

Gravitating Toward War: Preponderance May Pacify, but Power Kills*

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Abstract

Countries have better abilities and stronger incentives to engage in militarized conflicts the larger and more powerful they are. The paper applies Zipf's notion of a 'gravity model' to the risk and magnitude of interstate conflict, and argues that the empirical relationship between size and distance and conflict is stronger than any other identified in dyadic statistical studies of interstate conflict. The paper also shows that size is correlated with a series of important explanatory variables in the conflict literature. Still, most empirical studies of interstate conflict fail to take size properly into account. The paper explores the impact of omitting size variables for the investigation of the power preponderance versus power parity debate. The results indicate that even though a power capability ratio variable suggests asymmetric dyads are less conflict-prone, the risk-increasing effect of power itself means that a unilateral increase of power in one country increases the risk of conflict.

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1 Introduction

Military power – the ability to project physical force – is an essential factor in any explanation of militarized conflict. Power is a necessary condition for war: For a war to occur, the belligerents must be able to bring a minimum number of soldiers and weaponry to a joint location – power kills. In addition to this ‘absolute’ amount of power brought to bear in a conflict, the relative power of the belligerents is also likely to affect the nature of the conflict and even whether there will be any military action at all.

In this paper, I show that the empirical study of interstate conflict has not paid sufficient attention to the ‘absolute’ aspect of power. To demonstrate this, I make use of the gravity model of interaction. The gravity model is widely used by economists to predict volumes of trade flows between countries: The volume of trade is to a large degree proportional to the product of the two countries’ GDP and inversely proportional to the distance between them. However, the gravity model was initially suggested to predict other types of social interactions. In this paper, I argue that militarized conflict is not only most frequent between countries that are geographically close to each other – they are also more frequent between larger countries.

That large countries like the US engage more often in interstate conflict than small ones may seem trivial. Still, beyond entering a dummy variable for major power status, most quantitative studies do not include size as a control variable. This omission has serious consequences: If size in terms of GDP or population is an important predictor of interstate conflict and it is omitted as a control variable, then its impact will be captured by variables such as the power capability ratio, since any measure of this concept deals with size in some form. The major power dummy routinely included in quantitative studies of war is not sufficiently precise to avoid the bias resulting from this. Variables that are both related to the dependent variable and correlated with explanatory variables may be affected by omitted variable bias. Here, I will systematically analyze the impact for the study of power parity of controlling for the gravity model. I show that the argument has important implications for the interpretation of the variable estimates. The results obtained here clearly show that relations of power preponderance are less conflict-prone than relations of power parity only when interpreted as a description of how a dyad’s total capabilities are distributed. If dyads that differ in terms of their total size are compared, size differences are more important than asymmetry differences. Hence, any attempt to

increase asymmetry by increasing one state's size or power will unambiguously lead to a higher risk of conflict in the dyad.

The paper is organized as follows: In the next section, I describe the gravity model of trade, and argue that also the frequency of militarized disputes are well described by the gravity model. I then review the empirical literature on power preponderance and power parity and show how it fails to take absolute levels of power into account. I then test whether this argument is valid using data for all pairs of countries in the 1885–2001 period.

2 The Gravity Model

Newton's original gravity model is specified as $\frac{M_1 M_2}{d}$ where M_k are the masses of the bodies and d the distances between them. Zipf (1946) shows that the number of persons that move between any two cities with populations P_1 and P_2 respectively and separated by the distance D is proportional to the ratio $\frac{P_1 P_2}{D}$. The gravity model is widely recognized as a superior empirical description of bilateral trade patterns. Deardorff (1998) reviews various theoretical explanations for the gravity model relationship, and shows that it is consistent with a Heckscher-Ohlin model of trade.

The gravity model is also consistent with other trade models. In fact, Deardorff (1998) notes that 'I suspect that just about any plausible model of trade would yield something very like the gravity equation', and that the gravity model is 'just a fact of life'. Arguably, the extent to which two states form alliances and become joint members in international organizations also follows a gravity pattern (see Hegre, 2005).

But the gravity model is not restricted to positive interactions (Gleditsch & Singer, 1975). Militarized conflict is also likely to be much more frequent between pairs of countries that are large and geographically proximate. Large and proximate pairs of countries have both better opportunities for militarized conflict, and a stronger potential for being sufficiently motivated to escalate disagreements to a level where military forces are deployed and lives are lost. This is well recognized for geographical proximity (see Buhaug & Gleditsch, 2006, for a review). Distance and contiguity variables are routinely included in empirical models of interstate conflict. Countries that are close to each other are *able* to bring an amount of military units against each other sufficiently large to cause a high number of battle deaths. Distance increases the costs of bringing militarized units against

each other just as it increases the costs of transporting traded goods. Hence, if we conceive of a country as allocating a fixed proportion of their military resources to each of the other countries in the world, it will be able to bring fewer military units to a distant country. If the distance is sufficiently large, two countries will not be able to allocate a sufficient amount of military units to produce a single battle death.

Just as a model of trade volumes takes into account both supply and demand, a model of conflict must take into account both belligerents' *ability* and *motivation* to fight. Neighboring countries also have more to fight over. Countries obviously don't allocate a fixed proportion of their military resources to all countries. Countries are more likely to allocate military resources to counter the most threatening countries, which are among those that are able to inflict damage on them. In addition to concerns about local military power balances, countries are most likely to fight when they have conflicting interests. Interests are most likely to conflict between contiguous and proximate countries. Most wars are over territory and are fought out among neighbors (Vasquez, 1995; Gleditsch, 1995).

However, countries are also more likely to get into serious militarized conflicts the *larger* they are. Here, I will think of size both in terms of population and military capabilities. For a given average technological level, populous countries form larger markets, produce more goods, and are more militarily powerful. Countries' military strength is in part dependent on their population sizes. Hence, population forms part of the Correlates of War project's military capabilities variable (the CINC score). The CINC score is correlated by 0.84 with population.¹

Size affects states' opportunity to fight each other. Distance is more of an opportunity constraint for small countries than for large countries. Boulding (1962: 229–233) models military power at a given location as a function of a country's home strength (its strength at its home base) and the distance from the home base to the location. Each nation's strength declines as it moves away from its home base. The extent to which strength is reduced with distance is modeled by a loss-of-strength gradient (LSG). Figure 1 illustrates the relationship. The horizontal axis represents the distance between two countries A and B, and the vertical axis a country's military power at a given location. Country A's home strength is represented by the vertical line AH, and B's home strength by BK. The

¹Population and military capabilities are also correlated with economic output (Gross Domestic Product). The relationship between military conflict and economic factors is investigated in Author (XXXX).

