COMPARING CONTEST SUCCESS FUNCTIONS: EVIDENCE FROM VIRTUAL WORLDS

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Abstract. In this preliminary version of our paper, we claim that data coming from virtual worlds is very precious tool in research on conflict. Indeed, both historical dataset and laboratory experiments suffer from too many limitations making econometric works non-satisfactory. To overcome these issues we promote the use of “EVE online” – a Massive Multiplayer Online Roleplaying Game. Thanks to collaboration with game's developer, the empirical part can build on data encompasses practically everything the 390,000 players did in the month of January 2011. Thus, it can build on rich and objective empirical evidence about economic behavior in a warfare context; something difficult to achieve in real world or laboratory conflict setting. To the best of our knowledge, this study is the first of its kind in conflict theory. In this paper we estimate and compare the two main forms of contest success functions, the difference and ratio-form.

1. INTRODUCTION

Economic literature grants a growing interest to the question of conflicts between agents since the seminal work of Haavelmo suggesting that “there are other means of acquiring goods and services than by production and peaceful trade. One need not think only of brutal grabbing and exploitation” (Haavelmo, [1954] 1964, p. 84). Developing this pioneering intuition, Hirshleifer (1988, 1989, 1991, 1994) promoted the study of the impact of armed conflicts on economic activity, laying the foundation of the contest theory[1] in conflict economics. Considering more specifically the human warfare, a contest could be describe as “a game in which participants expend resources on arming so as to increase their probability of winning if conflict were to actually take place” (Garfinkel and Skaperdas, 2007, p. 652).

In a battlefield, the determination of the winner is fundamental because it could change the entire History. This winner is partly defined by the commitment of forces deployed by each contestant. However, victory is not always promised to the larger battalions[2] and also depends upon the technology of conflict, which corresponds to “how generalized resources devoted to struggle generate outputs in the form of gains and losses to each side” (Hirshleifer, 1991, p. 130). The technology of conflict is designed by a *Contest Success Function* (hereafter, CSF) describing the existing link between the level of input, namely the fighting effort, and the level of output, that is the probability of success in a conflict. Literature mainly distinguishes two canonical forms of CSFs[3]. First, the *ratio-form* was initially suggested by Tullock (1980) and considers that the probability of victory in a military struggle is a function of the ratio of fighting efforts devoted by each side. In contrast, Hirshleifer (1988, 1989) develops the second form of CSFs: the logistic-form (or difference-form). He estimates that the winning probability has to be viewed as a relation depending on the difference of efforts committed to the fight. In the case of human warfare, very few comparisons between these two forms of CSFs have been carried out while results of model using CSFs are extremely sensitive to the specific shape adopted (Hwang, 2012, p. 226). As a result, Jia, Skaperdas, and Vaidya (2013, p. 218) observe that “in contrast to rich literature in

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[1] In a general sense, “a contest is an economic or social interaction in which two or more players expend money or effort in hopes of winning a prize” (Dasgupta & Nti, 1998). They are used to depict elections campaigns, political lobbying, litigations, wars, arms races, cooperative production or even sports.

[2] One of the most striking illustrations could be found with the battle of Chancellorsville (1863) during the American Civil War in which Lee’s army defeated a twice bigger army in Spotsylvania County, Virginia.

[3] Corchón (2007) provides an exhaustive review of the different forms of CSFs used in contest theory.

contest theory, only a small body of the literature empirically estimates and tests the contest [success] functions”, and this is particularly true for human warfare.

