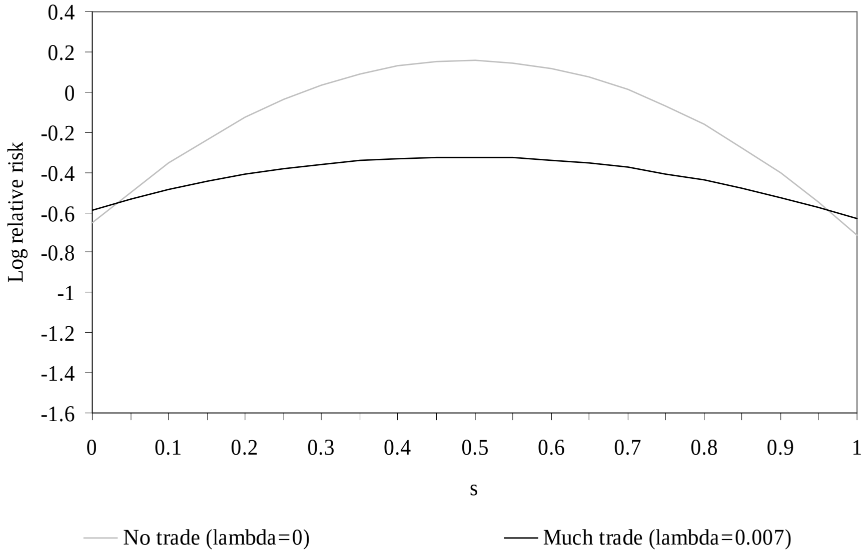

Figure 4: Estimated relationship between λ, s, and the risk of interstate conflict (Model II)

On the background of these control variables, I may test the hypotheses derived from the model in Section 3. Table 2 reports the results from estimating the models

$$h(t) = \alpha(t) \exp\left(\beta_1 s + \beta_2 s^2 + \beta_3 \lambda + \beta_4 \lambda s + \beta_5 \lambda s^2 + \boldsymbol{\beta} \mathsf{X}(t)\right)$$

(model II), and

$$h(t) = \alpha(t) \exp\left(\beta_1 s + \beta_2 s^2 + \beta_3 D_1 + \beta_4 D_1 s + \beta_5 D_1 s^2 + \boldsymbol{\beta} \mathsf{X}(t)\right)$$

(model III).

First note that the estimates for the control variables are virtually unchanged in Models II and III. Still, the addition of the five terms for trade and asymmetry significantly improves the fit of the model: The log likelihood drops from -3147.15 to -3130.16 and -3130.76, respectively. According to the likelihood ratio chi-squared statistic this improvement is significant at the .001 level.

It is not very fruitful to interpret the individual estimates for s and λ, because of the square and interaction terms $s^2, \lambda s$, and λs^2. Moreover, even when centering the main terms, there are severe collinearity in Model II. The estimates for λ and λs^2 are correlated by $r = 0.986$ (cf. Appendix A.4). Although this collinearity is likely to render the estimation inefficient, it is possible to interpret these five estimates as long as they are treated together. To facilitate this, the estimated risks of interstate conflict relative to the baseline estimated in Model II are plotted as a function of s for sample values for λ in Figure 4. The corresponding plots for sample values for D_1 given in Model III is found in Figure 5.

In both figures, the solid, black line plots the estimated probability of an actor carrying out fatal militarized actions towards a target with which it has no trade relationship. The results are roughly consistent with the expectations from the model given a low discount factor (cf. Figure 2), and with the preponderance-of-power school. The estimated risks of war in the no-trade case are similar in both models and both figures, since only the trade indicator distinguishes these two models.

Bennett & Stam (2000) also find a clear negative relationship between the 'balance of forces' and conflict. They define balance of forces as the CINC score (Singer, Bremer & Stuckey, 1972) for the larger country divided by the sum of the two countries' CINC scores. Their result implies that the larger the largest country, the less conflict in the dyad. In the directed dyads analysis, they find the non-directed measure of balance of power to be negative and strongly significant, implying that conflict is least likely in dyads characterized by high power asymmetry. They also enter a variable defined as the initiator's CINC score divided by the sum of the two countries' CINC scores. The directed measure is positive, but fails to meet the 0.05% threshold of significance. This implies that a country is more likely to initiate disputes the more powerful it is relative to the other state in the dyad. They do not discuss what is the net effect of the two variables, but their study seems to be in accordance with what found here.