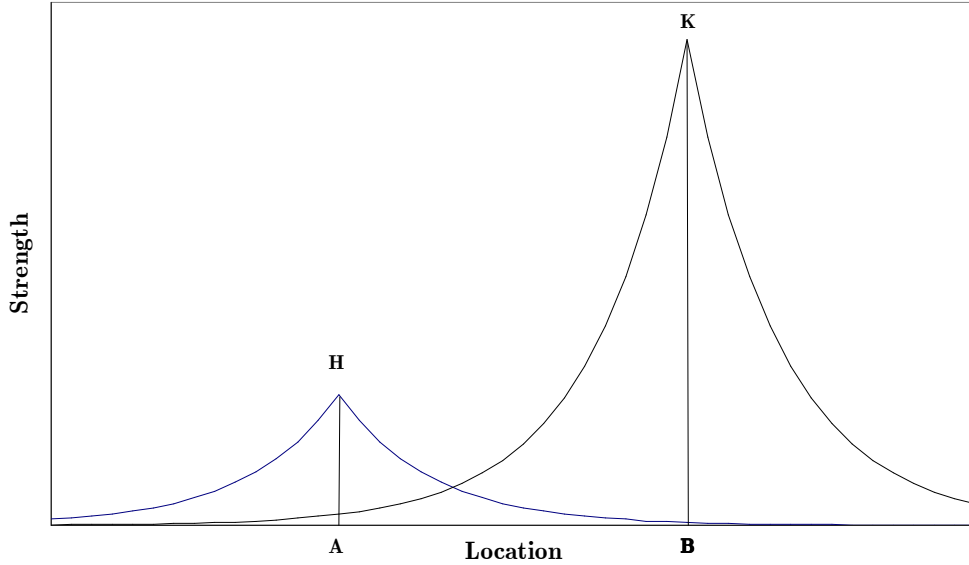


Figure 1: Boulding's (1962) Loss-of-Strength Gradient

slopes of the lines extending from H and K are the countries' loss-of-strength gradients. Here, I model the LSG using a distance discount factor. The decrease is then proportional to the log of distance from the home base:² A's strength S_x^A at location x is given by $S_x^A = S_{x_0}^A \delta^{(x-x_0)}$. The larger are the two countries' home strengths, the larger is the chance that they are able to jointly bring a sufficient amount of military units to produce a serious militarized dispute. Hence, for a given distance between two states, the two states have better opportunities to fight the more powerful they are. Halfway between A and B, for instance, both states are able to mobilize a non-negligible amount of military force. Country B is also able to mobilize at A's home base.

But just as large countries are both large producers and large consumers, size affects the states' motivations for fighting in addition to their abilities. Pairs of large countries with vast territories, long joint borders, and a high number of indirect relationships through joint neighbors are more likely to have strong conflicting interests than small countries. Moreover, Boulding's LSG implies that countries should be more concerned with any military moves done by countries that are either proximate or large, and the most about countries that are both proximate and large. Considerations of other states' willingness, again, affect states' strategic calculations and their perceived opportunities for fighting: Countries are likely to allocate most of their military resources such that they optimize

²Bueno de Mesquita (1981: 105) also use a logarithmic function of distance for the loss-of-strength gradient.

their defense against the most immediate threats: their neighbors and the large powers. This means less resources are left for more distant threats, and that their ability to wage wars decrease even more with distance than implied by the transportation costs only.

The size of a country also affects other countries' motivations for waging wars with them. The gravity model of trade implies that the larger a country is, the more important it is as a market for another country, or as an exporter of goods to it. In 'guns versus butter' models (e.g. Powell, 1999; Skaperdas & Garfinkel, 2000), military investment is generally increasing in the amount of resources in the two contenders. Decisions made within a country is more likely to seriously affect another country the larger it is.

Rosecrance (1986) argues that countries face a choice between the military-political and the trading-state strategy. More precisely, countries may contemplate gaining access to goods or resources by force rather than through trade. This means that a model explaining the volume of trade would also be appropriate to model the 'volume of conquest'. One may then reformulate a trade model in terms of the 'forced exchange' of goods, where the 'imports' or amount of expropriated goods is proportional to the production of the conquered country and the 'exports' or the military power used to acquire the goods is proportional to the production of the exploitative country. This would yield a gravity model with a theoretical justification that is close to that described in Deardorff (1998).

3 Power Parity vs. Power Preponderance

Does peace depend on a balance of power? Advocates of the 'balance-of-power' argument (e.g. Wright, [1942] 1965; Morgenthau, 1967; and Waltz, 1979) claim that 'equality of power destroys the possibility of a guaranteed and easy victory and therefore no country will risk initiating conflict' (Lemke & Kugler, 1996: 5). When there is power preponderance, Waltz (1959: 232) argues that wars occur 'because there is nothing to prevent them'. According to this argument, the risk of war between two states is therefore lowest when they are approximately of equal size. Advocates of the 'power preponderance' position, on the other hand (Blainey, 1988; Organski, 1968; Organski & Kugler, 1980; Lemke, 2002), argue that '*parity* is the necessary condition for major war...' (Lemke & Kugler, 1996: 4). The relationship between power balance and uncertainty about outcomes is also important in this argument: since it is more uncertain who will win a contest between equally powerful contenders, wars may occur. Fearon (1995) argues that war between two

states should occur only when at least one of them is uncertain about the capabilities or the resolve of the other, or when they have difficulties committing to a negotiated outcome. When the power balance clearly favors one of the states, this uncertainty (although not the commitment problem) is negligible, and pairs of states characterized by power preponderance will on average be more peaceful.

Reed (2003: 637) formalizes the information component of the power preponderance logic, arguing that the variance or uncertainty of a challenger's estimate of the distribution of power is larger the closer the states are to parity. In Reed's formal model, this increased uncertainty is translated into a higher risk of conflict between the two states.

The 'power preponderance' argument is closely related to Organski's 'power transition' argument: Major wars occur when one major power overtakes another. A similar logic underlies the argument of Powell (1996, 1999) and Werner (1999): Since demands are chosen strategically, 'potential belligerents must compare what they currently have with what they *reasonably* can demand' (Werner, 1999: 723). Hence, 'conflict ensues as a consequence of a perceived disparity between the status quo distribution of benefits and the underlying distribution of power' (ibid). Power transitions often bring about such disparities and will therefore be associated with a heightened risk of war. Powell and Werner's argument do not imply that wars occur more often in situations of power parity, however. A disparity between the distribution of benefits and of power may occur for any distribution of power.

In many treatments of both these arguments the focus is primarily on relations between major powers. Power arguments are in principle equally applicable to any rivaling pair of states, but in practice relations between minor powers are influenced by the power relationships of the major power. Still, where major powers are indifferent about the outcome of a minor power conflict the local power distribution alone is likely to have an impact on the form the conflict takes. Power distribution arguments should therefore apply at least to some extent to all pairs of states.

3.1 Absolute Versus Relative Power

Recent empirical studies of the determinants of the risk of war tend to support the 'power preponderance' argument. Bremer's (1992) pioneering study found that pairs of states where the 'Composite Index of National Capability' or the CINC score of the more powerful state is more than 10 times higher than that of the weaker state have had a considerably

lower risk of interstate conflicts. This finding has been replicated in a number of studies comparing the war risks in dyad years (e.g. Oneal et al., 1996; Russett & Oneal, 2001; Lemke, 2002; Reed, 2003, Bueno de Mesquita & Lalman, 1992).

These studies fail to take into account the crucial distinction between absolute (or nominal) and relative power, however. A closer look at Lemke (2002) is instructive, since Boulding's loss-of-strength gradient forms an important part of his argument. Lemke (2002: 68) defines a 'local hierarchy' that 'identifies the members of such international sub-systems [that are] able to interact militarily with each other'. The ability to interact is a function of the absolute capabilities of the two states. Among pairs involving dominant powers within such local hierarchies, Lemke finds parity to increase the risk of war. But he ignores an important implication of the loss-of-strength gradient that a 'gravity model of conflict' (and Lemke's own argument) implies: Since his restricted sample only includes dyads where at least one state is a locally or globally dominant power, parity as he defines it implies that the other state in the dyad is always a serious contender, i.e. also a large state. Their *combined ability* to wage war is then always larger than in dyads where there is no parity. But the gravity model of conflict states that the better two states can reach each other, the higher is the risk of war. It is not possible in Lemke's model to identify how much of the increase in war risk is due to parity, and how much is due to size.

