Journal of Economic Behavior and Organization 154 (2018) 137–155

Contents lists available at ScienceDirect

Journal of Economic Behavior and Organization

journal homepage: www.elsevier.com/locate/jebo

How does size matter for military success? Evidence from virtual worlds[☆]

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ARTICLE INFO

Article history:
Received 24 January 2018
Revised 5 August 2018
Accepted 11 August 2018

JEL classification:
D74
H56
C57

Keywords:
Contest success functions
Military victory
Virtual worlds

ABSTRACT

This paper investigates how differences in military spending translate into probability of victory in a conflict. To do so the paper empirically estimates and compares the four main forms of contest success functions – the *Tullock*, the *logit*, the *difference*, and the *relative difference form*. In order to circumvent measurement issues and endogeneity biases associated with historical battle-related data, we advocate the use of virtual worlds. Data from virtual worlds is an innovative and promising tool in conflict research. It allows conflict analyses based on rich and objective empirical evidence on economic behavior in a warfare context; something which is difficult to achieve in real world settings. Thanks to collaboration with the developer of a virtual world, we are able to construct an original database of 19,229 battles that occurred during January 2011. The results show that the relative difference contest success function as proposed by Beviá and Corchón (2015) outperforms other existing forms of contest success functions. Thus, the decisive factor to predict the outcome of a battle is the relative difference in forces devoted by rivals. *Relative* size matters.

1. Introduction

Since Pareto's observation that "[t]he efforts of men are utilized in two different ways: they are directed to the production or transformation of economic goods, or else to the appropriation of goods produced by others" (Pareto, 1971, p. 341, Section 17), appropriation and conflict gradually made their way into economic analysis. The most widely used economic models of violent appropriation are "guns versus butter" (hereafter 'GVB') models (seminal contributions are Hirshleifer, 1988; Hirshleifer, 1989).[1] In GVB models, rival agents compete over a prize. To increase the probability of success, each agent can devote resources to buy 'guns' (*i.e.* exercise effort to fight, grab, or extort). As guns cannot be used to create wealth, there is a trade-off between producing goods ('butter') or appropriating them from others.

☆ This paper hugely benefitted from insightful remarks and suggestions from Fancis Bloch, Raul Caruso, Luis Corchón, Bertrand Crettez, José de Sousa, Kai Konrad, Claude Ménard, Petros Sekeris, Stergios Skaperdas and Mehrdad Vahabi. We would also like to thank two anonmyous reviewers for JEBO and the editor Daniel Houser for their very valuable comments. Last but not least, we would like to express our gratitude to Thomas B. for his help with data processing. All mistakes remain ours.

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[1] These can easily be integrated into numerous economics frameworks including Edgeworth box analyses (Anderton and Carter, 2008; 2009), international trade (Garfinkel et al., 2012; 2015), growth models (Aizenman and Glick, 2006) or social network (Franke and Öztürk, 2015). The GVB framework constitutes a bridge between conflict and economics and allows a better understanding of economic activities.

https://doi.org/10.1016/j.jebo.2018.08.012
0167-2681/

GVB models depict conflict as a *costly lottery* in the sense that the probability of success is defined by a mathematical function depending on the fighting efforts devoted by each agent. A fundamental research question is to determine the form of the function explaining how increased fighting efforts are translated into an increased probability of winning, the so-called *Contest Success Function* (hereafter 'CSF').[2] Four forms received special attention in the literature. The *Tullock* form (Tullock, 1980) considers that the probability of winning is a function of the relative number of guns deployed on the battlefield by each side. The *logit* and *probit* forms (respectively proposed by Hirshleifer, 1988; Hirshleifer, 1989 and Baik, 1998) assume that victory depends on the absolute difference in guns involved in the battlefield. Lastly, the *Relative Difference* CSF (*RDCSF*), introduced by Beviá and Corchón (2015), considers that the key factor is the difference in fighting efforts scaled by the size of the conflict.