The main objective of our paper is to contribute to the recent empirical researches dealing with the estimation of the forms of CSFs. To the best of our knowledge, Hwang (2012) provides the only empirical comparison between forms of CSFs concerning human warfare. He finds that the *ratio-form* is able to yield a better estimation of the probability of winning for European wars during the 17th century. Nevertheless the results obtained by Hwang suffer from three important limitations (Jia, Skaperdas, and Vaidya, 2013). The most important one stands for the fact that fighting efforts are not directly observable and have to be approximate. These measures are imperfect and fail due to the “unquantifiable nature of some resources” (*ibid.* p. 219). Second, the probable measurement error and the potential reverse causality cause endogeneity issues[4]. Last but not least, they argue that comparing *ratio-form* and *logistic-form* CSFs “would require an unrealistic amount of data to achieve any reasonable power in testing between them statistically” (*ibid.* p. 220). An interesting solution is to use data originating from laboratory experiments to have a precise monetary measure of efforts devoting by players in a conflict (Ahn, Isaac, and Salmon, 2011; Ke, Konrad, and Morath, 2013, 2015). These approaches provide data that can be easily exploited by econometrical approaches, but they suffer from at least two strong limits. First, a laboratory participant is not a *fighter*: laboratory experiments involve individuals who have to make monetary choices in classroom context. Therefore they neglect the psychological influences of warfare context as the perception of relative deprivation (Gurr, 1970) or the fighting spirit on the battlefield. Second, participants systematically end up richer than before the experiment. Indeed, they are paid to participate and are able to win more regarding to their performances during the experiment. Something crucial appears here: despite the existence of an opportunity cost, there is no destruction as such. In stark contrast, conflicts and predation are destructive activities and involve “collateral damages” (Grossman and Kim, 1995, 1996) and “real destruction” (Vahabi, 2009, 2010). Therefore, although experimental analysis can bring us precise measurement of the fighting effort, laboratory context fails to be fully convincing to simulate human warfare.

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[4] For a description of channels through which feedback effects of dependent variable on explanatory variable operate, see Jia (2008).

Data originating from historic events or laboratory experiments appeared not to be sufficiently reliable to test CSFs. In contrast, virtual worlds do not suffer from these limits. In this paper, we propose to use data stemming from "EVE Online", a Massive Multiplayer Online Roleplaying Game. Thanks to collaboration with game's developer, the empirical part can build on data encompasses practically everything the 390,000 players did in the month of January 2011. Thus, it can build on rich and objective empirical evidence about economic behavior in a warfare context; something difficult to achieve in real world or laboratory conflict setting. In "EVE Online" conflicts lead to destruction and players really fight for something in the sense that they are conscious of the stakes involved. Thus, data originating from “EVE Online” (EVE) seems fit with empirical test on the form of CSFs.

In its present form, the paper does not provide empirical results but just describes the data we have and proposes a methodology we think consistent with critics formulated by Jia, Skaperdas and Vaidya (2013). Indeed, as it will be explained in Section 4, identifying battles is a quite long process, and for now we only have ten observations which is not sufficient to bring a salient illustration of the usefulness of data coming from virtual world. As a result we decided not to present our preliminary results in this version of the paper.

The paper is organized as follows. Section 2 presents the two traditional forms of CSFs. In Section 3, we promote the use of virtual worlds, and specifically EVE, in order to study conflicts and compare CSFs. Section 4 describes our data and how battles are identified in EVE and Section 5 briefly present our estimation method and Section 6 concludes the paper.

2. CONTEST SUCCESS FUNCTIONS

We consider a situation of armed conflicts in which two adversaries – says player 1 and player 2 – invest resources to increase their probability of winning. More precisely, we describe a specific battle involving two well-defined opposing groups struggling for their survival. In this framework groups act like unitary agents; consequently we postulate that the *free-rider problem* has been solved *ex ante* by an internal way (Hirshleifer, 1995; Skaperdas and Syropoulos, 1996).