Figure 4 shows that Hypothesis 1 in Section 3.6 is supported by the empirical analysis. The higher is the trade openness variable λ between a potential actor and a potential target, the lower is the estimated risk that the actor initiates hostilities. This is due to the negative and significant estimate for the main term λ in Model II. The figure also supports Hypothesis 2: the difference in log relative risk is largest for $s \approx 0.50$ as predicted by the model. Hypothesis 3, too, is clearly supported: The conflict-reducing effect of trade is zero both for actors that are very small relative to the opponent ($s \to 0$) and for actors that are very large relative to the opponent ($s \to 1$).

The results obtained here are not directly comparable to other studies since the operationalization of the importance of trade differs from almost all others. An exception is Hegre (2000), which measures the amount of trade in the dyad by using the residual from a gravity model estimation of trade for the actual country year. That study finds a negative relationship between trade and conflict for dyads with high levels of development, but does not address issues of asymmetry.

According to the fourth hypothesis stated in Section 3.6, s and D_1 should be negatively correlated. The actual correlation is only -0.14 which is not too convincing. The correlation between s and $\ln(D_1)$, however, is -0.56. This suggests that the low correlation may partly be due to the extremely skewed distribution of the D_1 variable.

Figure 5 allows evaluating the remaining hypotheses in Section 3.6: As stated

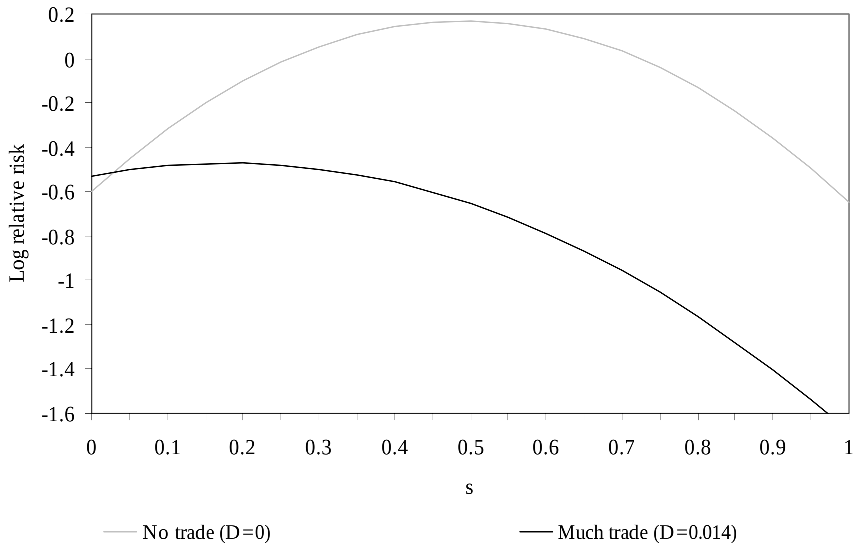

Figure 5: Estimated relationship between λ, D_1, and the risk of interstate conflict (Model III)

in Hypothesis 5, the trade dependence indicator D_1 is negatively related to the relative risk of conflict: Apart from when s is close to zero, the 'Much trade' line is well below the 'no trade' line in the figure. This is in line with the results obtained by Oneal & Russett (1997, 1999) using the same operationalization of trade dependence for undirected dyads. Although Bennett & Stam (2000) find trade dependence to significantly decrease the probability of conflict in a non-directed dyad analysis, they fail to find one in their directed dyads analysis. Target dependence is closest to having a significant parameter estimate. It is difficult to say why this is so. The results obtained in Model II and III imply that this result is not bound to disappear in a directed dyad analysis.

Moreover, Hypothesis 6 and 7 are clearly supported: the estimated effect of D_1 is clearly largest for actors that are large relative to the potential target, and clearly smallest for actors that are small relative to the potential target.

These results do not perfectly coincide with the only roughly comparable empirical study: Barbieri's (1996) plot of the estimated probabilities indicates that moderately asymmetric dyads are the least conflict-prone, whereas the highly asymmetric and the completely symmetric dyads have the highest probabilities of dispute involvement. Her unit of analysis, however, is the undirected country dyad not the directed dyad which makes it difficult to compare the results directly.

