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Daniel Spiro

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Economic Warfare

Abstract

What actions should we expect countries to take when engaged in economic warfare? This paper first shows that the goal of winning a war implies a very simple and intuitive objective of economic warfare: maximize one's own less the opponent's (weight-adjusted) payoff. This objective function is then applied to a number of canonical strategic economic environments showing how warfare transforms them. In a warfare-equilibrium between a buyer and a seller, the traded quantity is lower than in peace but, surprisingly, the price may be lower. The analysis shows when trade will altogether collapses in war and when trade will persist between the parties despite it. A prisoner's-dilemma game (e.g., monopolistic competition or climate-change mitigation) remains a prisoner's-dilemma game also in war, and cooperation may be impossible also under infinite repetition. A coordination game with heterogeneous preferences (e.g., choosing technological standard) in war collapses to either deliberate miscoordination or to 'matching pennies' where one country is trying to imitate the other which is trying to avoid this. The results are interpreted through the lens of the current economic warfare between Russia and the West.

JEL-Codes: C720, D740, F510.

Keywords: economic warfare, conflict, sanction, trade.

Daniel Spiro
Department of Economics
Uppsala University
Box 513
Sweden – 75120 Uppsala
daniel.spiro.ec@gmail.com

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1 Introduction

"The ultimate military purpose of war is the destruction of the enemy's ability to fight;...; Employ all combat power available in the most effective way possible"

From the US armed forces' Nine principles of war.

War does not always disrupt economic interaction between the adversaries. As a case in point, after the Russian invasion of Ukraine, the EU and Russia are essentially at war with each other, yet are still trading and keeping up substantial economic interaction (Eurostat 2023). Similarly, Russia is paying Ukraine which is allowing the transit of Russian gas over its territory (Bloomberg 2022). At the same time, economic warfare is clearly part of the general warfare (EC 2023).

In light of the coexistence of economic interaction and war this paper asks: What should we expect countries to do when engaging in economic warfare?

To answer this question, the paper proceeds in two steps. In the first step it derives the objective of economic warfare given that a country is at war; in the second it analyzes the consequences of this objective for the strategic economic interaction between the adversaries.

The first step starts from a classic contest function where economic interactions are modeled as battlefields in a greater war. It shows that a country which, alongside material payoffs, cares about winning a war will have a very simple goal in economic warfare. It will seek to maximize a weighted sum of its own economic payoff and the opponent's economic loss. That is, just like in any battleground and as expressed in the quotes above, the goal of economic warfare is to harm one's opponent while economizing of one's own loss. It thus includes the classic understanding of economic warfare nicely expressed by Lowe and Tzanakopoulos (2012) as the "decision to weaken the adversary's economy in order to diminish or eliminate its capacity to wage war".

Such an objective function is not new to economic modeling but has not been linked to warfare; it resembles that of 'spite' used in behavioral economics to explain outcomes in lab experiments (Levine 1998). But unlike in behavioral economics, the objective here is not 'irrational' or behavioral but is derived from the greater objective of war. Furthermore, unlike in the literature on 'spite', the weight one puts on harming one's opponent is not subjective or exogenous, but is derived endogenously from fundamental objectives.

The second step applies the derived objective function of economic warfare to three canonical economic settings. This analysis answers why and when economic peace-time interactions will be maintained between countries at war and how the transition from peace to war will change the economic decisions they take.

The first application is the relationship between a single buyer and a single seller. This application thus answers whether countries at war with each other will continue trading, how the transition from peace to war will affect supply and demand respectively and whether war will increase or decrease the price. It predicts that the traded quantity will be reduced but that, surprisingly, the price may in fact be lower than in peace. This happens, particularly, if the seller invests more in military capacity than the buyer.

The second application is the prisoner's dilemma. This analysis thus answers how warfare will affect classic prisoner's-dilemma situations, such as, monopolistic competition (Osborne 1976) and the formation of climate agreements (Barrett 1999). The prediction here is that prisoner's-dilemma situations will be aggravated by war. Thus, the adversaries will tend to pull out of environmental agreements and increase production in industries where they compete.

The third application is a coordination game with heterogeneous tastes (the battle-of-the-sexes game). This analysis thus answers how war will affect classic coordination settings, such as, the choice of technology standards and infrastructure investments (Mattli and Büthe 2003). It predicts when coordination will break down and in whose interest this is. In particular, in an all-out war (where nothing else than winning matters) there will be no mutual coordination. Either both countries will miscoordinate on purpose, or one country will try to mimic the other who is trying to avoid it (a matching-pennies game).

An extensive literature exists analyzing warfare; going back to classic thinkers and texts, across many scientific disciplines.[1] One cannot do it justice in short space. I will focus

[1] One of the first writings on economic warfare is by Thucydides describing the Peloponnesian war (431-404 BC). It is a recurring theme in military history covering most conflicts, e.g., the naval blockades in the 17th and 19th century. See, e.g. Draper (1990), Førland (1993), and Mulder (2022) for historical accounts.

here on *theoretical work* analyzing *economic warfare* and *sanctions* and briefly discuss what the current paper does that previous work has not.