2.1. Ratio and logistic forms

The technology of conflict is pictured by the so-called CSF, labeled p_i, $i = 1,2,$. This function provides the “rules of the game” in the sense that they defined how the effort committed to the fight by player i, e_i, turns into probability of success in the conflict. This *fighting effort* corresponds to the amount of resources committed to the conflict (Hirshleifer, 1988; Dasgupta and Nti, 1998). CSFs commonly respect three properties defined by Skaperdas (1996)[5]. First, the sum of the probabilities has to be equal to one. Second, $p_1(e_1, e_2)$ increases with the effort of player 1 and decreases with the effort of the other contestant. Third, the probability of success does not depend on the identity of players, but only of the amount of effort devoted. Skaperdas (1996, *Theorem 1*) suggests the following general form of CSF:

$$p_1(e_1, e_2) = \begin{cases} \dfrac{f(e_1)}{f(e_1) + f(e_2)}, & if\ e_1 + e_2 > 0 \\ \dfrac{1}{2}, & if\ e_1 + e_2 = 0 \end{cases} \tag{1}$$

where $f(.)$ is a twice continuously differentiable non-negative increasing function in $\mathbb{R}_{++}$. This function also accounts for technology deployed during the struggle. To do so, $f(.)$ contains a positive parameter, m, measuring the returns of the effort committed to the conflict, namely the *mass effect parameter* (Hirshleifer, 1988). The value of this parameter determines the degree “to which a side’s greater fighting effort translates into enhanced battle success[6]” (Hirshleifer, 2000, p. 776). In particular, a high m involves a comparative advantage of offensive technologies under defensive ones.

There are two canonical families of CSFs the most used in the literature, the ratio-form and the logistic-form. These two specifications correspond to different choices of the functional form of $f(.)$. The first one, initially designed by Tullock (1980), tends to explain that the probability of victory on the battlefield as a function depending on the ratio of fighting efforts devoted by each player. In this case $f\colon e_i \rightarrow e_i^m$, where $m > 0$ stands for the mass effect parameter. The *ratio-form* CSFs can be written as follows:

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[5] In the same vein as Skaperdas (1996), Corchón (2007, pp. 73-74) define five properties namely imperfect discrimination, monotonicity, anonymity, independence and consistency.

[6] Alcalde and Dahm (2007) denote that if m equals 0, the probability of success does not depend on the fighting effort invested but operates as a fair lottery. By contrast, a high m characterizes an important sensitivity to fighting effort that could result to an all-pay auction($m \rightarrow \infty$). For an illustration of the role of the mass effect parameter in human warfare, see Hirshleifer (1995, pp. 44-46).

$$p_1(e_1, e_2) = \begin{cases} \dfrac{1}{1 + \left(\frac{e_2}{e_1}\right)^m}, & if\ e_1 + e_2 > 0 \\ \dfrac{1}{2}, & if\ e_1 + e_2 = 0 \end{cases} \tag{2}$$

Equation (2) clearly shows that the victory largely depends on the ratio $\left(\frac{e_2}{e_1}\right)$, especially when the mass effect parameter is high.

The second traditional form is known as the *logistic-form* CSFs and was originally suggested by Hirshleifer (1988, 1989). According to this specification, the winning probability of each player depends on the difference of fighting effort committed to the struggle. Consequently the $f(.)$ function take the following form: $f: e_i \rightarrow \exp(me_i)$. The CSF associated to the probability of success detained by player 1 become such as:

$$p_1(e_1, e_2) = \frac{1}{1 + \exp\big(m(e_2 - e_1)\big)} \tag{3}$$

Equation (3) designs a conflict in which the probability of success is determined by the difference $(e_2 - e_1)$ of fighting effort devoted by the two players at stake.