The same problem occurs in the dyad-year empirical studies referred to above. The model of Russett & Oneal (2001) is the most widely used template. The studies based on this design typically include an asymmetry measure based on the CINC scores of the two states in the dyad. The CINC score (Singer, Bremer & Stuckey, 1973) is constructed from country-level data on six different 'resources'; military expenditures, military personnel, iron and steel production, energy consumption, urban population, and total population. A country's CINC score is constructed by calculating the proportion controlled by the country of the international system's total for each of these resources, and then calculating the average proportions. The corresponding measure of power asymmetry is called the 'capability ratio' and is the logarithm of the ratio of the CINC score of the more powerful country to that of the less powerful. But the capability ratio is obviously correlated with the capabilities of the weaker state. In Oneal & Russett's (2005) dataset used in this article, average log capability ratio is 5.36 (a ratio of 213) if the least 'capable' country in the dyad is in the lowest decile. If the smallest country in the dyad is in the highest decile, average log capability ratio is 1.54 (a ratio of 4.7). The correlation between the

log capability ratio and the log capabilities of the smaller country is -0.51 . By extension, the problem is the same if the unit of analysis is a pair of alliances (e.g. Kim & Morrow, 1992; Kim, 2002): If the study does not control for the size of the countries or the alliance, there is no way of telling whether the estimated effect of the asymmetry variable is due to asymmetry or to the size of the smallest alliance or country in the pair. It is necessary to control for the total size of the dyad to obtain a ‘clean’ estimate for asymmetry. I show this more formally in the next section.

4 Specifying a Gravity Model of Conflict

The unit of analysis in this paper is the non-directed dyad-year, or a pair of countries observed in a given year.³ Throughout this paper, I will refer to the largest country in the dyad (in that year) in terms of population as country i and the smallest as j in subscripts to variables that measure characteristics of a country.⁴ I will refer to the size of population as P , such that the population of the largest country in the dyad is referred to as P_i . The size of the population of the smaller country is referred to as P_j . The distance between the two is referred to as D_{ij} .

In log form, the gravity model of trade is often formulated as

$$\ln T_{ij} = \gamma_0 + \gamma_{P_i} \ln P_i + \gamma_{P_j} \ln P_j + \gamma_{I_i} \ln I_i + \gamma_{I_j} \ln I_j + \gamma_C \ln C_{ij} + \gamma_D \ln D_{ij} + \eta_{ij}. \quad (1)$$

where I_i and I_j are the average incomes (GDP per capita) of countries i and j .⁵ η_{ij} is a dyad-specific constant that may be decomposed into the average trade flow between states, a dyad-specific term, and possibly also variations over time within the dyad. Since this model will be estimated as a statistical model later, (1) is represented as a sum. γ_C and γ_D will therefore be negative.⁶

Since the focus of this paper is on ‘political’ interactions rather than economic ones,

³I take the common non-directed dyad-year design as the point of departure here to maximize comparability with previous studies. It may not be the best design, however (cf. Bennett & Stam, 2000).

⁴Referring to the largest as i and the smallest as j greatly eases the argument developed here. The precise justification is given in Author (XXXX).

⁵It is more common to include $\ln G_i$ than $\ln I_i$. But since $\ln I_i = \ln G_i - \ln P_i$, these formulations contain exactly the same information.

⁶I will label parameters according to the following convention: In models where trade is the dependent variable, parameters are labeled γ . I will use λ in models for magnitude of war, and β for models with fatal disputes as dependent variable. These symbols are subscripted according to the following convention: First, a number indicates which of several related models the parameter belongs to. Second, the variable name is used to identify which variable the parameter relates to. Hence, γ_{1P_i} refers to the parameter for country i ’s population in the first model below.

I will include information on military capabilities in the model rather than income in addition to population size. I will refer to countries' military capabilities (CINC scores) in absolute form as M_i and M_j . It is fruitful to express the expectations of these arguments both in terms of the magnitude and the relative frequency of militarized conflict and war. A plausible model of the magnitude of war is

$$\ln W_{ij} = \lambda_0 + \lambda_{M_i} \ln M_i + \lambda_{M_j} \ln M_j + \lambda_C C_{ij} + \lambda_D \ln D_{ij} + \eta_{ij}$$

where W_{ij} is the number of fatalities in the war.

The magnitude of war is likely to be increasing in the populations of the warring countries as well as in their military capabilities. To be able to distinguish between size in terms of population and differences between countries in terms of military investments and technology, it is useful to introduce a per-capita version of the capability measure: $m_i = M_i/P_i$. An extended model for the magnitude of war is then:

$$\ln W_{ij} = \lambda_0 + \lambda_{P_i} \ln P_i + \lambda_{P_j} \ln P_j + \lambda_{m_i} \ln m_i + \lambda_{m_j} \ln m_j + \lambda_C C_{ij} + \lambda_D \ln D_{ij} + \eta_{ij} \quad (2)$$

Since this is a log-log model, the $\lambda_{P_{i,j}}$ terms estimate by how much an increase in population size leads to an increase in fatalities for a given per capita capability level. In words, the gravity of conflict is supposed to increase in the population of the two enemies. In addition, the the $\lambda_{m_{i,j}}$ terms estimate how much the magnitude increase if the countries increase their military capabilities (at least after taking power asymmetry into account).

Most empirical studies of militarized conflict define the dependent variable as the probability of conflict defined dichotomously in terms of a fixed threshold Υ , e.g. *at least* $\Upsilon = 1000$ battle deaths: $p_{ij,W} = p(\ln W_{ij} > \Upsilon)$. Among the most straightforward statistical models to capture this monotonic relationship between a continuous variable and a probability is the logit model, which relates a latent probability of war to the (linear) term $\ln W_{ij}$: $\ln\left(\frac{p_{ij,W}}{1-p_{ij,W}}\right) = \ln W_{ij} + \beta \mathbf{X} + \varepsilon_{ij}$. This leads to the following models:

$$\ln\left(\frac{p_{ij,W}}{1-p_{ij,W}}\right) = \beta_{10} + \beta_{1M_i} \ln M_i + \beta_{1M_j} \ln M_j + \beta_{1C} C_{ij} + \beta_{1D} \ln D_{ij} + \varepsilon_{1ij} \quad (3)$$

$$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_{20} + \beta_{2P_i} \ln P_i + \beta_{2P_j} \ln P_j + \beta_{2m_i} \ln m_i + \beta_{2m_j} \ln m_j + \beta_{2C} C_{ij} + \beta_{2D} \ln D_{ij} + \varepsilon_{2ij} \quad (4)$$

Most recent quantitative studies of the risk of civil war at the country level include a population variable (e.g. Collier & Hoeffler, 2004; Fearon & Laitin, 2003). Size of population is not only significant, it is arguably the most robust and substantively important variables in these studies (Hegre & Sambanis, 2006). Moreover, basically all studies of trade volumes use the gravity model as ‘control model’ (e.g. Mansfield & Bronson, 1997; Mansfield & Pevehouse, 2000; Keshk, Pollins, & Reuveny, 2004). Below, I show that size variables are also strongly correlated with the risk of interstate war.

In contrast to civil war studies, indicators of size beyond a ‘major power’ dummy variable are routinely omitted in empirical studies of interstate war. There are only a few exceptions, and they have not had any impact on the modeling strategies of later studies: Werner (1999) comes very close to the control variable strategy advocated here as she estimates the dyadic ‘hazard rate for peace’ as a function of the power of the two states as well as the distance between them. She uses the log of the states’ CINC scores to measure power, to model that ‘[s]tates with few resources are much less able to project those resources abroad than states with greater resources’ (Werner, 1999: 718). The estimates are clearly statistically significant and indicate that war is more frequent among powerful countries. In their analysis of the determinants of interstate war duration, Bennett & Stam (1996) also include the countries’ total population and number of soldiers as explanatory variables. They systematically find at least one of those to significantly increase the duration of wars. This means that wars are likely to be more lethal where the warring parties are populous, since the number of fatalities is roughly proportional to the duration of wars (Lacina, 2006).