A first key distinction is that between economic sanctions and economic warfare. In real conflicts they overlap, both semantically and practically. But theoretically they differ. Economic sanctions are generally modeled as having an objective to *deter* war, decrease the *will* to fight or *coerce* the target to behave in a way one wants, i.e., getting the target to behave in a certain way (see, e.g., Kaempfer and Lowenberg 1986; 1992 and 1999; Morgan and Schwebach 1997; Tsebelis 1990; Drezner 1998; Eaton and Engers 1992 and 1999; see Kaempfer and Lowenberg 2007 for an excellent review). In such a setting, there is no reason to harm the opponent, other than as deterrence or coercion, i.e., to uphold an equilibrium. In that sense, sanctions are similar to trade wars (see e.g., Brander and Spencer 1984). Economic warfare, the way it is applied here, has the greater objective of winning an actual war and thus the specific goal of economic warfare is to reduce an opponent's *ability* to fight (and increase one's own). That is, just like bombs are meant to reduce the enemy's fighting capacity, harming the opponent has a direct value in economic warfare. Put differently, in economic sanctions the opponent's payoff is important since it affects its strategy; in economic warfare the opponent's payoff is (or becomes) part of ones own objective function.

In relation to the literature on economic warfare, the general contribution of this paper is providing a framework to analyze the objectives of economic warfare, and how actions and equilibria change when going from peace to war. The first contribution is thus in deriving the objective in economic warfare from fundamentals. No previous research doing that exists. The key insight is that the objective of economic warfare boils down to maximizing the enemy's loss and one's own income.

The second contribution is providing a structure for analysis of economic warfare across economic environments. A key and novel insight is that analysis of economic warfare necessarily includes

1. pinning down the effects an action has on both oneself and on one's enemy;
2. considering the enemy's possible response;
3. and considering that the enemy is also engaged in economic warfare hence wants to

harm you.

All previous research analyzing economic warfare excludes one or more of these.

The general theoretical analysis of war, not just economic, addresses why countries start wars and how they can be avoided (e.g., Fearon 1995; Cai 2003; Fey and Ramsay 2011) and how much they will invest in fighting capacity (see Zheng 2019; Schouten 2022 for recent contributions). It thus does not address how economic warfare is performed.

A large number of papers assume the objectives rather than derive them (e.g., Richman and Ayyılmaz 2019). Another part of the literature on economic warfare either does not include the best response of the enemy (Clemens 2013; Sturm, Menzel, and Schmitz 2022; Wachtmeister, Gars, and Spiro 2022) thus misses (2) above, or does not take into account how costly sanctioning is for the sanctioning countries (e.g., Clemens 2013) thus misses (1). Alternatively, like Sturm, Menzel, and Schmitz (2022) and to some extent Gros (2022), some do include an objective of harming the adversary when choosing actions, but the weight on this is exogenous and the adversary's response is void of the objective thus misses (3).

The literature that *does* include all three components (how economic warfare harms oneself and the enemy; considering the enemy's response; and considering that the enemy has a similar objective as oneself) is not about war but about 'spite' in behavioral and individual settings. For this reason the 'spite' literature has focused on settings where individuals, rather than states, interact such as auctions (e.g., Morgan, Steiglitz, and Reis 2003; Montero et al. 2008) and public-good games (Levine 1998; Alger 2010; Andersson 2020).[2] The objective in this literature is taken as given, as opposed to derived from fundamentals, and the weights on harm versus own payoff is exogenous. It does not interpret the actions or equilibria in terms of warfare. Thus, while a game theorist would recognize the flavor of a subset of the results in this paper, the setting and practical implications and predictions are new. The spite literature has not analyzed coordination games or trade.

[2] For a treatment of traffic, congestion, vaccination and auctions see Chen (2011). For general results and comparative statics of spite see Milchtaich (2012).

2 The goal in war

Two countries, A and B, are at war. The fundamental objective of each country $i \in \{A, B\}$ is to maximize

$$U_i(\mathbf{s}_i) = (1-\lambda)\sum_{g\in G} u_{i,g}(s_{i,g}; s_{j,g}) + \lambda P_i(F_i(\mathbf{s}_i;\mathbf{s}_j), F_j(\mathbf{s}_j;\mathbf{s}_i)). \tag{1}$$

This objective function consists of two components: the first is the sum of economic payoffs from a number of economic interactions (also called games) denoted by g; the second is the probability P_i of wining the war . The parameter λ (assumed the same for both countries) captures how important each objective is, with $\lambda = 1$ denoting an 'all-out war' and $\lambda = 0$ denoting 'peace'. $\mathbf{s}_i$ is country i's strategy across all games.

Starting with the first part of the objective function, in each economic game g, country i chooses a strategy denoted by $s_{i,g}$ and the payoff $u_{i,g}$ in that game depends on i's and the other country's (j's) strategies.

The probability of winning the war is based on a classic contest success function (Tullock 1980; Hirshleifer 1989)

$$P_i(F_i, F_j) \equiv \frac{e^{F_i}}{e^{F_i} + e^{F_j}} \tag{2}$$

and is determined by the countries' fighting capacities F_i and F_j. The fighting capacity F_i is formed by taking a fixed share $M_i \in [0,1]$ of the payoffs in the economic interactions and investing them militarily:

$$F_i = M_i \sum_{g\in G} u_{i,g}(s_{i,g}; s_{j,g}), \tag{3}$$

$$F_j = M_j \sum_{g\in G} u_{i,g}(s_{j,g}; s_{i,g}). \tag{4}$$

Now that the model is introduced it is appropriate to comment on its specification. Compared to the research on economic sanctions (see introduction), the key factor is the fundamental objective of winning a war which is typically not modeled there. Note further that M_i is constant and exogenous and is not analyzed in this paper. This is in fact one of the main differences between the current paper and a large part of the previous research on warfare in general (e.g., Zheng 2019; Schouten 2022). That research lets military investments (the equivalent of M_i) be the main variable of choice while letting the budget constraint be exogenous.[3] Here, on the contrary, the choice of military investments is taken as exogenous but the total budget comes from endogenous economic warfare.[4] Next note that, since the fighting capacities in (3) and (4) depend on the countries' incomes, each single economic interaction can be viewed as a single battleground in a greater war. The view that wars consist of multiple battlegrounds that jointly determine the outcome of war is old and formally goes back to at least Borel (1921). Here, for simplicity, these economic battlegrounds are additively separable in how they affect fighting capacity. For a more general treatment of the interaction between battlegrounds see, e.g., Kovenock and Roberson (2010).