2.2. Theoretical specificities of ratio and logistic forms

Some comparisons between these two specifications have been realized. First, equilibrium properties are different considering ratio or logistic forms. Indeed, CSF describes by equation (2) is not continuous at $(e_1, e_2) = (0,0)$ and there is no Nash equilibrium allowing the occurrence of a *full cooperation* (Skaperdas, 1992). Consequently, a state of total peace is not reachable using the ratio form CSFs[7]. In stark contrast, the logistic form allows the existence of reachable equilibrium without any fighting effort devoted. In this case each player has the same probability of winning, namely $p_i(e_1, e_2) = 1/2$. Consequently, logistic forms seem more fitted with armed struggled and ratio forms are "inconsistent with the observation that a two-sided peace or one-sided submission" (Hirshleifer, 1989, p.110). However logistic forms suffer from at least one severe pitfall: they consider only absolute difference in fighting effort. Quoting Hirshleifer (2000, p. 779), they picture situations in

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[7] Dasgupta and Nti (1998) and Amegashie (2006) add a parameter capturing the degree of noise to the *ratio-form*. With this peculiar design, total peace is achievable, but it exceeds the scope of our analysis.

which “a force balance of 1,000 soldiers versus 999 implies the same outcome (in terms of relative success) as 3 soldiers versus 2”. On the other hand, ratio form CSFs envisage respectively $\frac{3}{2}$ and $\frac{1000}{999}$ which corresponds to a clear military advantage in the first case. In this case, ratio forms seem much more convincing and offer a finer scale analysis of conflicts. Therefore, both forms have theoretical advantages and disadvantages so that it is extremely complicated to claim that one form is better than the other.

The choice of the functional appears fundamental in order to integrate conflicts in economic analysis. Indeed, predictions arising from theoretical models highly differ according to the choice of the CSF’s functional form (Hwang, 2012). An illustration of such volatility is provided by Anderton (2000). Using the sequential prey/predator model developed by Anderton, Anderton, and Carter (1999), he finds very different results according to the form of the CSF used. He considers a symmetric case in which both prey and predator are initially endowed with 100 resources units. In his model, the prey has to devote 11.11 resources units under ratio technology to promote peaceful trade, against 41.65 under logistic one (Anderton, 2000, *Observation 2*, p. 831). The author explains that this significant difference is explained by the fact that a marginal difference in fighting effort have stronger impacts in logistic than in ratio technology. This striking difference is not unique and Anderton also mentioned differences in the case of an increase in access to arms (no impact under ratio technology but is harmful for the economy under logistic technology) and when relative resource endowments are unequal (conflict is promoted under logistic technology but not under ratio one). Finally, he concludes that “we have no empirical estimates of the parameters of a conflict production function in a specific case, nor we know whether ratio or logistic technology is the better specification in particular conflict settings” (Anderton, 2000, p. 837). The reminder of the paper promotes the use virtual worlds in order to shed new light on this puzzle.

3. “EVE ONLINE” AS A RESEARCH TOOL FOR CONFLICT

The use of virtual worlds’ data constitutes a very young phenomenon, but considerable and diverse work concerning their politics and economics has already been done (e.g. Balkin & Noveck, 2006; Castronova, 2001, 2003, 2008; Lastowka, 2010; Lastowka & Hunter, 2004; Lessig, 1999; Ludlow, 2001a, 2001b; Mildenberger, 2013a, 2013b; Mnookin, 2001; Morningstar & Farmer, 1991). In this paper we propose to use virtual worlds as a tool for research on conflict. More specifically we claim that EVE Online (EVE) could shed new light on the estimation and comparison of CSFs.

3.1. General considerations about virtual world and conflict

Generally speaking, empirical research on conflict always deals with serious problems of empirical data. Regions and communities ridden with conflict are inherently chaotic. Obtaining objective information concerning their status quo is difficult as both conflicting parties try to make propaganda for their cause. Newspaper articles or historical records from crisis regions discussing battles and casualties for example may not be taken at face value. This is particularly true when they are used to estimate the efforts and losses of either side of a conflict, since both sides have strong incentives to distort this data. Given these problems, virtual worlds emerge as a promising environment for empirical research on violent conflict.[8]