4.1 Power Asymmetry and Omitted Variable Bias

4.1.1 Three Ways to Control for Size

The estimates for an explanatory variable in a statistical model will be biased if another variable is omitted that is correlated both with the dependent variable and with the explanatory variable of interest. In this section I will show how some simple algebraic manipulations can separate the size effects from the effects of size asymmetry.⁷

⁷In Author (XXXX), I show how the failure to control for size variables creates a different set of problems for studies of trade and conflict such as Russett & Oneal (2001).

The definition of the capability ratio variable in my notation is $\ln A_{ij} = \ln M_i - \ln M_j$.

A simplification of the standard specification is

$$\ln \left(\frac{p_{ij}}{1 - p_{ij}} \right) = \beta_{30} + \beta_{3A} \ln A_{ij} + \beta_{3C} C_{ij} + \beta_{3D} \ln D_{ij} + \varepsilon_{3ij}$$

But if the risk of disputes between the two countries is increasing in their military capabilities, this will be captured by the error term: $\varepsilon_{3ij} = \beta_{3M_i} \ln M_i + \beta_{3M_j} \ln M_j + \xi_{ij}$. Since $\ln A_{ij} = \ln M_i - \ln M_j$, there is obviously correlation between the error term and the explanatory variable $\ln A_{ij}$ and a serious potential for omitted variable bias.

The obvious solution is to control for the size variables. But since the log capability ratio is a linear function of the two capability variables, a model including all three variables $\ln A_{ij}$, $\ln M_i$, and $\ln M_j$ cannot be estimated. I explore two solutions to this below. In the first, I take the size of the smaller country as a measure of the size of the dyad. In the second, I set the sum of the sizes as the size of the dyad.

To explore the first solution, I include $\ln A_{ij}$ in the model while controlling for $\ln M_j$:

$$\ln \left(\frac{p_{ij}}{1 - p_{ij}} \right) = \beta_{40} + \beta_{4A} \ln A_{ij} + \beta_{4M_j} \ln M_j + \beta_{4C} C_{ij} + \beta_{4D} \ln D_{ij} + \varepsilon_{4ij} \quad (5)$$

β_{4A} is a direct and consistent estimate of the effect of power asymmetry as defined above. Will this model also produce consistent estimates for the absolute size variable? We can find this out by substituting $(\ln M_i - \ln M_j)$ for $\ln A_{ij}$, and collect terms:

$$\begin{aligned} \ln \left(\frac{p_{ij}}{1 - p_{ij}} \right) &= \beta_{40} + \beta_{4A} \ln A_{ij} + \beta_{4M_j} \ln M_j + \beta_{4C} C_{ij} + \beta_{4D} \ln D_{ij} + \varepsilon_{4ij} \\ &= \beta_{40} + \beta_{4A} (\ln M_i - \ln M_j) + \beta_{4M_j} \ln M_j + \beta_{4C} C_{ij} + \beta_{4D} \ln D_{ij} + \varepsilon_{4ij} \\ &= \beta_{40} + \beta_{4A} \ln M_i + (\beta_{4M_j} - \beta_{4A}) \ln M_j + \beta_{4C} C_{ij} + \beta_{4D} \ln D_{ij} + \varepsilon_{4ij} \quad (6) \end{aligned}$$

This shows that Model (5) will produce inconsistent estimates for the size variables - there is a tradeoff between getting consistent estimates for size and directly estimating the effect of power asymmetry. We do not have to estimate Model (5) to obtain an estimate for β_{3A} , however - the estimate may be derived from the original gravity model of conflict (6). The reparameterization obtained in (6) has the same form as model (3). The β_{1M_i} estimate is therefore also an estimate for β_{4A} . Simply estimating the gravity model is the

second solution to the identification problem.

But if the β_{1M_i} estimate (controlling for $\ln M_j$) is also an estimate for β_{4A} , we cannot be certain that it estimates the effect of asymmetry and not that of the size and capabilities of country i , over and beyond j . The alternative formulation is to define asymmetry as $\ln A_{ij} = \ln M_i - \ln M_j$ as before, but control for the joint size $\ln M = \ln M_i + \ln M_j$ of the two countries:

$$\ln \left(\frac{p_{ij}}{1 - p_{ij}} \right) = \beta_{50} + \beta_{5A} \ln A_{ij} + \beta_{5M} (\ln M_i + \ln M_j) + \beta_{5C} C_{ij} + \beta_{5D} \ln D_{ij} + \varepsilon_{5ij} \quad (7)$$

However, rearranging (7) yields

$$\ln \left(\frac{p_{ij}}{1 - p_{ij}} \right) = \beta_{50} + (\beta_{5M} + \beta_{5A}) \ln M_i + (\beta_{5M} - \beta_{5A}) \ln M_j + \beta_{5C} C_{ij} + \beta_{5D} \ln D_{ij} + \varepsilon_{5ij} \quad (8)$$

and we see that this model has the same form as model (3). Hence,

$$\beta_{1M_i} = \beta_{5M} + \beta_{5A}$$

$$\beta_{1M_j} = \beta_{5M} - \beta_{5A}$$

Solving these equations, we find that $\beta_{5M} = \frac{\beta_{1M_j} + \beta_{1M_i}}{2}$ and $\beta_{5A} = \frac{\beta_{1M_i} - \beta_{1M_j}}{2}$.

The sum of the log capabilities is the same as the logarithm of the product of the capabilities. For a given sum $M_i + M_j$, this product is larger the smaller is the difference between M_i and M_j . The sum $\ln M_i + \ln M_j$ is therefore correlated with asymmetry conceptualized as $(M_i - M_j)$. I will therefore also investigate the model

$$\ln \left(\frac{p_{ij}}{1 - p_{ij}} \right) = \beta_{60} + \beta_{6A} \ln A_{ij} + \beta_{6M} \ln (M_i + M_j) + \beta_{6C} C_{ij} + \beta_{6D} \ln D_{ij} + \varepsilon_{6ij} \quad (9)$$

4.1.2 Population Size and Military Capabilities

Population size is the most important determinant of military capabilities. It is desirable to separate population size from other determinants of military capabilities. To estimate the effect of power asymmetry controlling for both population and per-capita capabilities, I will estimate

$$\ln \left(\frac{p_{ij}}{1 - p_{ij}} \right) = \beta_{50} + \beta_{5A} \ln A_{ij} + \beta_{5m_i} \ln m_i + \beta_{5m_j} \ln m_j + \beta_{5P_j} \ln P_j + \beta_{5C} C_{ij} + \beta_{5D} \ln D_{ij} + \varepsilon_{5ij} \quad (10)$$

Here, I omit $\ln P_i$ for identification purposes. It is also possible to obtain the power asymmetry estimate directly from the model (4). Note that $\ln m_i = \ln M_i - \ln P_i \Leftrightarrow \ln M_i = \ln m_i + \ln P_i$ and substitute into the definition of asymmetry $\ln A_{ij} = \ln M_i - \ln M_j$. This yields $\ln A_{ij} = \ln m_i - \ln m_j + \ln P_i - \ln P_j$. Substituting into 10, we obtain

$$\begin{aligned} \ln \left(\frac{p_{ij}}{1 - p_{ij}} \right) &= \beta_{50} + \beta_{5A} (\ln m_i - \ln m_j + \ln P_i - \ln P_j) + \beta_{5m_i} \ln m_i + \beta_{5m_j} \ln m_j + \beta_{5P_j} \ln P_j \\ &\quad + \beta_{5C} C_{ij} + \beta_{5D} \ln D_{ij} + \varepsilon_{5ij} \\ &= \beta_{50} + \beta_{5A} \ln P_i + (\beta_{5P_j} - \beta_{5A}) \ln P_j + (\beta_{5A} + \beta_{5m_i}) \ln m_i + (\beta_{5m_j} - \beta_{5A}) \ln m_j \\ &\quad + \beta_{5C} C_{ij} + \beta_{5D} \ln D_{ij} + \varepsilon_{5ij} \end{aligned} \quad (11)$$

As above, model (11) is on the same form as (4), and the parameters must satisfy the following set of equations:

$$\begin{aligned} \beta_{2P_i} &= \beta_{5A} \\ \beta_{2P_j} &= \beta_{5P_j} - \beta_{5A} \\ \beta_{2m_i} &= \beta_{5A} + \beta_{5m_i} \\ \beta_{2m_j} &= \beta_{5m_j} - \beta_{5A} \end{aligned}$$

The reparameterization shows that of (10) shows that the estimate β_{2P_i} above will be identical to the estimate for β_{5A} in (10).