3 The objective of economic warfare

This section derives the objective of economic warfare from the greater objective of war in (1). To do so, it is instructive to point out what country i affects by its strategy $\mathbf{s}_i$. It does so in three ways. First through the economic interactions where its strategy affects its direct payoff $u_{i,g}(s_{i,g}; s_{j,g})$ in (1). Second, since $\mathbf{s}_i$ affects i's income, it also affects its fighting capacity F_i in (3) thus its probability of winning the war in (2). Third, i's strategy affects j's income $u_{j,g}(s_{j,g}; s_{i,g})$ thus j's fighting capacity F_j in (4) which in turn affects i's probability of winning the war in (2). It is the tension between these last two effects that is the key mechanism behind the first result.

Proposition 1 *Consider a single economic interaction g. The objective of that interaction can be first-order approximated by*

$$(5) \qquad \max_{s_{i,g}} w_{i,g}(s_{i,g}) \equiv u_{i,g}(s_{i,g}; s_{j,g}) - \gamma_i u_{j,g}(s_{j,g}; s_{i,g})$$

[3] Often the military investment simply incurs a convex cost in that literature.

[4] For balance of resources, the economic objective could have been multiplied by $1 - M_i$. But clearly, the payoffs in each u_i can be scaled accordingly.

where the constant

$$(6) \qquad \gamma_i \equiv \frac{\lambda M_j}{(1-\lambda)\frac{(1+e^c)^2}{e^c} + \lambda M_i} \quad \textit{and}$$

$$(7) \qquad c \equiv M_j \sum_{t \neq g} u_{j,t}(s_{j,t}; s_{i,t}) - M_i \sum_{t \neq g} u_{i,t}(s_{i,t}; s_{j,t})$$

and the outcomes in other economic interactions $t \neq g$ are taken as given.

PROOF: First rewrite the probability of winning (2) in a few steps: $P_i(F_i, F_j) = \frac{1}{1+e^{F_j - F_i}} = \frac{1}{1+e^c e^{M_j u_{j,g}(s_{j,g}; s_{i,g}) - M_i u_{i,g}(s_{i,g}; s_{j,g})}} = \frac{1}{1+e^c e^x}$ where $x(s_{i,g}) \equiv M_j u_{j,g}(s_{j,g}; s_{i,g}) - M_i u_{i,g}(s_{i,g}; s_{j,g})$ and c is defined in (7). A first order (linear) Taylor approximation yields

$$U_i(s_{i,g}; \mathbf{s}_{i,-g}, s_{j,g}, \mathbf{s}_{j,-g}) \approx \lambda \left(\frac{1}{1+e^c e^{x^*}} - \frac{1}{(1+e^c e^{x^*})^2} e^c e^{x^*}(x - x^*) \right) + (1-\lambda) u_{i,g}(s_{i,g}; s_{j,g})$$

where x^* is the center of approximation which can be normalized to zero. Noting that the first term in the parenthesis is a constant (so can be dropped from optimization), collecting $u_{i,g}$ and $u_{j,g}$ and normalizing by $1 - \lambda + \lambda M_A \frac{e^c}{(1+e^c)^2}$ gives $\arg\max U_i(s_{i,g}) \approx \arg\max w_{i,g}(s_{i,g})$ in (5). *Q.E.D.*

The proposition expresses that the goal of economic warfare boils down to maximizing the opponents loss and one's own income. This is in line with the initial quotes and with the general understanding of what to do in war: harm your opponent, but weigh in the cost to yourself when doing so. How much to prioritize harming the opponent depends on several fundamental factors. The following corollary shows this and addresses how good the approximation is.

COROLLARY 1 *The weight on harming the opponent (γ_i) economically is:*

- *Increasing in the opponent's military investment share (M_j) and decreasing in the country's own military investments (M_i);*
- *Hill-shaped in the relative payoff of the other economic interactions (increasing/decreasing in c when c is negative/positive);*
- *Increasing in the importance of war (λ).*

Furthermore:

- *In an all-out war, $\lambda = 1$, the approximation in Proposition 1 is exact with $\gamma_i = \frac{M_j}{M_i}$.*
- *In peace, $\lambda = 0$, the approximation in Proposition 1 is exact with $\gamma_i = 0$.*

Proof: The bullets follow directly from differentiating (6) where in the first bullet c is taken as given. For the statement on all-out war, let $\lambda = 1$. $\mathbf{s}_\mathbf{i}^* \equiv \arg\max U_i = \arg\max \frac{1}{1+e^{F_j - F_i}} = \arg\max F_j - F_i \iff \{\text{since } F_i \text{is linear in the payoffs of each game}\} \iff s_{i,g} = \arg\max w_{i,g} \forall g$ which is equivalent to the approximation from Proposition 1 when $\lambda = 1$. Finally, when $\lambda = 1$, it follows directly from (6) that $\gamma_{i,g} = 0$ and that maximizing (5) is equivalent to maximizing (1). *Q.E.D.*

The first bullet expresses that a country will prioritize minimizing the opponent's income if that opponent uses much of its income for war. This is of course natural and captures the marginal effect of additional funds to the opponent in any economic battleground. The second bullet describes the level effect of the opponent's income. To see this, note by the definition of c in (7) that it is positive when the total fighting capacity of the opponent $M_j \sum_{t \neq g} u_{j,t}(s_{j,t}; s_{i,t})$ is larger than one's own $M_i \sum_{t \neq g} u_{i,t}(s_{i,t}; s_{j,t})$. When c is positive, γ_i is decreasing in c implying that the larger the level difference is in favor of the opponent the less one should focus on harming the opponent in the current economic interaction. On the other hand, if the fighting capacity is in one's own favor ($c < 0$), then γ_i is increasing in c which implies that when one self is very superior one should focus less on harming the opponent. Put differently, when fighting capacity is even, both sides will focus on harming the other. For further analysis of the interaction between battlefields see Kovenock and Roberson (2010).