Polachek et al. (1999: 416–418) test their propositions using a 30-country sample for the period 1958–67. Their design is a directed dyad setup, and the dependent variable is the frequency of conflict minus the frequency of cooperation in the dyad, as coded in the Conflict and Peace Data Bank (COPDAB). They find clear evidence for level of exports and imports to reduce the amount of conflict. They also find a negative and significant interaction term between exports and target-actor GNP difference, which supports their hypothesis concerning size differences and the effect of trade: the larger the target is, the more does an increased level of exports decrease the amount of conflict directed at it. The results obtained above, then, are in contradiction to theirs. Their empirical analysis has important limitations, however. Firstly, it is conducted on a limited and distant time period, and cover a limited set of countries. Moreover, it is uncertain whether the COPDAB net conflict variable is sufficiently distinct from the trade variable: to what extent is agreements related to trade between two countries coded as cooperative acts in the dataset, and what is the weight of such cooperative acts in the net measure relative to more distinctly conflictual events?

6 Conclusion

The intention behind this paper was to investigate the claim that symmetrical dependence on trade between two states is required for the trade bond to reduce the probability of interstate conflict. I have argued that it is difficult to distinguish asymmetries in trade dependence from asymmetries in military power since large countries tend both to be less dependent on the trade flow with small countries and to be militarily superior. To handle this problem, I have reformulated the model proposed by Dorussen (1999) which allows treating relationships of power and of trade simultaneousy. In the reformulation of Dorussen's model, there are only two countries but they may vary freely in relative size, which facilitated discussing the question of asymmetry.

Apart from the proposition that trade reduces conflict (which also results from Dorussen's study), the model suggests that trade measured as 'openness' should be most efficient in reducing the probability of conflict in symmetric dyads, and that trade should have no effect in extremely asymmetric dyads. Openness was defined as the amount to which the potential for trade between the two states is exploited, given a model for this potential.

However, the model also points out that the conclusions regarding the effect of asymmetry changes dramatically when considering the effect of trade measured as 'dependence', or the trade-to-domestic production ratio. In that case, trade reduces a state's incentives for conquest more the larger it is relative to the potential target. I have argued that this is counter-intuitive, and due to the fact that the bilateral trade-to-production ratio is a function of the asymmetry itself. This suggests that the trade-to-production ratio is an inappropriate measure of trade interdependence, and particularly when studying the issue of asymmetrical trade.

The conclusions from the model differ somewhat from those drawn from the model of Polachek, Robst & Chang (1999). Their model implies that trade reduces the incentives for conflict less the smaller the target is relative to the actor (i.e., the larger is s), since trade with a small target has less impact on the actor's economy. The same is implied by the model developed here, but only as long as the target is smaller than the potential actor ($s > \frac{1}{2}$). When the actor is smalle than the target ($s < \frac{1}{2}$), increasing the size of the target (decreasing s) reduces the pacifying effect of trade. The reason is that the probability of succeeding in a militarized conflict with a very large target is so low that increasing trade makes little difference to the actors utility calculations.

In the empirical analysis, the propositions were largely supported: When formulating trade dependence in a way which is independent of the dyads' asymmetries in size, the amount of 'trade openness' with a potential target reduces the probability of militarized actions the most when the actor was the same size as the target. When operationalizing trade dependence with the traditional trade-to-GDP (approximating the trade-to-production ratio), however, trade appears to reduce the incentives for conflict more the larger the actor is relative to the potential target.

To the extent that this argument holds, it suggests that using the trade-to-GDP ratio is problematic. In particular, the results will be likely to depend on how the observations are distributed in terms of size asymmetries.

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A Appendix

A.1 Derivation of Probabilities of Victory, Defeat, and Stalemate

The ratio-form CSF is fine for obtaining probabilities for victory and defeat, but how to calculate the three probabilities for victory, defeat, and stalemate?