As pointed out by Hwang (2012), economic predictions and policy advice drastically hinge on the form of the CSF used. Consequently, comparing the different forms of CSFs is of critical importance for theoretical frameworks – in particular those dealing with countries' optimal resource allocation. However, few empirical comparisons have been carried out as regards human warfare (e.g. Lotzin, 2011 or Hwang, 2012).[3]' power to predict. His conclusion is in favor of the *probit* form. Yildizparlak (2017) uses European soccer leagues' data to estimate and compare CSFs accounting for the probability of a draw. The paper shows that the difference of efforts are more predictive than the aggregate level of effort. This is partly due to the fact that, for practical and ethical reasons, it is hard to get a hold of good, complete, and reliable data on human battles. Measurement and endogeneity biases further complicate the empirical estimation and comparison of CSFs (Jia et al., 2013). In light of these known issues, this article proceeds to use data taken from a virtual world to shed new light on the nature of the link between resources devoted to guns and the probability of success.

Virtual worlds are computer-created environments that visually mimic complex physical spaces, where people can interact with each other and with virtual objects in multiple ways (Bainbridge, 2007). They give rise to sophisticated political systems governed by distinct sets of institutions and well-developed economies (e.g. Castronova, 2001; Castronova, 2008; Lastowka and Hunter, 2004; Lessig, 1999; Ludlow, 2001 or Mildenberger, 2013a). Virtual worlds constitute a promising source of data as they provide a large amount of extremely precise data. Fine-grained analyses of battlefield behavior are possible as everything a user does within these worlds is registered on the servers. Thanks to a collaboration with the developer of a virtual world, we collected data on battles comprising more than 300,000 casualties in an online game called *EVE Online* (hereafter 'EVE').[4] EVE is a real-time massively multiplayer online game which closely fits a GVB framework. That is, EVE is neither an arcade game like *Space Invaders* nor a real-time strategy game like the *Command and Conquer* series, which both possess CSFs which are predetermined by the games' developers'. In EVE, you cannot let the computer fight for you - on "autopilot", so to speak - to let the game's "battle algorithm" automatically determine the result, but it is real people's software-mediated decisions and actions alone which decide the battle. The world of EVE is a virtual anarchic State of nature, in which the around 400,000 players of this game constantly face the paradigmatic choice of either making a living by producing things or by appropriating what others produced.

We built an original database made up of 19,229 virtual battles between two 'teams' of players. Among the four forms of CSFs cited above, we find robust evidence advocating the RDCSF (Beviá and Corchón, 2015). More generally we find that measurements taking into account relative difference of fighting efforts outperform measurements based on absolute difference or ratio measurements. In other words, relative size matters for military success. Because the choice of a CSF has dramatic effects on the predictions of a model of conflict, this finding is important. However, the article's contribution is also methodological. The comparison of CSFs based on virtual world data serves to exemplify the power and usefulness of the new approach of virtual-worlds research.

The article proceeds as follows. In the second section, we briefly introduce the four main forms of CSFs, as well as the results of the comparisons of CSFs by Lotzin (2011) and Hwang (2012). We also present the known data issues induced by the use of historical data sets. In the third section, we describe the economic, political, and military environment of EVE. Our fourth section describes our data, as well as the advantages and limitations of virtual-worlds research. Our identification strategy for battles, estimations and comparisons are presented in the fifth section. Section 6 presents our results, Section 7 concludes.

2. Theoretical and empirical basics of CSFs

CSFs map how fighting efforts devoted by each contestant are translated into an increased or lowered probability of success in conflict. The literature identifies different types of CSFs.

[2] CSFs are also used in several other different contests like litigation, technology races, lobbying, or sports. For an overview see for example Konrad (2009), Van Long (2013) or Corchón and Serena (2017). Surveys focusing on military contests can be found in Garfinkel and Skaperdas (2007) and Jia and Skaperdas (2012)

[3] By contrast, there exists a vast empirical literature on sports contests dealing with the estimation of the link between efforts devoted by sportsmen and their probability of success (e.g. golf (Ehrenberg and Bognanno, 1990), soccer (Maloney and McCormick, 2000) or tennis (Sunde, 2009)). Yet again, there are few papers addressing the *comparison* of the predictive performance of different CSFs for sports contests. Peeters (2011) collects data from the American major sports leagues and finds that the *Tullock* form provides better predictions than the *logit* one for basketball (NBA) and football (NFL). However, the difference of fit is not significant for hockey (NFL) and baseball (MLB). Jia (2008) focuses on the prediction of NBA game results in the 2004–2005 season. He relies on a Bayesian model comparison method to compare *Tullock*, *logit* and *probit* CSFs

[4] In recent years, video games have been widely used in the context of conflict theory: see for example Mildenberger (2015) or Robinson (2016).