5 Estimating the Gravity Models

The expectations were tested in a standard dyad-year setup based on the work of John Oneal and Bruce Russett. The dataset includes one observation for every pair of countries (the dyad) for every year. The dataset includes information on all pairs of countries for the 1885 – 2001 period.

5.1 Variables and Measurement: Dependent Variables

Battle deaths The battle deaths data are adapted from the ‘COW’ version of the Lacina & Gleditsch (2005) battle deaths dataset.⁸ The dataset reports the number of battle deaths for each participant in the war. I calculated dyadic battle deaths estimates based on these figures. For wars with only two participants, all battle deaths occurred in only one dyad, and the total number of deaths is the battle deaths estimate for the dyad. In wars with more than one participant on side j , we do not know which of the state’s on the enemies’ side killed each soldier. To arrive at an estimate for dyadic battle deaths, I assumed that the battle deaths for the dyads ij were distributed proportional to the participant-level number of deaths at side j . For instance, in the 1977 war between Somalia and Ethiopian assisted by Cuba, Ethiopia’s losses were 1,800 deaths whereas Cuba’s were 700. I therefore assume that $\frac{18}{25}$ of Somalia’s deaths were inflicted by Ethiopia and $\frac{7}{25}$ by Cuba. In general, in the dyad (ai, bj) pairing participant i at side a with participant j at side b , the dyadic battle death estimate is $Y_{ai}Y_{bj} = Y_iY_j \left(\frac{1}{Y_a} + \frac{1}{Y_b} \right)$ where Y_i and Y_j are the participant battle deaths estimates for countries i and j , and Y_a and Y_b are the total number of deaths at sides a and b , respectively.

Fatal MIDs and Wars The analysis is based on the dataset of Oneal & Russett (2005), which again draw on Maoz’ dyadic version of the Correlates of War’s MIDs and wars datasets.⁹ As do Oneal & Russett (2005), I restrict the analysis to the ‘fatal MIDs’ – militarized interstate disputes that lead to the death of at least one person.

5.2 Variables and Measurement: Independent Variables

Population All explanatory variables are calculated on the basis the dataset of Oneal & Russett (2005). A detailed description of the dataset may be found in Oneal & Russett (1999). The population size variable originates from the Correlates of War military capabilities dataset.

Military capabilities The COW military capabilities index (Singer, Bremer & Stuckey, 1972) is based on data on states’ total population, urban population, energy consumption, iron and steel production, military expenditures, and size of the armed forces. The COW

⁸ See http://www.prio.no/page/CSCW_research_detail/Programme_detail_CSCW/9649/45656.html.

⁹ Thanks to John Oneal for sharing a more extensive version of this dataset than the publicly available replication dataset.

project calculated each state's share of the world's total for each of these sub-indices. The CINC index is constructed as the unweighted average of each of these shares. The theoretical range for the index is [0, 1]. In practice, the log capabilities index ranges from -13.8 to -0.957 .

Direct contiguity Contiguity takes the value 1 if two states either share a land boundary or are separated by less than 240 kilometers of water.

Distance Distance is the great circle distance between the two states' capitals (or major ports for the USA, the USSR/Russia, and Canada).

System size Raknerud & Hegre (1997:390–91) show that in dyadic studies, the probability of dispute for 'low-relevance' dyads must be dependent on the number of states in the system. Consider the logistic model

$$\ln \left(\frac{p_{ij}}{1 - p_{ij}} \right) = \beta_{20} + \beta_{2C} C_{ij} + \varepsilon_{2ij}$$

When there are N_0 states in the system, the constant β_{20} specifies the predicted log odds of conflict in the non-neighboring states, and the $\beta_{20} + \beta_{2C}$ term the predicted log odds in neighboring states. When the number of states increases from N_0 , the number of neighboring dyads increases as a linear function of $N_t - N_0$, but the number of non-neighboring dyads increases as a quadratic function. If β_{20} is constant, then the country-level probability of conflict increases for each new country. This is not plausible – there is no reason to believe that the risk of conflict involving Peru intensifies just because East Timor became independent. An adaption of Raknerud & Hegre's solution is to add the variable $\ln \left(\frac{N_0}{N_t} \right)$ to the model, where N_0 is the lowest number of states in the system in the period of analysis, and N_t the number of states at a given time t . $\ln \left(\frac{N_0}{N_t} \right)$ is set to zero for neighboring countries. In the extended model

$$\ln \left(\frac{p_{ij}}{1 - p_{ij}} \right) = \beta_{20} + \sigma_2 \ln \left(\frac{N_0}{N_t} \right) + \beta_{2C} C_{ij} + \varepsilon_{2ij} ,$$

σ_2 specifies by how much the risk of conflict in non-neighboring dyads increase when the number of states increase.¹⁰

¹⁰Here, I define dyads as high-relevance if they are contiguous and assume that the probability of conflict in such high-relevance dyads is independent of N_t . Raknerud & Hegre also include dyads containing a major

	Col. A
Link function/model	OLS
Dep. Variable	$\ln M_i$ Military Capabilities
Variable	$\hat{\mu}$ (<i>s.e.</i>)
Constant	-16.54*** (.29)
$\ln P_i$ Population _{<i>i</i>}	1.071*** (.032)
R^2	0.860
N	184
* : $p < 0.10$, ** : $p < 0.05$, *** : $p < 0.01$ (robust standard errors)	

Table 1: Estimated relationship between CINC score and population, all countries, 2000 (OLS)

Proximity of War Raknerud & Hegre (1997) and Beck et al. (1998) argue that temporal dependence in BTSCS designs may be handled by adding a function of time since previous conflict in the dyad to the set of explanatory variables. I use the decay function suggested by Raknerud & Hegre (1997) here. Proximity of war is defined as $2^{-py/\alpha}$, where py is the number of years since last conflict and α a half-life parameter. I set $\alpha = 8$, assuming that the risk-increasing effect of a previous war is halved every 8 years.

Trade The trade variable measures the value in million dollars of the trade between the two countries in the dyad. Zero observations of T_{ij} were replaced with USD 500 to allow log-transforming the variable.

5.3 Measuring Size

Size affects both the motivation and the ability wage wars. Size then, should not be measured exclusively in terms of military power. The size of the population is the most fundamental size variable, since both military power and non-military importance in terms of cultural, strategic, and economic factors are increasing functions of population size. I will take both the demographic and military size into account in the analyses reported below, in terms of size of population and the Correlates of War projects CINC scores (Bremer, Singer & Stuckey, 1972). Table 1 shows the relationship between $\ln M_i$ and $\ln P_i$ for all countries in 2000. Note that the elasticity of the CINC score to population is one or slightly above, and that population explains 86% of the variance in the CINC score.

power in the set of high-relevance dyads. Since the focus in this paper is on the effect of country size it is necessary to isolate major power status – a size variable – from the relevance concept.

