

## Mistaken Identity: A Reply to Hegre

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*Hegre (2005) offers an interesting example of cumulative science. By relaxing a restrictive assumption in Gartzke and Li (2003a), Hegre shows formally that the relationship between trade share and trade dependence need not be negative. Still, Hegre's assumptions are also in tension with his basic insight. We apply his logic in a more thorough manner to demonstrate that our original theoretical argument and empirical results are robust to the critique. Hegre (2005) also suggests that the pacifying effect of trade openness is likely an artifact of our failure to control for the size of the national economy. We re-estimate the effect of trade openness while controlling for the economic size of both states in the dyad and show that trade openness continues to reduce the likelihood of military conflict between countries.*

**Keywords** economic interdependence, militarized interstate disputes, openness, bilateral trade, conflict

Hegre (2005) argues that Gartzke and Li (2003a) mistakenly interpret the identity linking competing measures of bilateral trade (trade share and trade dependence) with monadic economic openness. While we applaud his constructive approach to cumulative science, we disagree with his conclusions. Rather than arguing that Hegre has gone too far in his critique, we show that he has probably not gone far enough. Hegre applies his insight somewhat arbitrarily, relaxing some restrictive assumptions but not others. We apply his approach in a more thorough manner and produce results consistent with our original claims. Once we interpret the relationship between output and trade in line with economic logic, Hegre's claims are debatable deductively and dubious empirically. Hegre (2005) usefully points out that a negative effect of trade openness on military conflict could have been spurious due to our previous failure to control for economic size. We re-estimate the effect of trade openness while controlling for the size of economies for both states in the dyad and find robust evidence that trade openness reduces the likelihood of disputes.

### A Quick Summary of the Controversies

In a series of articles, Oneal and Russett (1997, 1999) and Barbieri (1995, 1996) reported contrasting empirical effects of economic interdependence on militarized interstate disputes

(MIDs). These results could be due to differences in data (measurement, temporal, or spatial domain), but different coding procedures could also be a contributing factor. Gartzke and Li (2003a) set out a mathematical identity between trade share (the proportion of dyadic trade to total trade, championed by Barbieri) and trade dependence (dyadic trade weighted by gross domestic product, preferred by Oneal and Russett). As equation (1) indicates, the two competing measures of dyadic trade can be negatively related through the consensus measure of trade openness, a state's total trade weighted by its gross domestic product.

$$\left(\frac{T_i}{Y_i}\right) = \left(\frac{T_{ij}}{Y_i}\right) / \left(\frac{T_{ij}}{T_i}\right), \quad (1)$$

where  $T_i$  is state  $i$ 's total trade,  $T_{ij}$  represents bilateral trade between states  $i$  and  $j$ , and  $Y_i$  equals GDP for state  $i$ , so that  $(T_i/Y_i)$  is openness,  $(T_{ij}/Y_i)$  is trade dependence, and  $(T_{ij}/T_i)$  is trade share.<sup>1</sup> Gartzke and Li (2003a) then report multivariate statistical results indicating that the two measures of dyadic trade are negatively related, suggesting that at least part of the explanation for the contrasting findings in the literature can be attributed to the different coding decisions used by protagonists in the debate.

Hegre (2005) notes that equation (1) assumes that bilateral trade and total trade are independent. This is an empirically implausible assumption and relaxing it alters implications drawn from the identity. Hegre modifies equation (1), allowing total trade ( $T_i$ ) to be a function of bilateral trade ( $T_{ij}$ ). This yields equation (2), in which changes in trade share and trade dependence are generally positively related.

$$\left(\frac{T_i + \varepsilon}{Y_i}\right) = \left(\frac{T_{ij} + \varepsilon}{Y_i}\right) / \left(\frac{T_{ij} + \varepsilon}{T_i + \varepsilon}\right), \quad (2)$$

where  $\varepsilon$  indicates some change in bilateral trade. Hegre goes on to offer a different interpretation of Gartzke and Li's (2003a) statistical results following from his version of the mathematical identity.