Data from virtual worlds is more controllable and richer than real world field data. Everything a user does can potentially be monitored. For example, we gain access to data concerning all the fights he engaged in, how much material resources he invested in each of them, the size of his losses, and so on. Consequently, we are able to measure the fighting effort devoted in a battle by each participant. Second, data coming from EVE allow us to gather objective empirical evidence on social interactions in a state of conflict without having to rely on the tales of victims and perpetrators. Indeed (Rotte & Schmidt, 2003, p. 8, brackets are ours) correctly observe that “one fundamental methodological problem ... *[of using historical datasets]* is obviously that the data are all based on ex-post judgments. The military historians of course knew the outcome of the battles when they made the codings”. This problem simply does not arise in virtual worlds. Neither we nor anybody else knows the outcomes of these battles before coding them. Thus, the “winner writing history” bias or biases coming from previous knowledge of historical matters are eliminated.[9]

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[8] For an in-depth discussion of what virtual worlds are, why virtual worlds constitute and useful environment for microeconometric empirical research, as well as what their limitations are, see Mildenberger (2013a, p. 77‑120).

[9] Obviously, there might still be some bias present, as our criteria for determining the winners and losers of battles might unconsciously but constantly favor a certain side. It is not the computer software itself which objectively determines the codings for wins and losses.

3.2. EVE online

This paper examines the virtual world of EVE Online. EVE was published by *CCP Games* in May 2003. It is a science-fiction themed virtual world. When you log in, you freely navigate a space ship through a vast, three-dimensional universe. The user's main task is to compete with others in both economic and military ways. Whatever goals you set yourself, you will have to earn virtual money as a means for achieving them. You can do so either by violently appropriating what other users have, or by productive means. For example, you always have the option of mining virtual resources, using them as inputs for producing goods, and then sell these goods on the virtual market. In January 2011, EVE had around 400,000 active users and an average of around 30,000 concurrent users logged in at any time of the day. These numbers make EVE one of the internationally most successful virtual worlds.

Demographic description. Users come from nearly every country in the world, with the top three being the United States (36 per cent), the UK (11 per cent), and Germany (9 per cent). EVE has a smooth age distribution from 12 to 75 years, the average age being 31 years. 95.7 per cent of the users are male. That is, we are clearly looking at a male-dominated environment, which it is consistent with the analysis of a specific battle. Indeed, throughout History, battlefields were almost fully crowded by young males.

Costs of conflict. One of the most important difficulty is how to take into account the costs of conflict borne by a belligerent (Vahabi, 2009, 2010). EVE allows us to capture these costs by two channels: i) the opportunity cost and ii) the real destruction. First, the opportunity cost relative to conflict is mainly taken into account regarding the time spent by users on EVE. Indeed, the average EVE user spends the astonishing amount of 17 hours per week online, i.e. roughly the equivalent of a half-time job. In addition, the average user has been this active for two years (Guðmundsson, 2009, p. 12). Consequently, investment in time is huge (much more than in laboratory experiments) and losing a ship during a battle implies that the hours spent on its construction are definitely lost. Second, although EVE does not have a domestic territory, it is a clearly delimited economic area and possesses its own currency: ISK ("InterStellarKredit"). The exchange rate between ISK and EUR in January 2011 was about 1 EUR = 19,444,364 ISK.[10] This equivalence fundamental is important because it founds the

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[10] This exchange rate can be calculated since in EVE there is a possibility of buying in-game currency with real-life money: the PLEX-system. Players can buy a PLEX[10] in CCP Games' real-life online store for the price of EUR 17.495 (in January 2011). If they do so, a PLEX appears as an in-game item in their virtual inventory. In a second step, this virtual item can then be traded via the in-game market for in-game currency. Thus, the process

link between virtual destruction and real destruction: a ship destroyed during a battle has a (real) monetary cost.