Idea: Each period contains two battles: One battle where the two possible outcomes are victory for side 1 (defeat for side 2) or victory for neither, another battle where the two possible outcomes are victory for side 2 (defeat for side 1) or victory/defeat for neither. The two probabilities of victory are obtained through a ratio-form CSF :

$$\begin{aligned} p_{v1} &= \frac{(b_1 F_1)^m}{(b_1 F_1)^m + (b_2 F_2)^m} \\ p_{s1} &= 1 - p_{v1} \end{aligned}$$

$$\begin{aligned} p_{v2} &= \frac{(b_2 F_2)^m}{(b_1 F_1)^m + (b_2 F_2)^m} \\ p_{s2} &= 1 - p_{v2} \end{aligned}$$

For simplicity, I assume that $b_1 = b_2 = 1$ and $m = 0.5$. F_i is assumed to be a fixed share f_i of each state's per-period production: $F_i = f_i I_i$. I assume that $f_1 = f_2 = f$. Substituting from (1)–(2) yields the following four probabilities:

$$\begin{aligned}
p_{v1} &= \frac{(fI_1)^m}{(fI_1)^m + (fI_2)^m} = \frac{(P_1)^m}{(P_1)^m + (P_2)^m} \\
&= \frac{\left(s^2\right)^{0.5}}{(s^2)^{0.5} + \left((1-s)^2\right)^{0.5}} \\
&= s \\
p_{s1} &= 1 - p_{v1} = 1 - s
\end{aligned}$$

$$\begin{aligned}
p_{v2} &= \frac{(fI_2)^m}{(fI_1)^m + (fI_2)^m} = \frac{(P_2)^m}{(P_1)^m + (P_2)^m} \\
&= \frac{\left((1-s)^2\right)^{0.5}}{(s^2)^{0.5} + \left((1-s)^2\right)^{0.5}} \\
&= 1 - s \\
p_{s2} &= 1 - p_{v1} = 1 - (1 - s) = s
\end{aligned}$$

These four probabilities are aggregated to three desired probabilities p_1, p_0 and $p_2 = 1 - p_1 - p_0$ in this way: State 1 wins if it wins battle 1 and achieves stalemate in the second. State 2 wins if it achieves stalemate in battle 2 and wins the second. The period ends in stalemate if the two states wins one battle each or noone wins either:

$$p_1 = p_{v1} \times p_{s2} = s^2$$

$$p_2 = p_{v2} \times p_{s1} = (1 - s)^2$$

$$\begin{aligned}
p_0 &= p_{v1} \times p_{v2} + p_{s1} \times p_{s2} \\
&= s(1 - s) + s(1 - s) \\
&= 2s(1 - s) = 2s - 2s^2
\end{aligned}$$

A.2 Proof of Propositions

A.2.1 Proposition 1

To explore the effect of increasing trade on the incentive for conflict, I derive the first-order partial derivative of $\underline{\gamma}$ with respect to λ:

$$\begin{aligned}\frac{\partial \underline{\gamma}_1}{\partial \lambda} &= \frac{\partial \left(s\left(s-p_E\left(1-\delta\right)\right)-\lambda s\left(1-s\right)\left(p_E\left(1-\delta\right)+\tau\right)\right)}{\partial \lambda} \\ &= -s\left(1-s\right)\left(\left(1-\delta\right)p_E+\tau\right) \\ &= -s\left(1-s\right)\left(\left(1-\delta\right)\left(1-2s\left(1-s\right)\right)+\tau\right)\end{aligned} \tag{12}$$

The proposition states that $\frac{\partial \underline{\gamma}_1}{\partial \lambda} < 0$ for all relevant s, δ, and τ, or that $-\frac{\partial \underline{\gamma}_1}{\partial \lambda} > 0$. $-\frac{\partial \underline{\gamma}_1}{\partial \lambda}$ is the product of $s\left(1-s\right)$ and $\left(\left(1-\delta\right)\left(1-2s\left(1-s\right)\right)+\tau\right)$, and is positive when both these terms are positive. Since $0 < s < 1$, $s\left(1-s\right)$ is always positive and less than $\frac{1}{2}$. δ and τ are also restricted to have values betwen 0 and 1. Hence, $\left(1-\delta\right)$ is always positive, $\left(1-2s\left(1-s\right)\right)$ is always positive since $2s\left(1-s\right) < 1$, such that $\left(1-\delta\right)\left(1-2s\left(1-s\right)\right)$ is always positive. Since $\tau > 0$, this means that $\left(\left(1-\delta\right)\left(1-2s\left(1-s\right)\right)+\tau\right) > 0$ for the relevant ranges, and also $s\left(1-s\right)\left(\left(1-\delta\right)\left(1-2s\left(1-s\right)\right)+\tau\right) > 0$. This proves proposition 1.