### A (More) More Fruitful Use of the Identity

Models are constructs; they offer at most logically consistent claims that await testing and always involve some simplification of reality. Indeed, since reality is elusive, one must adopt useful fictions as a matter of course in attempting to specify cause and effect. Hegre (2005) offers a constructive criticism, relaxing some assumptions of our previous study to see whether the findings are robust.<sup>2</sup> Our concern is not with what Hegre has done, but with what he has failed to do. Indeed, the logic of Hegre's argument goes much farther than

<sup>1</sup>We adopt Hegre's (2005) notation to simplify comparison of the argument and critique.

<sup>2</sup>Hegre argues that Gartzke and Li (2003a) "err" in using equation (1) to draw empirical implications (p. 3). He also argues that the use of certain assumptions is "misleadingly restrictive" (p. 4). Errors can result from deduction (as when a researcher does not draw the correct conclusions from his or her assumptions), empirical analysis (as when a researcher fails to correctly test hypotheses logically drawn from assumptions), or primitives (a researcher may have adopted the wrong assumptions). Hegre seems to accept that Gartzke and Li (2003a) have solved their model correctly and that they have tested the model appropriately (with the exception noted of controlling for state size, addressed later): "Gartzke and Li's empirical analysis follows the same logic as the theoretical argument" (p. 8). This implies that this is a debate over assumptions, which of course can only be adjudicated using the "true" model underlying nature.

does Hegre. If bilateral and total trade are to be treated as endogenous, then why treat other aspects of the identity as unrelated variables? Hegre notes that “When comparing, we want to hold all other factors constant, but *not factors that are a function of the bilateral trade itself*” (p. 219, italics in the original). We agree and identify correlates of bilateral trade that bring to fruition Hegre’s argument.<sup>3</sup>

Are bilateral trade and total trade the only components of the identity that appear related? Hegre (2005, 219) shows through equation (2) that “an increase in a bilateral trade flow will always be reflected as an increase in both trade share and trade dependence, as long as GDP and trade with other countries is constant.” He thus assumes that GDP and trade with other countries are uncorrelated with bilateral trade. The claim that GDP is constant is again invoked on page 220 to show that Gartzke and Li’s (2003a) interpretation of the empirical estimates of trade dependence and trade share are incorrect. Hegre argues that “when controlling for trade openness, increasing bilateral trade share reduces the risk of war” (Hegre, 2005, 222). Hegre’s treatment of GDP and trade is inconsistent with his basic argument that components of the identity are endogenous empirically.

First, GDP and trade are not independent (Frankel & Romer, 1999). Gross domestic product (GDP) is defined as “the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products” (World Bank, 2002). Annual statistical data on GDP are obtained by adding up domestic absorption (DA) and the net foreign balance (NFB), where DA is the sum of the national expenditures on consumption, investment, and government, and the NFB is the difference between exports and imports (Heston, Summers, & Aten, 2002). An increase in bilateral trade must *always* be reflected in a country’s GDP, with the direction of change in GDP depending on whether the increase is in imports or exports. Nor does Hegre’s thought experiment—varying trade while holding GDP constant—conform to the way that economic data are measured or estimated. Annual aggregates of GDP are computed based on summing all value-added activities, including exports. Just as economic openness includes changes in bilateral trade, so too does GDP contain these same bilateral trade changes. Hegre himself acknowledges this relationship in previous research “*ceteris paribus*, states trade more with states that have large GNPs than they do with smaller economies” (Hegre, 2000, 12). Thus Hegre’s insight would seem to require that he (and we) *not* hold GDP constant.