The last three bullets are informative for evaluating how much generality is lost by the approximation in Proposition 1. Corollary 1 says that, the more important the war is, the more the adversaries focus on harming each other and in the limit, in an all-out war, harming the opponent is maximized and the approximation is exact.[5] Similarly, in peace ($\lambda = 0$) $\gamma_i = 0$ and the objective is to maximize one's own income ignoring how it affects the

[5] It should be noted that with other functional forms for P_i (see, e.g., Hirshleifer 1989) the approximation may not be exact. E.g., if $P_i = \frac{F_i^\alpha}{F_i^\alpha + F_j^\alpha}$ the limit case is $w_i = \log F_i^\alpha - \log F_j^\alpha$ i.e., the same as here but short of a transformation of the payoffs.

opponent. Also here the approximation is exact. Finally, like with any approximation it is better when the variable changes marginally, i.e., when the current economic game g is one out of many, the approximation is better.

The model can be viewed as describing the transformation from peace to war. This warfare transformation will now be applied to a few canonical economic environments. As will be seen, some of the applications imply a true trade off between harming the opponent and enriching oneself, but in others those objectives go hand-in-hand.

4 Trade in war

Consider an economic environment where a single seller A meets a single buyer B. This may capture, e.g., fossil gas or some other market that relies on joint infrastructure for distribution. The research questions asked here are whether there will be trade and how prices and quantities are affected by war.

I start by outlining the economic environment in peace. The timing is as follows. First, the seller chooses a price p with the peacetime objective to maximize payoff

$$u_A = pq,$$

where q is the quantity sold. For simplicity, there is no cost of production. Second the buyer chooses quantity q with the peacetime objective of maximizing the payoff

$$u_B = b\left(q - \frac{kq^2}{2}\right) - pq$$

given the price offered by the seller.

Using backward induction it is trivial to show that in the subgame perfect equilibrium in peacetime $p^* = \frac{b}{2}$, $q^*=\frac{1}{2k}$. The price and quantity are positive so there is trade when A and B are in peace.

Now consider economic warfare. The timing is the same, but the objectives are different. The problem is thus still solved with backward induction but with B's objective function adapted to economic warfare following Proposition 1

$$w_B = b\left(q - \frac{kq^2}{2}\right) - pq - \gamma_B pq.$$

γ_B denotes the weight B puts on harming A. Taking the first-order condition[6] yields B's best response

$$q = \begin{cases} \frac{b-p(1+\gamma_B)}{bk} & \text{iff } p \leq b/\left(1+\gamma_B\right) \\ 0 & \text{otherwise} \end{cases}. \tag{8}$$

The seller A, following Proposition 1, chooses p to maximize the warfare objective function

$$w_A = pq - \gamma_A\left(b\left(q - \frac{kq^2}{2}\right) - pq\right)$$

which, taking B's best response (8) into account, yields

$$w_A = \begin{cases} p\frac{b-p(1+\gamma_B)}{bk}\left(1+\gamma_A\right) - \gamma_A b\left(\frac{b-p(1+\gamma_B)}{bk} - \frac{k\left(\frac{b-p(1+\gamma_B)}{bk}\right)^2}{2}\right) & \text{iff } p \leq b/\left(1+\gamma_B\right) \\ 0 & \text{otherwise} \end{cases}$$

with the derivative in the first region being

$$w_A' = \frac{b - 2p\left(1+\gamma_B\right)}{bk}\left(1+\gamma_A\right) - \gamma_A b\left(\frac{-\left(1+\gamma_B\right)}{bk} + k\left(\frac{b - p\left(1+\gamma_B\right)}{bk}\right)\frac{\left(1+\gamma_B\right)}{bk}\right). \tag{9}$$

Note that at zero $w_A'(0) = \frac{1}{k}\left(1+\gamma_A\right) > 0$. Hence A never offers a price of zero. Letting the right-hand side in (9) equal zero gives the first-order condition of an interior solution. Solving yields

$$p = b\frac{\left(1+\gamma_A\right)}{\left(1+\gamma_B\right)\left(2-\gamma_A\left(\gamma_B-1\right)\right)}. \tag{10}$$

[6]It can be verified that the second-order condition holds.

This expression is positive if and only if $\gamma_A(\gamma_B - 1) < 2$. We need to check that there exists an inner solution: $w_A'' = -\frac{2(1+\gamma_B)}{bk}(1+\gamma_A) + \gamma_A bk\left(\frac{(1+\gamma_B)}{bk}\right)^2$ which is negative iff $\gamma_A(\gamma_B - 1) < 2$ which is the same requirement as for a positive p in (10). Hence we can conclude that if $\gamma_A(\gamma_B - 1) < 2$ then there is a positive price given by (10). In this case the warfare-equilibrium quantity q^w is given by the first row of the buyer's solution in (8). But if $\gamma_A(\gamma_B - 1) > 2$ then $p^w \in [b/(1+\gamma_B), \infty[$ and $q^w = 0$ (since $w_A'(0) > 0$).[7] After some manipulation, the inner solution yields

$$q^w = \frac{1 - \gamma_A\gamma_B}{k(2 - \gamma_A(\gamma_B - 1))}$$

which is positive iff $1 > \gamma_A\gamma_B$.[8] From this constraint and the constraint from the second-order condition we can conclude that there is an interior solution with non-zero trade iff both

$$\begin{aligned} \gamma_A\gamma_B &< 1 \text{ and} \\ \gamma_A\gamma_B - \gamma_A &< 2 \end{aligned}$$

where the second constraint holds if the first does. More generally, the quantity under war is lower than in peace since $q^* = \frac{1}{2k} > q^w = \frac{1-\gamma_A\gamma_B}{k(2-\gamma_A(\gamma_B-1))} \leftrightarrow \gamma_B > -1$.