A.2.2 Proposition 2

Proposition 2 states that the $\underline{\gamma}_1$ threshold is decreasing most strongly in λ when $s = \frac{1}{2}$ for all relevant combinations of s, δ, and τ.. In other words, the derivative of $\underline{\gamma}_1$ with respect to λ has a minimum for $s = \frac{1}{2}$. This is shown by differentiating (12) with respect to s, and solving the equation

$$\begin{aligned}\frac{\partial^2 \underline{\gamma}_1}{\partial \lambda \partial s} &= 0 \\ &\Leftrightarrow \frac{\partial\left[-\tau-\left(1-2s\left(1-s\right)\right)\left(1-\delta\right)\right]}{\partial s} = 0 \\ &\Leftrightarrow 6s\left(1-\delta\right)-12s^2\left(1-\delta\right)+8s^3\left(1-\delta\right)+\tau\left(2s-1\right)-\left(1-\delta\right) = 0\end{aligned}$$

This only real-number solution to this equation is $s = \frac{1}{2}$.

A.2.3 Proposition 3

Proposition 3 states that the $\underline{\gamma}_i$ threshold is decreasing in λ only for moderately symmetric dyads: $\frac{\partial \underline{\gamma}_1}{\partial \lambda} \rightarrow 0$ when $s \rightarrow 1$ and when $s \rightarrow 0$ for all relevant s, δ, and τ. Substituting 1 and 0 for s in (12) demonstrates this:

$$\frac{\partial \underline{\gamma}_1}{\partial \lambda}^0 = -\left(0\right)\left(1-0\right)\left(\left(1-\delta\right)\left(1-2\left(0\right)\left(1-0\right)\right)+\tau\right) = 0,$$

and

$$\frac{\partial \underline{\gamma}_1}{\partial \lambda}^1 = -\left(1\right)\left(1-1\right)\left(\left(1-\delta\right)\left(1-2\left(1\right)\left(1-1\right)\right)+\tau\right) = 0$$

A.2.4 Proposition 5

Proposition 5 states that the $\underline{\gamma}_1$ threshold is decreasing in D_1: $\frac{\partial \underline{\gamma}_1}{\partial D_1} < 0$ for all relevant s, δ, and τ. This is shown by deriving the first-order partial derivative of $\underline{\gamma}$ expressed in terms of D_1 with respect to D_1:

$$\begin{aligned} \frac{\partial \underline{\gamma}_1}{\partial D_1} &= \frac{\partial \left(s\left(s - p_E\left(1-\delta\right)\right) - D_1 s\left(p_E\left(1-\delta\right)+\tau\right)\right)}{\partial D_1} \\ &= -s\left(p_E\left(1-\delta\right)+\tau\right) \\ &= -s\left(\left(1-2s\left(1-s\right)\right)\left(1-\delta\right)+\tau\right) \end{aligned} \tag{13}$$

The proof of Proposition 1 showed that all the terms in the product

$$s\left(\left(1-2s\left(1-s\right)\right)\left(1-\delta\right)+\tau\right)$$

are positive for the relevant ranges, such that

$$-s\left(\left(1-2s\left(1-s\right)\right)\left(1-\delta\right)+\tau\right)$$

is always negative.

A.2.5 Proposition 6

Proposition 6 states that the $\underline{\gamma}_1$ threshold is decreasing most strongly in D_1 when $s = 1$. As for Proposition 2, this Proposition is shown by differentiating (13) with respect to s:

$$\begin{aligned} \frac{\partial^2 \underline{\gamma}_1}{\partial D_1 \partial s} &= \frac{\partial\left(-s\left(\left(1-2s\left(1-s\right)\right)\left(1-\delta\right)+\tau\right)\right)}{\partial s} \\ &= \left(1-\delta\right)\left(s-6s^2-1\right)-\tau \end{aligned}$$

$\frac{\tau}{(1-\delta)} > 0$ and $s - 6s^2 - 1 < 0$ for all relevant values of the parameters. Hence, $\frac{\partial \underline{\gamma}_1}{\partial D_1}$ is decreasing monotonically in s, such that it has a minimum for the largest value in the range, which is $s = 1$. This proves Proposition 6.