Second, Hegre’s assumption that trade between two states,  $i$  and  $j$ , is unrelated to trade with third parties ( $T_{ik}$ ) is also problematic in terms of his critique. Hegre defines  $T_i^\omega \equiv \sum_{k \neq j} T_{ik}$  as the sum of bilateral trade relationships exempting  $T_{ij}$ , such that  $T_i = T_{ij} + T_i^\omega$ . Hegre goes on to vary  $T_{ij}$  by  $\varepsilon$ , while keeping the other bilateral relationships constant ( $T_i + \varepsilon = T_{ij} + \varepsilon + T_i^\omega$ ). If  $T_{ij}$  is “not like the other” bilateral trade relationships, then Hegre’s critique is asymptomatic and fails to capture the overall characteristics of bilateral trade. If instead Hegre’s critique applies more generally, then the critique needs to be applied more generally in Hegre’s model. The pairing of states— $i$  with  $j$ , or  $i$  with  $k$ —is entirely arbitrary. Since we can switch the notation without altering the substance of the critique, there is no reason within the argument to endogenize  $T_{ik}$  while failing to do so for  $T_{ij}$ . Nor can  $T_{ij}$  and  $T_{ik}$  be independent of *each other* as both share in common state  $i$  as a member. Thus, treating  $T_i^\omega$  as a constant is as flawed as treating  $T_{ij}$  as a constant. Trade openness ( $T_i$ ), then, does not vary by  $\varepsilon$ , but by some aggregation of the  $\varepsilon$ ’s of all relevant bilateral relationships.

<sup>3</sup>Hegre acknowledges in a footnote that trade is tied to gross domestic product. “Naturally, increasing  $T_{ij}$  will increase  $Y_i$  and  $Y_j$ ” (p. 219, fn. 3). He goes on to argue that this is not important and can be omitted from his version of the model. We show below how this assumption helps to determine the results from Hegre’s model.

The third inconsistency in Hegre's endogeneity critique involves the number of trade partners. Hegre treats trade partners as a constant for every state, an assumption that is again incorrect empirically and directly contradicts a key component of our argument.<sup>4</sup> Heavily trade dependent and economically open states like the Netherlands and Singapore tend to have many trade partners. States that are relatively less dependent on trade (Rwanda, Tajikistan) tend to have fewer partners. In the extreme, autarkic economies (North Korea, Bhutan) are characterized by having effectively no trade partners. Ignoring this feature of international trade biases analysis in favor of Hegre's claim and against the conclusions of Gartzke and Li (2003a).

Hegre's insight that the components of the identity covary can be extended in the ways discussed above.<sup>5</sup> We modify equation (2) to endogenize state  $i$ 's (a) GDP, (b) third party trade, (c) number of trade partners. First, let us treat gross domestic product as some function of trade ( $Y_i = Y_0 + \phi T_i$ ), where  $0 \leq \phi \leq 1$  is an arbitrary weight of the effect of total trade on GDP, and where  $Y_0$  is some baseline value for the national economy.<sup>6</sup> Second, assume that third party trade relationships,  $T_{ik} = T_{ij}$ , for all states  $i \neq k$ .<sup>7</sup> Finally, we endogenize the scope and scale of bilateral trade relationships. Let  $T_i^\omega = \sum_{k \neq j}^{n-1} (T_{ik} + \varepsilon)$ , where  $n = f(\varepsilon)$ ,  $n > k$ ,  $n$  is an integer increasing in  $\varepsilon$ . Thus,  $T_i = n(T_{ij} + \varepsilon)$ . In ordinary words, we adopt Hegre's assumptions about how trade varies between  $i$  and  $j$ , and adapt them to trade with third parties:

$$\left( \frac{n(T_{ij} + \varepsilon)}{Y_0 + \phi[n(T_{ij} + \varepsilon)]} \right) = \left( \frac{T_{ij} + \varepsilon}{Y_0 + \phi[n(T_{ij} + \varepsilon)]} \right) / \left( \frac{T_{ij} + \varepsilon}{n(T_{ij} + \varepsilon)} \right). \quad (3)$$