Variable	Mean	Standard deviation	Minimum	Maximum
$\ln P_i$	9.70	1.43	3.18	14.1
$\ln P_j$	7.69	1.58	2.89	13.8
$\ln M_i$	-5.62	1.73	-13.8	-.957
$\ln M_j$	-8.06	2.04	-13.8	-1.60
$\ln m_i$	-15.4	.985	-21.3	-11.0
$\ln m_j$	-15.6	1.03	-21.3	-10.7
$(\ln M_i + \ln M_j)$	-13.7	3.26	-27.6	-2.9
$\ln (M_i + M_j)$	-5.42	1.68	-13.8	-.689
$\ln A_{ij}$	2.44	1.92	0	12.0

Table 2: Descriptive Statistics, Size Variables

Hence, to minimize collinearity in the models estimated below and ease interpretation, I disaggregate the CINC score into what is explained by population and what is explained by the other components in the CINC score (urban population, energy consumption, coal and steel production, military expenditures and military personnel). The variable is disaggregated simply by calculating the per-capita CINC score, or $\ln m_i = \ln M_i - \ln P_i$.

Table 2 reports descriptive statistics for the most important variables in the models analyzed below.

5.4 The Gravity of War

Table 3, column A, reports the estimates for the gravity model of trade using population size and income per capita as size variables (Model 1). In Column B, I have replaced the income variable with the per-capita military capabilities variable. As is conventional in gravity models of trade, the estimates for log population are close to 1 – the volume of trade between two countries is proportional to the product of the number of inhabitants of each country. The estimates for average income are positive – each citizen trade more the higher income he or she has. The estimate is also significantly larger than 1, implying that a larger share of each citizen’s income is spent on imported goods or derive from exports the richer he or she is. Finally, proximate countries trade more. The estimates for per-capita military capabilities are comparable to those of average income.

In Column C, the dyadic estimate for battle deaths is the dependent variable. Only the 280 dyads for which I have estimates for battle deaths are included. The gravity model pattern is clear also here. The estimates for $\ln P_i$ and $\ln P_j$ are significantly larger than 0 – the number of people killed in war is clearly increasing in the population size of the contestants. But the estimates are also significantly lower than 1 – wars are less bloody

	Col. A	Col. B	Col. C
	Model 1	Model 1*	Model
Link function/model	OLS	OLS	OLS
Dep. Variable	$\ln T_{ij}$ Trade	$\ln T_{ij}$ Trade	$\ln B_{ij}$ Battle deaths
Variable	$\hat{\gamma}$ (<i>s.e.</i>)	$\hat{\gamma}$ (<i>s.e.</i>)	$\hat{\omega}$ (<i>s.e.</i>)
Constant	-37.28*** (.410)	30.16*** (.428)	18.13*** (3.49)
$\ln P_i$ Population _{<i>i</i>}	1.04*** (.0170)	1.04*** (.0196)	.651*** (.128)
$\ln P_j$ Population _{<i>j</i>}	1.16*** (.0144)	.712*** (.0172)	.401*** (.148)
$\ln I_i$ Mean income _{<i>i</i>}	1.87*** (.0194)		
$\ln I_j$ Mean income _{<i>j</i>}	1.58*** (.0213)		
$\ln m_i$ Mil. cap. residual _{<i>i</i>}		1.41*** (.0307)	.734*** (.160)
$\ln m_j$ Mil. cap. residual _{<i>j</i>}		.981*** (.0273)	.460** (.192)
C_{ij} Contiguity	1.19*** (.141)	1.02*** (.154)	1.26*** (.391)
$\ln D_{ij}$ Distance	-1.45*** (.0343)	-1.29*** (.0398)	-.552*** (.154)
R^2 / pseudo- R^2	.538	.410	.342
log likelihood			
N	553, 591	553, 591	280
* : $p < 0.10$, ** : $p < 0.05$, *** : $p < 0.01$ (robust standard errors)			

Table 3: Regression Estimates for Gravity Models of Trade and Battle Deaths, 1885–2001

per capita the larger the countries are. In terms of elasticities, a 1% increase in population in the larger belligerent is associated with a .65% increase in fatalities. The corresponding increase for the smaller country is .40%.

Just as rich countries trade more per capita, countries with high per-capita military capabilities kill more per capita. The estimates for $\ln m_i$ and $\ln m_j$ are positive and significant. For a given population, a change that increases the other components of the military capabilities component by one percent, is estimated to incur .73% more fatalities if it is the larger country in the warring dyad, and .46% more if it is the smaller one.

The last component of the gravity model of war relates to the geographical distance between the countries in war. As one would expect, wars between neighbors are more bloody: Contiguous countries have $\exp(1.26) = 3.5$ times more fatalities, whereas increasing the inter-capital distance between two belligerents by 1% decreases the predicted number of

	Col. A	Col. B	Col. C	Col. D	Col. E
	Model 3	Model 3	Model 4	Model 4	
Link function/model	logit	logit	logit	logit	logit
Dep. Variable	$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right)$ Fatal MIDs	$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right)$ Wars	$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right)$ Fatal MIDs	$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right)$ Wars	$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right)$ Fatal MIDs
Variable	$\hat{\beta}$ (<i>s.e.</i>)	$\hat{\beta}$ (<i>s.e.</i>)	$\hat{\beta}$ (<i>s.e.</i>)	$\hat{\beta}$ (<i>s.e.</i>)	$\hat{\beta}$ (<i>s.e.</i>)
Constant	.992 (.731)	1.77** (.751)	-5.32*** (1.18)	-.073 (1.25)	-2.91*** (.745)
$\ln M_i$ Mil. capabilities _{<i>i</i>}	.160*** (.0494)	.329*** (.0629)			
$\ln M_j$ Mil. capabilities _{<i>j</i>}	.390*** (.0449)	.533*** (.0520)			
$\ln P_i$ Population _{<i>i</i>}			.281*** (.0558)	.343*** (.0766)	
$\ln P_j$ Population _{<i>j</i>}			.476*** (.0506)	.575*** (.0665)	
$\ln m_i$ Mil. cap. per capita _{<i>i</i>}			-.062 (.0770)	.294*** (.0946)	
$\ln m_j$ Mil. cap. per capita _{<i>j</i>}			.211*** (.0683)	.444*** (.085)	
C_{ij} Contiguity	1.40*** (.233)	-.105 (.216)	.682*** (.283)	-.300 (.280)	1.27*** (.285)
$\ln D_{ij}$ Distance	-.605*** (.0789)	-.480*** (.0954)	-.763*** (.0890)	-.529*** (.103)	-.463*** (.091)
System size	.345 (.144)	1.39*** (.166)	.778*** (.175)	1.52*** (.185)	1.05*** (.146)
Proximity of war	2.44*** (.146)	2.08*** (.204)	2.41*** (.141)	2.07*** (.199)	2.20*** (.150)
R^2 / pseudo- R^2	0.256	0.257	0.266	0.257	0.209
log likelihood	-3941.63	-1559.74	-3890.47	-1558.36	-4192.00
N	607, 313	607, 313	607, 313	607, 313	607, 313
* : $p < 0.10$, ** : $p < 0.05$, *** : $p < 0.01$ (robust standard errors)					

Table 4: Estimates for Gravity Models of Conflict, 1885–2001

deaths by .55%.

The explanatory power of the gravity model of war is also reasonably good – 34% of the number of deaths are explained using only six variables.