Political environment. The political environment of EVE lends itself particularly well for empirically testing CSFs in the case of battlefield studies. The largest part of the virtual universe of EVE closely resembles a Hobbesian natural state, where everybody is at war with everybody else, and where no governmental organization with the power to limit conflict exists. In in-game terms, this region of the universe is aptly called “null security space” (nullsec). Nullsec is a region in EVE where players can officially claim territory, erect their own production facilities, and so on. Furthermore, nullsec is where the most money is to be made in EVE, because the most resource-rich solar systems are located in nullsec. That is, there is something worth fighting for. It is this part of the virtual universe from which we will draw our data. It is a virtual anarchy in which depredation is not only an accepted but a widespread way of making a living and competing with others. It fits perfectly with a battlefield environment.

4. DATA

4.1. General description of data

This paper essentially draws on data from two .csv-files made available by *CCP Games*. The first contains information on all the ship destructions that happened in January 2011 in EVE (Table 1).

<INSERT TABLE 1 HERE>

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comes down to buying a virtual item for real money. Calculating the monthly average for the price of one PLEX in the in-game market in January 2011 (340,179,152 ISK) and dividing it by the cost of one PLEX (17.495 EUR), yields the exchange rate mentioned above. It is, basically, the average number of ISK that you could buy in January 2011 with one Euro. In December 2010, the money supply M1 for EVE’s economy amounted to 445 trillion ISK (around 23m EUR). Note that while buying in-game currency with real-life money is legal, exchanging money made in the virtual world for real-world money is not. This does not mean, though, that the latter is done less often, as there are huge black markets for this practice.

The second file contains information on important attributes for all the characters in EVE (Table 2).

Tab. 1 Contents of the file *kills.csv*

Attribute	Typical value	Description
no. of kill	42	Each kill is attributed a consecutive number
place	30001409	The ID number of the solar system where the kill occurred
time	03.01.11 10:44	The time of the kill
victim	90225239	The ID of the character whose ship was destroyed
victim’s ship	670	The ID of the ship that was destroyed
victim’s alliance	99000198	The ID of the alliance to which the victim belonged
destroyer	756884476	The ID of the character who fired the last shot destroying the victim’s ship
destroyer’s alliance	100958673	The ID of the destroyer’s alliance
destroyer’s ship	346	The ID of the ship the destroyer flew
For each of the potential additional attackers besides the destroyer that also participated in the kill		
attacker’s security status	-2.0	The security status of the attacker
attacker’s alliance	1000958673	The alliance ID of the attacker
attacker	472395793	The character ID of the attacker
attacker’s ship	346	The ID of the ship the attacker flew
attacker’s damage	123	The damage done by each attacker to the ship of the victim in absolute numbers
For each item that was in the ship of the victim (or fitted on it)		
item	266	The ID of the item
item’s amount	400	The quantity of the item in question
item’s amount dropped	200	The quantity of the item in question that was dropped after the kill, i.e. that was not destroyed due to the explosion of the ship

Tab. 2 Contents of the file *characters.csv*

Attribute	Typical value	Description
character	90225239	The character ID
user	7354628	The ID of the user-account on which the character is created.
character’s create date	12.11.2005	The date when the character was initially created by the user
user’s date of birth	15.08.1984	The date of birth of the user
last login	14.01.2011	The time when this character last logged in
user’s gender	Female	The gender of the user
no. of logins	02. [6 to 20]	Specifies how often the character has logged in since creation. Given in categories.
total login minutes	03. [201 to 300]	Total login minutes of this character. Given in categories.
balance	02. [0 to 5000]	How much cash the character had at the time of the snapshot. Given in categories.
country	Russia	Country in which the account was registered

A third file details the average market values of all virtual objects (including ships) in EVE in the examined period. Taking these three files together, we can develop an encompassing picture of the battles taking place in EVE.

4.2 Reconstruction of battles and variables

The following strategy was employed in order to identify individual and self-contained battles in the pool of over 300,000 kills[11] in EVE in January 2011. First, a kill which involved more than 30 attackers is picked at random. This is done in order to eliminate minor skirmishes. Second, all kills that happened up to 24 hours before and after the randomly picked one, and that took place either in the same solar system[12] or in neighboring systems (up to third degree neighboring systems), were listed, to spatially and temporally zoom in on the battle.