What does this new identity look like? Figure 1 replicates Figure 1 in Hegre (2005). Based on his equation (2), Hegre depicts in Figure 1 how the three measures change with a change in bilateral trade from 0 to 25 units. He assumes that  $Y_0 = 100$ ,  $T_{ij} = 0$ , and  $\varepsilon$  varies between 0 and 25. Our Figure 1 describes the same relationships, but is based on our more general identity expression in (3) above, which allows GDP and the number of trade partners to vary as well. In addition to the parameter values provided by Hegre, we assume that  $\phi = 0.1$  (all other values in the interval  $[0,1]$  produce equivalent results for trade share) and that  $n = \varepsilon$  for the sake of simplicity.<sup>8</sup>

The patterns in our Figure 1 clearly differ from those in Hegre's Figure 1. Varying bilateral trade between state  $i$  and  $j$  leads trade openness and trade dependence to increase as in Hegre (2005), but trade share is now decreasing. As we conjectured in our previous study, allowing the number of trade partners to covary with the level of bilateral trade is

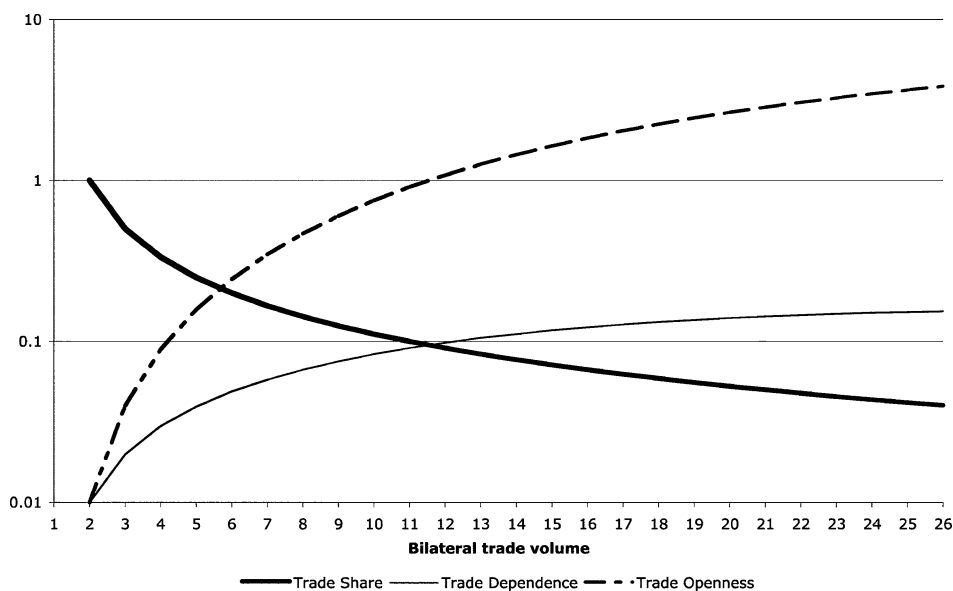
<sup>4</sup>In an earlier critique of Dorussen, Hegre (2002) appears to make a similar point, showing that increasing the size of trade or the number of trade partners must decrease the likelihood of conflict in an interdependent system.

<sup>5</sup>In order to maintain comparability, we attempt as much as possible to retain Hegre's framework. Thus we are forced to adopt fairly arbitrary assumptions about parameter values and functional forms. Still, we show that the strong form of Hegre's critique is invalid. Trade share and trade dependence do not always increase together, but instead covary negatively over a range of values proposed by Hegre.

<sup>6</sup>In correspondence Hegre suggested adopting these boundaries for  $\phi$ . We see them as arbitrary but adequate.

<sup>7</sup>More accurately, we are assuming  $E[T_{ik}] = E[T_{ij}]$ . There are a multitude of ways to model this relationship. Since we are interested here only in the consequences of correlated bilateral trade on trade openness, we assume that Hegre's model correctly captures the bilateral dynamic of a given pair of states, and simply extend this to all pairs.