5.5 The Probability of Dispute

I have argued that since the severity of war is likely to follow a gravity model pattern, the probability of war onset also should follow one. The results of estimating the gravity models of conflict (Models 3 and 4) are presented in Table 4. In addition to the gravity model variables, the models include two variables to address two estimation problems: The

‘system size’ variable that corrects for the dependence of the baseline probability of war on the number of states in the international system (Raknerud & Hegre, 1997: 390–391), and a decay function of time since previous dispute in the dyad called ‘proximity of war’ (Raknerud & Hegre, 1997). Columns A and B report the results for Model (3) using total military capabilities as the only size variable, for fatal MIDs and wars, respectively. Again, the estimates clearly support the idea of a gravity model of conflict. The estimates for the distance and contiguity variables are consistent with previous studies of conflict onset. For MIDs, these estimates are very close in magnitude to those of the gravity model of fatalities (column C, Table 3). For wars, the ‘system size’ variable picks up the effect of contiguity, but these results are close to those for MIDs. The two capabilities variables are positive and significant for both dependent variables. The estimates for $\ln M_i$ and $\ln M_j$ are larger for wars than for MIDs. This is consistent with the argument made above – distance and size are less constraining in the cases of MIDs (that may lead to as little as a single battle death) than is the case for wars (that require 1,000 deaths to be registered in the dataset).

Column C presents the estimates for fatal MIDs of model (4). The estimates show that the risk of conflict increases with increased population both in the smaller and the larger country in the pair. The probability of MID also increases in the per-capita capabilities of the smaller country, but not in the military effectiveness of the larger country. For fatal MIDs, Model (4) clearly describes data better than Model (3). The log likelihood of the model has increased by 50 points relative to Column A.

Column D reports the same set of estimates for COW wars. All the four size variables are positive and significant. For this model, however, the log likelihood only increases with 1.5 points when adding the population variables.

The individual parameter estimates reported in Table 4 strongly suggest that size variables are important components of empirical models of interstate conflict. To further validate this, I report in Column E the results of a model that completely excludes the size variables (for fatal MIDs). First note that the pseudo-log likelihood is more than 250 points lower than that in Column A, and that the pseudo- R^2 is .209 as compared to .256. The explanatory power of size variables is clearly enormous. It is obvious that dyads involving large countries are more likely to become enemies in militarized disputes. The size effects are also substantially important. A pair of countries that is at the 75th percentile for all four size variables is 3.7 times more likely to have a fatal militarized

	Frequency of predicted values					
	Model without size variables			Model with size variables		
Actual outcome	$\hat{p} < .25$	$\hat{p} > .25$	Total	$\hat{p} < .25$	$\hat{p} > .25$	Total
No dispute (%)	231,667 99.9991	2 0.0009	231,669 100.00	231,641 99.999974	28 0.015	231,669 100.00
Dispute (%)	262 100.00	0 0.00	262 100.00	247 94.27	15 5.73	262 100.00
Total	231,929 99.9991	2 0.0009		231,888 99.9815	43 0.0185	

Table 5: Out-of-sample predictions, models with and without size variables, 1885-2001

dispute than a pair of countries at the 25th percentile. Pairs with variables at the 90th percentile are 11 times more likely to have conflict than those on the 10th percentile.

To further validate this conclusion, I reestimated the models in Column C and E for a random sample of 50% of the dyad-years, and compared out-of-sample predictions for the two models with the observed fatal MIDs in the other 50% of the dyad-years. The summary of this exercise is presented in 5. Since wars are rare events, I regard a MID onset as predicted if the predicted probability exceeds .25. The left half of Table 5 cross-tabulates this prediction variable with the observed dispute outcome for the model without size variables. The model predicts only 2 out of 231,931 dyad-years with dispute, and none of these predictions are correct. The right half of the Table reports the same cross-tabulation for the predictions based on the size model. This model predicts 43 onsets of fatal disputes, 15 of which are correct. Even though the out-of-sample prediction success is fairly low (5.73%), the model including population size and per-capita capabilities is clearly better than the conventional distance-only model.

5.6 Is Power Parity Associated With Peace?

Table 4 shows that the size variables in the gravity model of conflict are clearly significant and have explanatory power at par with the distance variables. They are therefore indispensable as control variables in dyadic-level empirical studies of the risk of militarized interstate conflicts if they are also correlated with other explanatory variables of interest. I have noted that the capability ratio variable $\ln A_{ij}$ is a linear function of the two states' capabilities $\ln M_i$ and $\ln M_j$, and that previous studies including the capability ratio variable may suffer from omitted variable bias. Table 6 investigate the extent of this bias.

Column A presents the results from a standard model that includes contiguity and

	Col. A	Col. B Model 5	Col. C	Col. D Model 7	Col. E Model 9
Link function/model	$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right)$	$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right)$	$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right)$	$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right)$	$\ln B_{ij}$
Dep. Variable	MIDs	MIDs	MIDs	MIDs	Battle deaths
	$\hat{\beta}$ (<i>s.e.</i>)	$\hat{\beta}$ (<i>s.e.</i>)	$\hat{\beta}$ (<i>s.e.</i>)	$\hat{\beta}$ (<i>s.e.</i>)	$\hat{\lambda}$ (<i>s.e.</i>)
Constant	-2.99 (.736)	.992 (.731)	.992 (.731)	.765 (.722)	.124 (.0889)
$\ln A_{ij}$ Asymmetry	-.143*** (.0378)	.160*** (.0494)	-.115*** (.0379)	-.338*** (.0436)	
$\ln M_j$ Mil. capabilities; ($\ln M_i + \ln M_j$) Tot. Mil. caps		.550*** (.0563)			.534*** (.0531)
$\ln(M_i + M_j)$ Tot. Mil. caps			.275*** (.0281)		
C_{ij} Contiguity	1.33*** (.287)	1.40*** (.233)	1.40*** (.233)	1.40*** (.234)	1.22*** (.377)
$\ln D_{ij}$ Distance	-.422*** (.0899)	-.605*** (.0789)	-.605*** (.0789)	-.603*** (.0790)	-.545*** (.148)
$\ln(N_t/N_0)$ System size	1.01*** (.146)	.345** (.144)	.345** (.144)	.341** (.143)	
$2^{-py/\alpha}$ Proximity of war	2.23*** (.149)	2.44*** (.146)	2.44*** (.146)	2.44*** (.146)	
R^2 / pseudo- R^2	.212	.257	.257	.257	.340
log likelihood	-4176.83	-3941.63	-3941.63	-3939.93	
N	607, 313	607, 313	607, 313	607, 313	279
* : $p < 0.10$, ** : $p < 0.05$, *** : $p < 0.01$ (robust standard errors)					

Table 6: Estimates for Power Symmetry and Militarized Conflict, 1885–2001

distance in addition to the asymmetry variable and two control variables.¹¹ The estimate is negative and significant, and the magnitude of the estimate is close to previous studies. The pseudo- R^2 of this model is .211. The result has a seemingly straightforward interpretation: The more asymmetric in terms of power a dyad is, the lower is the risk of conflict. Pakistan with $\ln M = -4.41$ in 2000 has a 20% higher risk of fatal MID with Iran ($\ln M = -4.47$) than with India ($\ln M = -2.74$). China ($\ln M = -2.10$) has three times lower risk of conflict with Bhutan ($\ln M = -9.28$) than with Russia ($\ln M = -2.16$), and the risk of conflict between China and Russia is estimated to be roughly the same as that between Mali ($\ln M = -7.65$) and Burkina Faso ($\ln M = -7.57$).

However, Table 4 shows that the last comparison is not correct. In column B, I control for the capabilities of the least powerful country (Model 5). In Section 4.1, I showed that the estimate for $\ln A_{ij}$ in Model 5 will be the same as the estimate for $\ln M_i$ in Model 3. A comparison between the estimates in Column B, Table 6 with those in Column A, Table 4 shows that this holds. Also note that except for the estimate for $\ln M_j$, all other estimates are identical in the two models.