Given that the quantity is lower in war, will the price be higher in war than in peace? This holds iff $p^w = b\frac{(1+\gamma_A)}{(1+\gamma_B)(2-\gamma_A(\gamma_B-1))} > p^* = \frac{b}{2}$ which after some rearranging yields $\gamma_A(1+\gamma_B^2) > 2\gamma_B$. Whether this inequality holds is ambiguous, depending on γ_A and γ_B. For instance, when γ_B is small the price is higher in war. But if γ_A is sufficiently small, then the price is lower. That the price may be lower in war may seem surprising, but it reflects that when γ_A is small and γ_B is large the buyer is more interested in harming the seller than vice versa. This gives the buyer a negotiation power of sorts (the buyer becomes price sensitive when the profit benefits the seller) so in order to sell any quantity the seller has to lower the price.

We can summarize these results in the following proposition.

PROPOSITION 2 *Consider the trade environment.*

[7] Note that when $\gamma_A(\gamma_B - 1) > 2$ then $\gamma_A\gamma_B > 1$.

[8] Recall that we only have a inner solution for the price if the $(2 - \gamma_A(\gamma_B - 1))$ is positive.

- *There is trade under economic warfare iff* $\gamma_A \gamma_B < 1$.
- *The traded quantity is strictly smaller under economic warfare than in peace* ($q^w < q^*$).
- *The price under economic warfare is higher than in peace iff* $\gamma_A (1 + \gamma_B^2) > 2\gamma_B$.

These results resonate with traded quantities and prices of Russian energy following the invasion of Ukraine. After the invasion, both the oil and gas quantities exported from Russia to the EU have fallen. Yet, the price of Russian gas has increased while the price of Russian oil has decreased.[9]

The previous proposition outlines how trade will be affected when the countries have mixed motives $\lambda \in]0,1[$ and the results depend on the weights of harming the other which are given by Proposition 1. In case of an all-out war the result is unambiguous.

COROLLARY 2 *In an all-out war* ($\lambda_A = \lambda_B = 1$) *there is no trade.*

PROOF: When $\lambda_A = \lambda_B = 1$, following Corollary 1, $\gamma_A = \frac{M_B}{M_A}$ and $\gamma_B = \frac{M_A}{MB}$ implying $\gamma_A \gamma_B = 1$ which by Proposition 2, point 1, implies no trade. *Q.E.D.*

5 The prisoner's dilemma in war

Consider the economic environment of the prisoner's dilemma on the left panel of Figure 1. Countries are denoted by A and B and payoffs by lower letters a and b respectively. Since this is a prisoner's dilemma, $a_3 > a_1 > a_4 > a_2$ and $b_2 > b_1 > b_4 > b_3$. This environment can be interpreted, for instance, as monopolistic competition or climate change mitigation. The setting of public-good games with spiteful preferences has been analyzed by Levine (1998) and Andersson (2020). Hence, the theoretical results presented here are not in themselves novel, though the interpretation of how it affects economic warfare and real-world applications is.

[9] For data on prices and quantities see, e.g., Zachmann et al. (2023) and investing.com. The Russian oil price (Urals) is sold at a discount on the world market, which includes the price EU countries have paid after the invasion (see Gars, Spiro, and Wachtmeister 2022 for a discussion). The price of Russian natural gas has been historically high after the invasion. This price increase actually started a year prior to the invasion as Russia, pre-emptively, emptied the gas storage in the EU.

FIGURE 1.— Prisoner's dilemma in war

Economic environment

A↓ \ B→	**Cooperate**	**Defect**
Cooperate	a_1, b_1	a_2, b_2
Defect	a_3, b_3	a_4, b_4

Warfare environment

A↓ \ B→	**Cooperate**	**Defect**
Cooperate	$a_1 - \gamma_A b_1, b_1 - \gamma_B a_1$	$a_2 - \gamma_A b_2, b_2 - \gamma_B a_2$
Defect	$a_3 - \gamma_A b_3, b_3 - \gamma_B a_3$	$a_4 - \gamma_A b_4, b_4 - \gamma_B a_4$

Notes: Prisoner's dilemma in peace (left) and in war (right).

The warfare transformation of the prisoner's dilemma is depicted in the right panel of Figure 1. Since $b_1 > b_3$ follows that warfare payoffs $w_A(D,C) > w_A(C,C)$ where C and D denote Cooperate and Defect; and since $b_2 > b_4$ $w_A(D,D) > w_A(C,D)$. Similarly $w_B(D,C) > w_B(C,C)$ and $w_B(D,D) > w_B(C,D)$. Hence the prisoner's-dilemma logic is maintained in economic warfare with Defect being a strictly dominant strategy and {Defect, Defect} constituting the unique Nash Equilibrium. In fact, not only is the logic maintained in war, but it is amplified as $w_A(D,C) - w_A(C,C) > u_A(D,C) - u_A(C,C)$ and $w_A(D,D) - u_A(C,D) > w_A(D,D) - u_A(C,D)$ and equivalently for w_B and u_B.