<sup>8</sup>The exact relationship between  $n$  and  $\varepsilon$  is not critical, though they must increase together. Hegre (2005) assumes that  $T_i^w = 40$ . We omit this value in Figure 1 for simplicity, but it can be added without changing the key results.



**FIGURE 1** Trade dependence, trade share, and trade openness.

critical in determining the result from the identity. GDP also increases with trade, though this appears not to be critical to the results. We hasten to add that both Hegre's construction of the identity and our extension (as well as our original specification of the identity) are logically tenable, given the respective assumptions. However, the argument Hegre uses in advocating his equation (2), that is, relaxing the restrictive assumptions on the relationships among the three measures should result in something like our equation (3), as a more general representation and the consensus choice. We next address some of the empirical issues brought up by Hegre (2005).

### Misidentification of the Parameters

Based on what we argue is an incomplete interpretation of the identity, Hegre extends the algebraic manipulations of trade dependence, trade openness, trade share, and war through equations (3)–(5), concluding that based on Gartzke and Li's calculation, "when controlling for trade openness," increasing bilateral trade share reduces the risk of war." Hegre's conclusion is incorrect for several reasons.

First, Hegre's interpretation of our parameter estimates depends on his version of the identity. "It is more natural to hold the scaling factor constant than the variable itself when interpreting the estimates" (Hegre, 2005, 221). As trade affects GDP, the scaling factor is not likely to be held constant. Holding economic size ( $Y_i$ ) constant is certainly not appropriate when the size of  $Y_i$  is a function of trade.

Second, Hegre's reinterpretation of what the coefficient of trade share means, i.e., the difference between the effect of trade share and the effect of trade openness, as noted in his equation (6) on page 222, hinges on his own assumptions about the causal process of war and the true model he claims that Gartzke and Li believe in. Hegre (2005, 221) hypothesizes that Model B (containing both trade share and trade dependence along with control variables) as noted in his equation (4) "gives the best approximation to the true relationship between trade and conflict." On the next page, he asserts that (5) (containing both openness and trade share) is the true model. If the three trade indicators (trade openness, trade dependence, and

trade share) measure different theoretical concepts, then (4) and (5) cannot both be the true model. If the three variables measure the same concept, then putting any two in the same model is redundant. More important, based on his discussion of the parameters in his (6), Hegre concludes that the estimate of trade share in (6) is “the effect of ‘trade share’ minus the effect of general ‘openness’.” He arrives at this conclusion because he assumes that his (5) represents the true model, into which the identity is substituted. Nowhere in Gartzke and Li (2003a, 2003b), however, is it indicated that (5) is the model they evaluate. Hegre’s conclusion does not follow if he does not substitute his own (5) for the model Gartzke and Li actually estimate.

Third, Hegre interprets the empirical estimates from Gartzke and Li (2003a) incorrectly. He equates their estimates based on the weak-link measures of trade openness, trade dependence, and trade share, derived following the steps detailed in Table V of Gartzke and Li, with his coefficients for those variables defined in his equations (3)–(6). Yet, his variables are not equivalent conceptually with the weak-link variables. Hence, his calculation of the effect of trade share on page 222 is questionable.

### Clarification of the Interpretation of the Gartzke and Li Estimates

Hegre’s critique does bring up a pertinent issue regarding the interpretation of the coefficients for trade share and trade dependence when both variables appear at the same time in the models offered by Gartzke and Li. As noted in Gartzke and Li (2003a, 563), the analysis is intended to “examine empirically the relationships among the three measures of interdependence.” Gartzke and Li’s assumption is that trade openness must negatively affect dyadic dispute behavior. Based on the identity, they then infer that trade share can increase militarized disputes while trade dependence can decrease MIDs. The identity implies that the log of trade openness can be substituted for the log of trade share and the log of trade dependence. That is, “we are able to use the two terms as an equivalent of openness in one statistical model.” This makes it possible to “test our expectations of the relationships among the three measures in an additive model.” Evidence in Gartzke and Li corroborates this expectation. The log of trade openness negatively affects MID onset. Correspondingly, in the model of both trade share and trade dependence, the log of trade share positively affects MID onset, while the log of trade dependence negatively affects MID onset.

