Using the Beer Game for more than education and inventory management research

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In addition to its broad educational applications, researchers have used the beer distribution game (BDG) in laboratory experiments, primarily to study how human agents manage inventories in supply chains. Nearly all of the research in this area deals with the phenomenon known as the *bullwhip effect*, specifically its causes and effective mitigation strategies (see Alfieri & Zotteri, 2017; Forrester, 1961; Lee et al., 1997). There has been, however, little effort to use the game to study other topics within operations management. This may be, in part, due to its relative analytical complexity, making it hard to develop and test theories emerging from the field. Unfortunately, this may, in the long run, limit how useful the game is perceived to be, by both the practitioners and the researchers. Exploring novel research opportunities may help change this and shine a new light on how the game itself, as well as system dynamics in general, is used and perceived by the operations management community.

In this study, we show how the BDG can be used as an experimental tool to test and validate theoretical predictions in the field of behavioral operations management with the help of system dynamics modeling and simulation. We do that by analyzing the literature on inequity aversion, leading to the development of quantitative models applicable to the context of the BDG. Using computer simulation, we elicit a set of testable predictions, design a BDG-based laboratory experiment, and test the said predictions. In doing so, we contribute to the field of behavioral operations management by applying and testing its models of inequity aversion in a previously unexplored context, and to the BDG itself by demonstrating that it can be used to answer questions outside of inventory management.

Pertaining to Kahneman et al.'s (1986) finding that firms as well as individuals are frequently driven by fairness concerns in business relationships, Haitao Cui et al. (2007) were among the first to research the impact of fairness considerations on supply channel coordination and channel efficiency. They used a dyadic channel structure with one supplier and one retailer to model a distribution channel and applied Fehr and Schmidt's (1999) concept of inequity aversion to their model, which proposes that individuals are inequity averse if they dislike outcomes that are perceived as inequitable or unfair. They experience inequity both if they are worse off or better off in material terms than other individuals in their relevant reference group, although Fehr and Schmidt (1999) assume that they suffer more if the inequity is to their disadvantage. Under the assumptions of their model, individuals have complete information about the payoffs of all other individuals in their reference group and compare their payoff to each of them individually.

Bolton and Ockenfels (2000) independently proposed similarly effective but slightly different model of inequity aversion, which they named ERC – A theory of Equity, Reciprocity, and Competition. Their model provided two important innovations: (1) it assumes that along with monetary payoff, the relative payoff motivates individuals, and (2) it is an incomplete information model, which means that individuals do not have information about other individuals' payoffs but instead information about their own share in the total monetary payoff. Their model is also capable of explaining a wide variety of experimental evidence. The two models can also be presented in the form of generalized stock and flow diagrams, as seen if Figure 1.

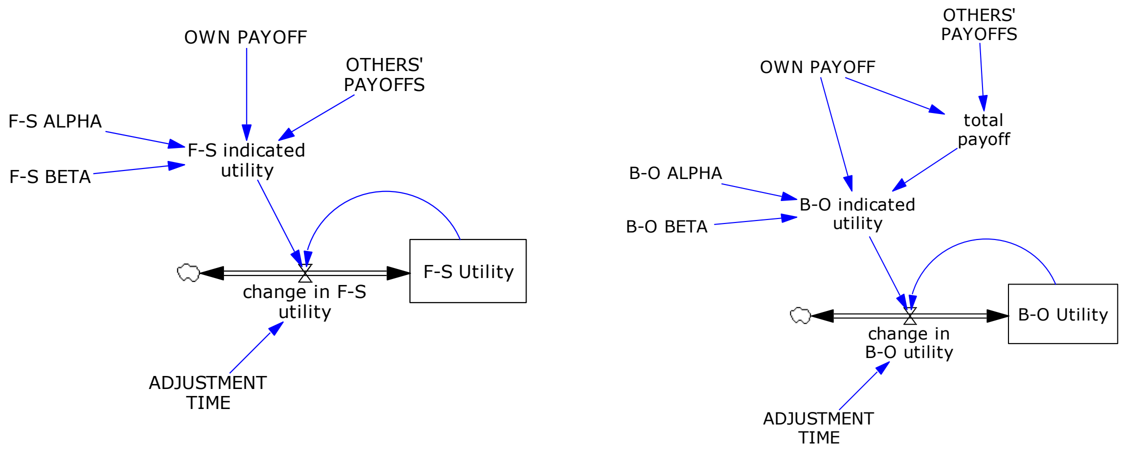

Figure 1. Stock-and-flow structure if dynamic inequity aversion models with complete and incomplete information

In this from, it possible to combine the models of inequity aversion with the BDG model and perform computer simulation in order to obtain testable predictions. System dynamics model of the BDG was developed by Kirkwood (1998). While observing the resulting simulations, it is possible to elicit the following hypotheses:

H1: Profit has a positive effect on utility;

H2: Incomplete information leads to higher utility than complete information;

H3: The distributor suffers more than the factory due to lower utility.

In order to test the three hypotheses, a laboratory experiment based on the BDG was designed and conducted. This experiment had four separate treatments based on all possible combinations of variations of two control variables, namely the completeness of information and the position in the game. Participants played the game in either the complete or the incomplete information setting and as either the distributor or the factory (manufacturer). In each of the four treatments, alongside standard demographic measurements, participant's profit and utility (in-game satisfaction measurement and the post-game distributive fairness measurement) was measured. The quantitative analysis focuses on identifying significant relationships between profit and utility measurements, as well as significant differences between the two inequity aversion models and stages in the BDG.

We found good evidence that players' own profits indeed predict their utility during the game, however, this changes once the game ends and they are asked evaluate retrospectively the distribution of profits. We did not find evidence in the post-game evaluations to suggest that players' own profits significantly contribute to their evaluations. A possible explanation for our findings is that we detected a strong influence of social comparison. Simply said, the reason why those players with higher end-game profits are also not the ones with higher levels of post-game distributive fairness evaluations (and the other way around) is that they are comparing their profit to other stages in the game. Having higher end-game profit means little if other stages are doing better than you. Similarly, if you performed poorly, but so did everyone else, you might not feel as bad as you should if you were completely rational. Future research should certainly look to explore this idea further as it may demonstrate that human decision-makers exhibit strong social preferences even when they are the only human decision-maker in the economic environment.

We did not find enough evidence to support the prediction of the simulation model that having complete information about the profits of all stages in the game, leads to a decrease in utility compared to having incomplete information. As we mentioned earlier, the lack of evidence may be due to relatively small sample size in one of the treatments. Another explanation is that there simply no substantive difference between these two settings or the two inequity aversion models. Once again, future research may look to explore this idea in more detail, as we did find that the distributors in the incomplete information setting have a significantly higher in-game satisfaction compared to the distributors in the complete information setting. Finally, we did find evidence that it is the distributor who suffers the most in the BDG due to order amplification. This opposes the current literature, which would suggest that it is the factory which suffers the most. Once again, the evidence suggest that this holds true only during the game. When the game ends, there appears to be no significant differences between distributors and factories. This and the previous findings suggest that during the game players tend to focus primarily on their own performance (profit) and that they, to some extent, ignore other stages. When evaluating their performance post-game, they do so in relation to other stages, which may be why no effect between profit and utility was detected.

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