Consider next an infinitely repeated version of the prisoner's dilemma.[10] As is well known, cooperation may be upheld under a trigger strategy which prescribes to cooperate until the opponent defects, and afterwards defect forever. In the notation of our environment, and letting $\beta \in]0,1[$ denote the discount factor, this holds in peace if and only if $\beta \geq \frac{a_3 - a_1}{a_3 - a_4}$

[10]This comes at a little bit of formal abuse as the objective function in Proposition 1 has not been derived for a repeated environment. We can think of the setting here as one of prolonged war.

and $\beta \geq \frac{b_2-b_1}{b_2-b_4}$. For any parameter values that abide by the prisoner's-dilemma constraints there exists a sufficiently large $\beta < 1$ that fulfills these requirements.

Under warfare this does not necessarily hold. To see this, it is useful to introduce some additional notation. Let $w_{1,A} \equiv w_A(C,C)$, i.e., the payoff of A in the north-west box, and equivalently $w_{2,A}$ is in the north-east box etc. For a trigger strategy to discipline the countries to cooperate, a necessary condition is that

$$(11) \qquad w_{1,A}\frac{1}{1-\beta} = w_{1,A} + w_{1,A}\frac{\beta}{1-\beta} \geq w_{3,A} + w_{4,A}\frac{\beta}{1-\beta}.$$

Otherwise A would defect. A necessary condition for this is in turn that $w_{1,A} > w_{4,A}$.[11] But this is not guaranteed and holds only if $a_1 - \gamma_A b_1 > a_4 - \gamma_A b_4 \leftrightarrow \frac{a_1-a_4}{b_1-b_4} > \gamma_A$. In words, A needs to value the own gain of the cooperative outcome more than the enemy's gain of cooperation. Generally, for (11) to hold,

$$\beta \geq \frac{a_3 - a_1 - \gamma_{1,2}(b_3 - b_1)}{a_3 - a_4 - \gamma_{1,2}(b_3 - b_4)}.$$

From the payoff structure in the prisoner's-dilemma game follows that both the numerator and denominator are positive (the parenthesized terms are negative). Comparing the constraint on β in the peacetime prisoner's dilemma with that under warfare $\frac{a_3-a_1-\gamma_{1,2}(b_3-b_1)}{a_3-a_4-\gamma_{1,2}(b_3-b_4)} > \frac{a_3-a_1}{a_3-a_4} \leftrightarrow ... \leftrightarrow a_1(b_3-b_4) - (a_3-a_4)b_1 - a_3 b_4 - a_4 b_3 < 0$ which holds since $b_3 < b_4$ and $a_3 > a_4$. These results are summarized in the following proposition.

Proposition 3 *Consider the Prisoner's-dilemma.*

[11] Recall from the static game that $w_{3,A} > w_{1,A}$.

- *In a static game under economic warfare, "Defect" is the best response for each country, and {Defect,Defect} is the unique Nash Equilibrium.*
- *In an infinitely repeated prisoner's dilemma:*
  - *Under peace there exists a cooperative equilibrium upheld by trigger strategies if and only if* $\beta \geq \beta^p \equiv \max\left\{\frac{a_3-a_1}{a_3-a_4}, \frac{b_2-b_1}{b_2-b_4}\right\}$.
  - *Under economic warfare there exists a cooperative equilibrium upheld by trigger strategies if and only if* $\beta \geq \beta^w \equiv \max\left\{\frac{a_3-a_1-\gamma_A(b_3-b_1)}{a_3-a_4-\gamma_A(b_3-b_4)}, \frac{b_2-b_1-\gamma_B(a_2-a_1)}{b_2-b_4-\gamma_B(a_2-a_4)}\right\}$.
  - $\beta^w > \beta^p$.

The general implication of this proposition is that prisoner's-dilemma situations will be aggravated by war. This is of course intuitive. In peace, the prisoner's dilemma leads to mutually suboptimal outcomes since each country ignores that it harms the other. In war, this harm is viewed by each country as an additional benefit. So there is no trade off between maximizing one's own payoff and harming the other. Positively, this predicts that countries in war will tend to pull out of environmental agreements or reduce their efforts to mitigate climate change. To the extent that the adversaries are competitors on a market (like Russia and the US are in oil and gas), they will increase their supply. This latter prediction has in part already been materialized (Forbes 2023; Politico 2023).

Nevertheless, the proposition predicts that repeated interaction may still uphold cooperation in war. But a necessary condition for this is that the war is not too important as expressed in this corollary:

COROLLARY 3 *In all-out war ($\lambda_A = \lambda_B = 1$) there exists no sufficiently high discount factor to uphold a cooperative equilibrium in a repeated prisoner's dilemma.*

PROOF: Proposition 3 implies that a sufficiently high β exists only if $\frac{a_3-a_1-\gamma_A(b_3-b_1)}{a_3-a_4-\gamma_A(b_3-b_4)} < 1$ and $\frac{b_2-b_1-\gamma_B(a_2-a_1)}{b_2-b_4-\gamma_B(a_2-a_4)} < 1$. Simplifying these two inequalities using $\gamma_A = \frac{M_B}{M_A}$ and $\gamma_B = \frac{M_A}{M_B}$ from Corollary 1 shows that the two inequalities are mutually exclusive. *Q.E.D.*

6 Coordination in war

Consider now a coordination game as depicted in the left panel of Figure 2. Assume $e > f > g \geq h = 0$. The first inequality implies A and B have different tastes for which point of coordination is the best – A prefers Red and B prefers Blue. The second inequality is what makes it a coordination game – no country wants to deviate if both take the same action. Finally, the third inequality implies that both countries weakly prefer to miscoordinate while playing their favorite action (A playing Red, B playing Blue) than the reversed. This game captures situations such as the choice of technology standard where each country has an advantage in one of the standards.