If both trade share and trade dependence are valid measures of interdependence, then including both in one model is redundant. Hence, we need to put the results of Gartzke and Li regarding the effect of trade share and trade dependence into perspective. Our previous results indicate that variability in trade share correlates negatively with the consensus measure of monadic trade (openness). In this sense, trade share is an inferior measure of trade interdependence. If we introduce trade share by itself into the model of MID onset, it will be statistically significant but negative because of the absence of theoretically more relevant measures that include GDP. High correlation between trade share and trade dependence, as Hegre correctly points out, is evidence consistent with this interpretation of the effect of trade share alone.

The effects of trade share and trade dependence in Gartzke and Li (2003a) should be understood in the context of high collinearity, an issue that unfortunately was only noted in a footnote on page 567. The individual *ceteris paribus* effects of two collinear variables on a dependent variable cannot be estimated using their common covariation with the dependent variable, because the shared covariance by definition means that it is not uniquely attributable to either variable alone. The shared covariance is thrown out in estimating the individual effects of the correlated variables on the common dependent variable. High correlation between trade share and trade dependence implies that the coefficient of trade share is the effect of trade share on MIDs after dropping the high covariation between trade share

and trade dependence. It is likewise for the coefficient of trade dependence. Thus, the significant positive coefficient for trade share in the MID model means that variations in trade share that are independent from trade dependence tend to promote MID onset. This interpretation follows from the argument posed in Gartzke and Li (2003a, 2003b) regarding the relationships among the three trade variables.

### The Effect of Trade Openness Is Not Spurious

It is well known in political economy that a country's trade openness tends to be negatively related to the size of the country. Hegre suggests that because Gartzke and Li's analysis fails

**TABLE 1** Logit estimates of MID onset, 1950–1992, replicating Gartzke and Li (2003a) and controlling for economy size

	Model 1 (All dyads)	Model 2 (Relevant)	Model 3 (All)	Model 4 (Relevant)	Model 5 (All)	Model 6 (Relevant)
Openness (log) <sub>t-1</sub>	-0.3134** [2.869]	-0.3078** [2.901]	-0.1876* [1.962]	-0.2025* [2.376]	-0.2628* [2.448]	-0.2627** [2.628]
GDPA(log) <sub>t-1</sub>	0.1688** [4.325]	0.1545** [4.335]	0.2199** [5.673]	0.1724** [5.228]	0.2133** [5.127]	0.1880** [5.150]
GDPB(log) <sub>t-1</sub>	0.0640 [1.733]	0.0604 [1.853]	0.0831* [2.478]	0.0451 [1.628]	0.0874* [2.484]	0.0714* [2.305]
Demlow <sub>t-1</sub>	-0.0627** [5.249]	-0.0613** [5.597]	-0.0726** [6.106]	-0.0631** [6.390]	-0.0643** [5.169]	-0.0629** [5.604]
Demhigh <sub>t-1</sub>	0.0112 [1.257]	0.0216* [2.430]	0.0198* [2.175]	0.0291** [3.555]	-0.0004 [0.042]	0.0164 [1.853]
Contiguity <sub>t-1</sub>	2.3839** [10.444]	0.9600** [4.360]	2.5565** [10.912]	0.9246** [4.798]	2.2382** [10.429]	0.8918** [4.447]
Distance <sub>t-1</sub>	-0.3775** [5.011]	-0.2003** [3.599]	-0.5071** [6.722]	-0.2241** [4.403]	-0.3777** [5.086]	-0.1726** [3.054]
Major power <sub>t-1</sub>	0.6485** [3.373]	-0.3590 [1.779]	0.7231** [3.477]	-0.4496* [2.338]	0.6342** [2.941]	-0.4801* [2.283]
Allies <sub>t-1</sub>	0.1021 [0.569]	-0.0083 [0.053]	0.0150 [0.088]	-0.1394 [0.964]	0.0210 [0.106]	-0.0701 [0.427]
Capability ratio <sub>t-1</sub>	-0.0885 [1.734]	-0.1765** [3.303]	-0.1151* [2.349]	-0.2162** [4.889]	-0.0984 [1.947]	-0.1954** [3.810]
Peace year	-0.3404** [8.039]	-0.3261** [7.857]	-0.3533** [9.449]	-0.3325** [9.280]	-0.3256** [7.515]	-0.3089** [7.367]
_spline1	-0.0011 [1.587]	-0.0010 [1.374]	-0.0016** [2.630]	-0.0013* [2.098]	-0.0008 [1.069]	-0.0006 [0.862]
_spline2	0.0000 [0.002]	-0.0001 [0.154]	0.0004 [0.905]	0.0002 [0.390]	-0.0002 [0.495]	-0.0003 [0.666]
_spline3	0.0003** [2.897]	0.0003** [2.967]	0.0002* [2.243]	0.0002** [2.714]	0.0003** [3.345]	0.0004** [3.458]
Constant	-4.3048** [6.573]	-3.4419** [6.392]	-4.0227** [5.939]	-2.8493** [5.200]	-4.6567** [6.775]	-3.7698** [6.405]
N	104270	19444	208374	25125	114251	21358

