

# **Response to Replication Report for “Behavioral Causes of the Bullwhip Effect and the Observed Value of Inventory Information”**

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We would like to thank the Management Science Replication Project (MSRP) team for conducting this important study (Davis et al. 2022). We are strong advocates of replication-based research, both in principle, and as a way to deepen our knowledge of why, when, and how a behavioral effect of interest emerges. Identifying that an effect exists within a single setting should propel further inquiry rather than being the last word. The MSRP team provides a great service to the behavioral operations community in delivering this impressive set of replication studies, and we encourage everyone in our profession to support this important work, especially encouraging more editors to support and publish replication research. This direction will help ignite further inquiry into behavioral phenomena that is critical to improving how operations and supply chains function. The methodological rigor shown in this particular effort also serves as an aspirational benchmark for how experimental work should be conducted and is sure to elevate the research of future behavioral operations scholars.

When we began studying the bullwhip effect within the context of the classic Beer Distribution Game (Sterman 1992) over 20 years ago, one of the most surprising results was that the effect remains even when the distribution of demand is commonly known to all supply chain members. The base-case setting of the original paper (Croson and Donohue 2006) controlled for other well-known operational causes of the bullwhip effect (Lee et al. 1997), isolating the role of behavioral factors as important contributors to the bullwhip effect and confirming supply line underweighting (Sterman 1989) as one significant factor. These results, which are featured in Study 1 of our paper, set the stage for Study 2 which looked further at a possible intervention for reducing this form of bullwhip behavior; specifically sharing inventory information across the supply chain.

The MSRP team's work focuses on replicating the finding that "sharing inventory information with supply chain members helps alleviate, but not eliminate, the bullwhip effect" (i.e., Hypothesis 3 within Study 2). To do this, they conduct experiments at two sites: UTD and UW-Madison. The results are mixed, with the UW-Madison sample providing stronger support of Hypothesis 3 than the UTD sample. Both samples also show a wider range of order variation, with a "non-trivial number of apparent outliers" (Katok et al. 2022, page 3) compared with the sample generated through our original experiment.

These results are interesting in themselves, especially in comparing the UTD and UW-Madison samples. The results also raise other interesting questions in comparison to the original study. We offer three questions that we think are worthy of further exploration.

The first question is *what is the role of physical presence in creating common knowledge?* One difference in protocol between the UTD and UW-Madison samples was the physical location of the participants. In the UTD sample, students took part in the experiment in a hybrid mode with some in class and others connected from home. In the UW-Madison sample, as in our original experiment, students took part in the experiment together in a classroom. When participants are together in a physical setting, common knowledge is straightforward to create and obtain. Could this difference in physical proximity be a contributing factor to the differences seen in the UTD sample (which did not replicate), versus the UW-Madison and original samples (which did)? Physical proximity may reassure participants about the knowledge, attention and perceived capabilities of other players, something that may be missing when participants engage virtually. This finding and observation raises interesting methodological issues about how we run experiments. Perhaps more importantly, it raises substantive issues about the influence of proximity on decision making; issues that will gain more salience given changing trends toward working from home within the supply chain profession.

The second question is *how should outliers in experimental data be interpreted?* Both the UTD and UW-Madison samples contained a significant number of extreme outliers, compared to none in our original sample. One reason for this difference could be the larger size of the replication samples (roughly 8 times as large as the original sample), which increases the likelihood of drawing in individuals or groups with unusual strategies. While the main conclusions of both replication samples appear to be robust to various approaches to removing outliers, the existence of outliers also raises interesting issues about the volatility of this decision setting. We know that the Beer Distribution Game has a fragile equilibrium which can be hard to converge upon or reestablish once bullwhip behavior is triggered (Croson et al. 2014). Most behavioral research has examined what causes the bullwhip effect or what conditions (such as sharing

inventory information, in the case of our original study) helps to alleviate its magnitude. Evidence of extreme outliers suggests it would be helpful to also explore what interventions are effective when the bullwhip has already taken hold and supply chains seek to return to more stable ordering behavior. Such “out of equilibrium” settings are becoming the new normal, as we deal with uncertainty caused by global supply shortages, shipping delays, and swings in economic conditions.

The final question is *whether individual knowledge and experience of supply chain dynamics has changed in a way that leads to different outcomes in the Beer Distribution Game setting?* Our original study was conducted over 20 years ago, at a time when the bullwhip effect was less well known to our student population or the broader public. Today, a vast majority of students have learned about supply chain dynamics in their curriculum, and have recently witnessed order volatility first-hand, especially with the rollercoaster of demand shifts during the pandemic. While this goes well beyond the implications of this replication study, revisiting this research in today’s environment allows us to identify the impact of this additional information and experience on behavior.

These questions were, and hopefully the answers will be, directly inspired by this replication. We look forward to continuing this conversation, and want to reiterate our support for replication research in general, and this initiative (and this project) in particular. It is only through replication, information and data-sharing that our science progresses, and this initiative is pivotal to that progress.

## References

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