Compared to the model in Column A, the estimate for $\ln A_{ij}$ in Column B has changed sign to be positive and statistically significant. Is it so that power preponderance *increases* the risk of militarized disputes? Not necessarily, since the estimate for $\ln A_{ij}$ is a function of both the asymmetry in the dyad and of the size of the more powerful country. As suggested in Section 4.1, I report in Column C the estimate for $\ln A_{ij}$ where I control for the total capabilities ($\ln M_i + \ln M_j$) in the dyad. In this specification, the estimate for $\ln A_{ij}$ is again negative and significant. In Column D, I control for $\ln (M_i + M_j)$. In this version of the model, the power asymmetry estimate is even more strongly negative and significant.

The four sets of estimates in Column A, B, C, and D demonstrate the difficulty of making inferences regarding the effect of power asymmetry. It is impossible to compare dyads in terms of relative power levels without also taking absolute power levels into account. The results in Column B tell us that if we take a dyad and hypothetically increase asymmetry by increasing the power of the largest country, the risk of militarized conflict increases. Conversely, if we increase asymmetry by decreasing the power of the least powerful, the predicted risk decreases since the estimate for $\ln M_j$ is larger than that

¹¹In Author (XXXX), I show that all conclusions reached below also hold when adding additional variables such as trade and democracy to the model.

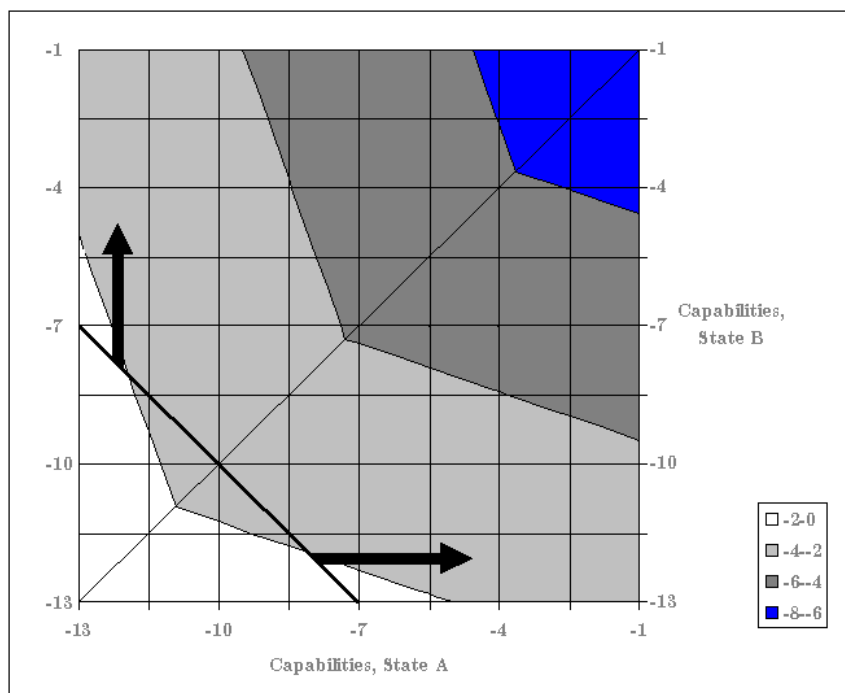


Figure 2: Predicted Log Odds of Fatal MID, By Capabilities of States A and B.

of $\ln A_{ij}$. According to these estimates, military investments in one country unambiguously increases the risk of conflict, whereas disarmament decreases it. The results in Columns C and D inform us that a territory with a given amount of capabilities will be less risk-prone if it is split into one large and one small state than if it is split into two equally powerful ones.

It is worth noting that the substantive importance of asymmetry is considerably smaller than that of absolute size. In all models in Table 6, the estimates for $\ln A_{ij}$ are less than half the size of the corresponding estimates for the size variables, despite the variables's standard deviations being roughly comparable. This is evident in Figure 2 which plots the estimated relative log odds of war as a function of the capabilities of the two states in the dyad.¹² Darker shades represent a higher estimated risk of conflict. The least powerful dyads are located in the lower left corner of the figure. The capabilities of State A is represented by the x axis, that of State B by the y axis. The perfectly symmetric dyads are situated along the diagonal from this corner to the upper right one. The most asymmetric dyads are found close to the lower and left axes. The lines between the colored areas are iso-risk lines – lines with similar estimated log odds of fatal MIDs. The iso-risk lines are concave, reflecting that the symmetric dyads are more conflict-prone than the

¹²The Figure is based on the estimates in Column A, Table 4. The baseline is a dyad where both states have $\ln M_i = \ln M_j = 0$.

asymmetric ones.

The black line drawn from the $(-13, -7)$ coordinate to $(-7, -13)$ connects dyads that have total capabilities equal to -20 . One may think of this line as representing all possible distributions between two states of a given set of resources. The 50-50 distribution (at the diagonal) has the highest risk of dispute. When moving along this line toward either the x or the y axis, the estimated risk of conflict increases with increasing power asymmetry.

The two arrows in the chart, on the other hand, shows what happens if one country increases capabilities while the power of the other is held constant. This leads to an increase in asymmetry that also increases the total size of the dyad. The figure shows that a movement along one of the arrows *increases* the risk of conflict. Preponderance may pacify, but power kills.

One important caveat to this discussion should be noted. I showed above that population size explains 86% of the variation in the power index. Hence, most variance in power is due to demographic factors, not by any deliberate governmental policies (apart from wars of conquest).

6 Conclusion

In this paper I have shown that an analogy to the gravity model of the volume of trade also is a good description of the severity and risk of militarized disputes between countries. Militarized conflict is not only most frequent between countries that are geographically close to each other – they are also more frequent between larger countries. I show that a set of size variables – based on countries' population and their military capabilities – significantly and strongly increases the probability of militarized disputes between countries. Including the four size variables lead to an increase in log likelihood of about 250 points. This improvement in goodness of fit cannot be neglected. The size variables are indisputably associated with the probability of militarized disputes between countries.

Despite their obvious importance, most quantitative studies of conflict do not control for size apart from including dummy variables for whether the dyad consists of one or two major powers. The implications of this strong empirical relationship are therefore not trivial. Omitting an important predictor of interstate conflict such as size means that its impact will be captured by variables that are closely related to size. I have shown that this applies to several important variables in the literature on interstate conflict. I have

explored the impact of omitting the size variables for the power preponderance–power parity variable. Elsewhere (Hegre, 2007), I explore the importance for the trade and conflict literature. I argue that size variables should form part of any fully specified model of interstate conflict, just as population size has become an indispensable item in civil war studies.

The analysis of power or size asymmetry and the risk of militarized disputes show that this relationship is far from straightforward. Even though I replicate the finding that the power capability ratio variable is negatively associated with conflict, the risk-increasing effect of power itself complicates the interpretation of this result. Among potential allocations of a given territory between two states, the most asymmetric constellations are least conflict-prone. But any attempt to increase asymmetry by increasing the power of the larger and more powerful one is estimated to increase the risk of interstate disputes. Conversely, any attempt to increase asymmetry by decreasing the power of the least powerful one decreases the risk of conflict. Still, two-sided power reductions would be even more beneficial seen from the perspective of reducing the overall risk of militarized disputes. Lemke & Kugler (1996: 4) claim that ‘*parity* is the necessary condition for major war...’. Although the results obtained in this paper supports their position re the balance-of-power proponents, a more appropriate conclusion is that ‘*power* is the necessary condition for large-scale war’.

7 References

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