FIGURE 2.— Coordination game in war

Economic environment

B→ / A↓	**Red**	**Blue**
Red	e, f	g, g
Blue	0,0	f, e

Warfare environment

B→ / A↓	**Red**	**Blue**
Red	$e - \gamma_A f, f - \gamma_B e$	$g - \gamma_A g, g - \gamma_B g$
Blue	0, 0	$f - \gamma_A e, e - \gamma_B f$

Notes: Coordination game in peace (left) and war (right).

Under peace there exist two equilibria in this game: $\{Red, Red\}$ and $\{Blue, Blue\}$. Under warfare it depends on γ_A and γ_B. Suppose, wlog, $\gamma_B \geq \gamma_A$.[12] Then whether coordination exists depends on how large is γ_A. The first possibility is that $f - \gamma_A e < g - g\gamma_A \leftrightarrow$

[12]This is wlog since the game is symmetric in payoffs e, f, g and h. Had the opposite supposition been made then Red and Blue are reversed in the upcoming description.

$f-g<(e-g)\gamma_A \leftrightarrow \gamma_A>\frac{f-g}{e-g}$. In this case no coordination exists in equilibrium (since $\gamma_B \geq \gamma_A$). A would deviate if both play Blue and B would deviate if both play Red. Is $\{Blue, Red\}$ an equilibrium? This requires that $e-\gamma_A f \leq 0 \leftrightarrow \frac{e}{f} \leq \gamma_A$. Note that, since each country is choosing their enemy's preferred action, both countries may be tempted to deviate to coordinate on their own favorite action. For this not to happen (for $\{Blue, Red\}$ to be an equilibrium) both countries have to put sufficient weight on harming the other. In fact, for this to be an equilibrium we need $\gamma_A, \gamma_B > 1$ since $e > f$.

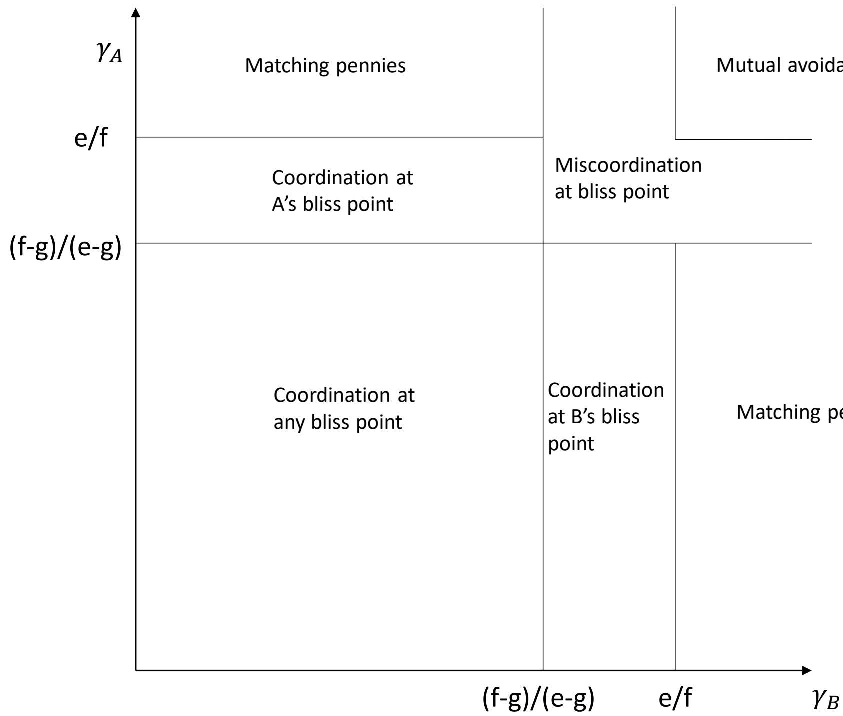
Is $\{Red, Blue\}$ an equilibrium? This requires that $g-\gamma_A g \geq f-\gamma_A e \leftrightarrow \gamma_A \geq \frac{f-g}{e-g}$ which also implies $\gamma_B \geq \frac{f-g}{e-g}$. Note that $\frac{e}{f} > \frac{f-g}{e-g}$ since $e\left(e-g\right) > f\left(f-g\right)$ hence it is harder to uphold $\{Blue, Red\}$ than $\{Red, Blue\}$ in equilibrium.

Now suppose $\gamma_B \geq \frac{f-g}{e-g} > \gamma_A$. $\{Red, Blue\}$ is no longer an equilibrium (and neither is $\{Blue, Red\}$). $\{Red, Red\}$ is not an equilibrium either as B would deviate when $\gamma_B \geq \frac{f-g}{e-g}$. $\{Blue, Blue\}$ is an equilibrium if and only if $\frac{e}{f} > \gamma_B \geq \frac{f-g}{e-g}$. Hence the game becomes a matching pennies game if $\gamma_B > \frac{e}{f}$ and $\frac{f-g}{e-g} > \gamma_A$. In this case A puts little weight on B's losses and hence tries to coordinate, but B, who puts a lot of weight on harming A, will try to avoid this. Matching pennies is a classic game of warfare where one player (the attacker) is trying to hit the other and the other player is trying to avoid this. In the economic-warfare transformation of the coordination game here, we also arrive at a matching-pennies game but with a somewhat reversed interpretation. The attacker (here B) is trying to inflict harm on the defender by breaking the coordination.