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[11] A *kill* is the destruction of another user’s space ship.

[12] The virtual universe of EVE comprises over 7,500 individual *solar systems* that are connected to each other via *star gates*. The average solar system is connected to two to three neighboring solar systems. For maps of the overall network of solar systems, see (Dotlan, 2015).

For each examined battle a very clear picture evolved. Most battles take place in one or (at the most) two directly neighboring solar systems, as can be judged by no kills taking place at the same time in nearby systems. Furthermore, a clear beginning and end of the battle can be identified. There always is a pattern to be seen that many kills are happening in a very short amount of time (i.e. the battle itself), with the killing starting and ending rather abruptly. That is to say, no kills are happening in the given solar systems for two or three hours. Then the battle takes place and usually lasts between half an hour and an hour, usually with several kills taking place each minute. Then again, no kills are taking place for hours in the same or nearby systems.

Once all kills that belong to an individual battle have been identified in this way, the users are allocated in two teams. Starting from the initial randomly picked kill, this is done on the basis of the assumption that all those users that jointly destroyed the ship form one team, whereas the victim belongs to the other team. Based on this initial classification, two teams can be reconstructed on the basis of who contributed to which kill.

The final step is the calculation of the values used in the econometric analysis, i.e. notably the total number of ships flown by each team, the total number of ships lost by each team, and the according amounts of the total value invested in ships and the total value that was lost due to ship destruction. Given that exact data is available on which ships are flown by whom, and which ships are destroyed, as well as the market values of the ships, this is a straightforward process.

4.3 Variables

Proxies used

As a proxy for fighting effort, we use the total market value of the ships one team brings to the battlefield. Exact data is available on which ships are flown by whom, as well as the market values of the ships, so this value can be easily calculated.

Using the total economic value invested in the army is a widely adopted approach, but it may raise some endogeneity problems (e.g. Hwang, 2012). Jia, Skaperdas and Vaydia. (2013, pp. 219–20) highlight that the value invested is not the same as the actual fighting effort. Because the actual military power of an army does not only depend on its size or the value of its weapons, but also on how committed the soldiers are and similar things, a measurement error might occur. To this effect, it is noteworthy that the available data allows for some refinement of the proxy, making it multi-factorial, in order to counter the measurement error. First, there is data available about the fighting skills of each individual player.[13] Thus, there is a way to control for the effect that skilled users of expensive weaponry are more effective than amateurs. Second, there is a way to compare how much damage individual users dealt in comparison to other users flying the same ships.[14] This seems to be a good additional way to capture effort that goes beyond mere value invested. The more damage a certain user dealt relatively speaking to his potential and what others realized, the more effort he seems to have exercised.

We code victory and defeat in a binary way. As a proxy for determining the winner, we calculate ratio of the total value lost in a battle to the total value invested for each team. The team with the smaller quotient, i.e. the one with less value lost per value invested is considered the winner.[15]

Known data issues

Jia et al. (2013, pp. 218–20) raise some additional issues about data used for the econometric estimation of CSFs (cf. also Sunde, 2003). First, our dataset satisfies the Ford competition. Second, although our dataset is not about individualistic competition but about a team competition, we do not consider this a problem. This is because military contests very rarely are individualistic in nature. To use data on individualistic contest might be preferable for theoretical reasons, but is not for reasons of external validity. Third, only two parties are involved in the battles we analyze. Fourth, the structure of information is such that it closely resembles the assumptions of theoretical models. All the information about which team brings which ships as well as how much they are worth on the market and how powerful they are is known to all contestants. Fifth, there is the issue of dynamic effects and long-term benefit streams which might be embedded in the data. Given that we are studying a random sample of isolated battles without being concerned about historical paths, this does not pose a major problem for our dataset.