Note: Robust z statistics in brackets, adjusted for clustering over dyads.  
Two tailed test: \*significant at 5%; \*\*significant at 1%.

to control for the size of the countries in the dyad, the negative effect of trade openness on MID onset may be spurious. This is an important critique that is worth additional empirical analysis.

Table 1 presents the empirical results from re-estimating the effect of trade openness on MID onset for the period of 1950–1992 for all dyads and for politically relevant dyads as in Tables VI, VII, and VIII in Gartzke and Li (2003a). Models 1–2 use the Barbieri trade data, models 3–4 use the Oneal and Russett trade data and set missing trade values to zero, and models 5–6 also use the Oneal and Russett data but treat missing trade values as missing. All variables are the same as in Gartzke and Li (2003a), except that we now control for the size of the two countries in the dyad by including the log of GDP for each country in the dyad. Trade openness remains highly significant and negative, even after controlling for economic size. We thus conclude that the pacifying effect of openness on military conflict is not spurious.

## Conclusion

Hegre (2005) presents an important, relevant, and informative critique of Gartzke and Li (2003a). He notes, correctly, that Gartzke and Li adopt assumptions about the independence of components of an identity relating trade variables that are contestable. If some of these assumptions are relaxed, the conclusions Gartzke and Li provide may be reversed. Hegre goes on to argue for a reinterpretation of the empirical results in Gartzke and Li (2003a) based on his reformulation of the mathematical identity.

Scientific learning requires that we question what we think we already know. Gartzke and Li (2003a) seek to inform the community of researchers studying conflict and interdependence by suggesting a new way to explain contradictory findings of Barbieri (1995, 1996) and of Oneal and Russett (1997, 1999). Hegre (2005) teaches us something new, both about the claims of Gartzke and Li and about how to build on existing conclusions. We hope we have continued that process here, further extending the insights of Hegre, while showing that they lead back in the direction we initially proposed. Science also demands that we give deference to logical coherence and empirical evidence. All three interpretations of the identity between trade share, trade dependence, and openness are virtuous in this regard. All are deductively sound. Our versions of the identity conform with the evidence we provide, while Hegre's re-interpretation of our evidence is also largely consistent with his claims. The differences that remain thus revolve around assumptions. We argue that Hegre's critique can be made more consistent, and that by doing so, we show that our original claims obtain. We have found the process stimulating and hope it proves informative to others. No doubt, there will be more debate on the subject in the future.

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