A.2.6 Proposition 7

Proposition 7 states that the $\underline{\gamma}_1$ threshold is not decreasing in D_1 for a small state 1: $\frac{\partial \underline{\gamma}_1}{\partial D_1} \to 0$ when $s \to 0$ for all relevant s, δ, and τ. This is demonstrated by substituting 0 for s in (13):

$$\frac{\partial \underline{\gamma}_1}{\partial D_1}^{0} = -\left(0\right)\left(\left(1-2\left(0\right)\left(1-\left(0\right)\right)\right)\left(1-\delta\right)+\tau\right) = 0$$

A.3 Correlation Matrix for Model II, Table 2

	s	s^2	λ	λs	λs^2	Dem A	Dem T	Dem Int
s	1.00							
s^2	.05	1.00						
λ	.00	−.05	1.00					
λs	−.25	−.03	−.21	1.00				
λs^2	−.02	.03	−.986	.31	1.00			
Dem A	−.08	−.01	−.03	.04	.02	1.00		
Dem T	.03	−.10	.00	−.14	−.03	.25	1.00	
Dem Int	.05	.01	−.24	−.11	.19	.08	.09	1.00
Dev. A	−.29	.09	−.18	.11	.18	−.32	−.10	−.05
Dev. T	.34	.18	−.21	−.11	.18	−.05	−.28	.02
Dist	−.03	.01	.13	.00	−.13	.05	.02	.04
Cont	−.01	−.01	−.16	−.06	.11	.17	.14	.06
Size	−.03	−.38	−.14	.04	.14	−.20	−.13	.07
Pr(I)	.02	−.16	−.02	.08	.05	−.16	.20	−.06
Pr(A)	.06	.18	.11	.05	−.07	−.11	−.07	.13
Pr(T)	.00	−.26	−.24	.08	.24	.02	−.02	.00

	Dev. A	Dev. T	Dist	Cont	Size	Pr(I)	Pr(A)	Pr(T)
Dev. A	1.00							
Dev. T	−.16	1.00						
Dist	.16	.19	1.00					
Cont	.15	.20	.68	1.00				
Size	−.17	−.23	−.46	−.39	1.00			
Pr(I)	.11	.12	−.04	−.03	.24	1.00		
Pr(A)	.05	.13	.01	−.36	−.07	−.03	1.00	
Pr(T)	.00	−.10	−.11	−.03	.20	.05	−.23	1.00

A.4 Correlation Matrix for Model III, Table 2

	s	s^2	D_1	$D_1 s$	$D_1 s^2$	Dem A	Dem T	Dem Int
s	1.00							
s^2	.16	1.00						
D_1	.34	.11	1.00					
$D_1 s$	.41	.30	.53	1.00				
$D_2 s^2$	.18	.25	−.26	.68	1.00			
Dem A	−.08	−.01	−.04	.00	.03	1.00		
Dem T	−.01	−.11	−.04	−.02	.01	.25	1.00	
Dem Int	−.11	−.07	−.29	−.24	−.03	.08	.08	1.00
Dev. A	−.31	.09	−.17	−.07	.06	−.32	−.10	−.05
Dev. T	.18	.10	−.23	−.21	−.04	−.05	−.28	.01
Dist	.02	.03	.14	.09	−.02	.05	.01	.03
Cont	−.13	−.08	−.21	−.16	−.02	.17	.13	.04
Size	−.08	−.39	−.15	−.09	.03	−.21	−.13	.07
Pr(I)	.05	−.12	.00	.06	.07	−.16	.20	−.05
Pr(A)	.14	.23	.15	.12	.02	−.11	.07	.14
Pr(T)	−.06	−.27	−.23	−.09	.09	.02	−.02	.01

	Dev. A	Dev. T	Dist	Cont	Size	Pr(I)	Pr(A)	Pr(T)
Dev. A	1.00							
Dev. T	−.16	1.00						
Dist	.16	.18	1.00					
Cont	.14	.19	.68	1.00				
Size	−.17	−.23	−.46	−.39	1.00			
Pr(I)	.12	.12	−.04	−.03	.24	1.00		
Pr(A)	.05	.13	.01	−.36	−.07	−.03	1.00	
Pr(T)	−.10	−.11	−.03	.10	.20	.05	−.23	1.00