Now suppose $\frac{f-g}{e-g} > \gamma_B \geq \gamma_A$. Then both A and B would deviate from $\{Blue, Red\}$ and from $\{Red, Blue\}$ implying $\{Red, Red\}$ and {Blue,Blue} are equilibria. The game in war has the same outcome as in peace since both countries put little weight on trying to harm each other.

The results are summarized in Figure 3 and in the following proposition.

FIGURE 3.— Coordination game in war, outcomes



Notes: Parameter space depicting what a coordination game in peace turns into in war.

PROPOSITION 4 *Consider the coordination game with $e > f > g \geq h = 0$. In economic warfare:*

1. If both countries put little weight on harming the other ($\gamma_B, \gamma_A \leq \frac{f-g}{e-g}$), then coordination on either color are pure Nash equilibrium outcomes.
2. If one country puts little weight on harming ($\gamma_i \leq \frac{f-g}{e-g}$) and the other puts intermediate weight on harming ($\frac{f-g}{e-g} < \gamma_j \leq \frac{e}{f}$, $i \neq j$), then in the unique Nash equilibrium the countries coordinate on the harmful country's ($j's$) preferred color.
3. If one country puts little weight on harming ($\gamma_i \leq \frac{f-g}{e-g}$) and the other puts high weight on harming ($\gamma_j > \frac{e}{f}$, $i \neq j$), then the game is matching pennies: the harmful country's BR is $s_j^w \neq s_i$ and the other country's BR is $s_j^w = s_i$.
4. If one country puts intermediate weight on harming ($\frac{f-g}{e-g} < \gamma_i \leq \frac{e}{f}$) and the other puts intermediate or high weight on harming ($\gamma_j > \frac{f-g}{e-g}$, $i \neq j$), then in the unique Nash equilibrium each country plays their own preferred color.

5. If both countries put high weight on harming the other ($\gamma_B, \gamma_A > \frac{f-g}{e-g}$), then two pure Nash equilibria exist. In these the countries miscoordinate.

The proposition expresses a rich set of results, indirectly depending on the importance of war (λ) and military spending (M). Coordination becomes harder but may not be impossible in war. However, in an all-out war, miscoordination will be the practical objective of either one or both of the countries.

COROLLARY 4 *In an all-out war ($\lambda = 1$) there is no coordination in equilibrium. Either both choose their own preferred color, or the game is matching pennies.*

PROOF: By Corollary 1, $\gamma_B = 1/\gamma_A$ when $\lambda = 1$. This rules out that jointly γ_B, $\gamma_A \leq (f - g)/(e - g)$ and that jointly γ_B, $\gamma_A > e/f$ hence the outcomes in points 1 and 5 in Proposition 4 are ruled out. Similarly, it can be shown that $\gamma_i \leq e/f$ and $\gamma_j = 1/\gamma_i \leq (f - g)/(e - g)$ are mutually exclusive constraints hence the outcome in point 2 in Proposition 4 is ruled out. Next note that as $\gamma_i \to \infty$ then $\gamma_i > e/f$ and $\gamma_j = 1/\gamma_i \to 0 \leq (f - g)/(e - g)$, hence the outcome in point 3 in Proposition 4 is possible for any f, e, g. Finally, when $\gamma_i = 1$ then $\gamma_i \leq e/f$ and $\gamma_j = 1/\gamma_i = 1 > (f - g)/(e - g)$, hence the outcome in point 3 in Proposition 4 is possible for any f, e, g. *Q.E.D.*

The intuition for this is that, in a situation of extensive war, whenever one country would benefit sufficiently from coordination, the other country necessarily gains from harming the other thus trying to miscoordinate. It can be easily verified that a matching-pennies game in peace remains a matching-pennies in war. Thus, in a sense, the game of matching pennies is an absorbing state.

7 Concluding remarks

This paper models economic interactions as battlefields in greater wars. It shows that a country which, alongside material payoffs, cares about winning a war will have a very simple objective in its economic warfare. Namely, it will seek to maximize a weighted average of its own income and the enemy's economic loss. The endogenous weight on harming the opponent is increasing in how important the war is and in the enemy-country's military investments.

The derived objective function of economic warfare is used to analyze strategic economic interaction between countries at war. The first is the interaction between a buyer and a seller, i.e., trade. The model predicts that war will reduce the traded quantity, but not necessarily to zero unless it is an all-out war where nothing else matters except winning. The model's prediction regarding the price is more nuanced and depends on market and warfare fundamentals: the price may increase in war if the buyer does not put much weight on harming the seller, e.g., if the war is not important to the seller; but the price may decrease, e.g., if the seller uses much of the profits for military investments.

The second application is prisoner's-dilemma settings, i.e., monopolistic competition and climate mitigation. The analysis shows that the prisoner's dilemma is worsened by war and that infinite repetition may not (and in an all-out war *will* not) discipline the countries, independently of how much they value the future. The model thus predicts that countries at war will reduce their climate-mitigation efforts; and that in industries where the adversaries compete, they will increase their supply.

The third application is a coordination game, i.e., choosing technology standard or infrastructure investments. Depending on the salience of war, coordination may still occur (if low salience), joint miscoordination may ensue (if the war is very salient) or one country may 'chase' the other who is trying to avoid coordination ('matching pennies' under asymmetric salience). In an all-out war there will be no coordination in equilibrium.

The derived objective function resembles one of 'spite' used in behavioral economics (Levine 1998). But unlike in individual and behavioral settings, here the will to harm one's enemy comes out endogenously from the cold and rational objectives of war and the weight one puts on harming the opponent is derived from fundamentals.

The contribution of the paper is both positive – this is the first paper to provide general predictions about the objectives and actions of countries engaged in economic warfare – and policy oriented – the paper provides a coherent framework for analyzing one's own and an adversary-country's strategic objective and behavior in economic warfare.

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