Finally, there is the major issue of feedback effects. Notably, the worry is that once the outcome of the battle is pretty much clear, both sides might cut back their efforts

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[13] The *skill points* value in the file characters.csv

[14] The value *attacker's damage* in the file kills.csv

[15] An alternative measure of victory and defeat could be to look which team scored more kills in, say, the last third of the battle. The underlying assumption would be that the winning side is able to effectively destroy the opponent's forces in this stage once it has come out on top in the middle stage of the battle.

substantially. Thus, the development of the battle might have a feedback effect on the effort exercised. But to stop exercising effort once the winner has been determined is not how EVE battles work in general. First, as soon as one side substantially reduces its effort, there is the very real possibility to still be defeated by the weaker party. Second, because in EVE it is not only important who wins and who loses a battle, but also by how much, this kind of feedback effect is unlikely to arise. What the winning team wants to do is to weaken its opponent as best as it can in each battle, not just to stop fighting once victory has been secured. Each hostile ship destroyed has to be replaced by the opponent. This is typical of real world military conflicts as well.[16]

5. ESTIMATION

In order to estimate the two alternative CSFs we proceed as follows. The success, y_1, follows a Bernoulli of parameter p_1 and takes a value of 1 if the side 1 wins and 0 otherwise. Thus p_1 is the winning probability of side 1 and comes either from the ratio form or the difference form. We can rewrite equation (2) and (3) as $p_1 = F\big(m(ln\, e_1 - ln\, e_2)\big)$ and $p_1 = F\big(m(e_1 - e_2)\big)$. As $F(s) = 1/(1 + e^{-s})$ the difference form corresponds to the logit regression model while the ratio form is the logit regression with a log-transformed. In order to estimate the mass effect parameter, m, and the goodness-of-fit of each model on our data we perform a maximum likelihood estimation of both functions.

In terms of model comparison we first use the classical BIC index and compare the models according to Rafetry's grade of evidence (1995). Nevertheless as pointed by Jia, Skaperdas and Vaidya (2013) the non-linear forms of the functions as well as the fact that they are nested together may affected the classical index of goodness-of-fit. Following the authors recommendation we will use in addition the Bayes factor to compare models (Kaas and Raftery, 1995). By computing the ratio of the marginal likelihoods of the two models we will obtain different grades of evidence in favor of one of the two models (see Jeffreys, 1961, for the values of each grade). As the computation of exact marginal likelihood is not possible we use an approximation by constructing a Markov chain Monte Carlo (MCMC) sampler.

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[16] Here is another potential feedback problem that we do not address yet, but can eventually control for. If it is quite unclear which team will win for a long period of time, each side might choose to mobilize additional forces while the battle is still lasting. Notably, in EVE, pilots whose ships have been destroyed might decide to come back with a new ship. One way to deal with this kind of feedback effect is to do estimations for a sub-sample of battles in which each pilot only flies one ship per battle.

Different methods are available but here we will use the Metropolis-Hasting algorithm to estimate our Bayes factor (see Chib and Greenberg, 1995).

Unfortunately we cannot show in the present version of the paper the results of the estimations and the model comparison. As the creation of the variables takes time we only have 10 observations available for now. We think that it is not enough to offer robust results and it will be in contradiction with our main point claiming that data from online world are very pertinent for CSFs estimation due to their quantity and quality.

6. CONCLUSION

In this preliminary version of the paper, we try to demonstrate how data coming from virtual worlds could shed new light on conflict economics. More precisely, we claim that by taking into account warfare context (integrating destruction costs), and due to the quality of data, virtual worlds represents a very interesting tool for research on conflicts. Particularly, we think that it better performs than historical data and laboratory experiments in estimating and comparing theoretical analysis on conflict.

To the best of our knowledge, this study is the first of its kind in conflict theory. We think that it could open a very promising field of research allowing social research to have a better understanding of agents' behavior in a situation of (armed) conflict.

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