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Interactive comment

Interactive comment on "How Robust is Your System Resilience?" *by* Mehran Homayounfar et al.

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Dear reviewers and interested readers:

As you read the manuscript, please be aware of the following changes we plan to implement: a revised definition of the robustness metric and an addition of the author who suggested it.

Soon after the manuscript was submitted, I had a long and productive discussion with Chitsomanus P. Muneepeerakul about the manuscript. After much debate, we are convinced that using high variance of resilience to mean lower robustness could be misleading and, importantly, the variance should not be used as a dimension in determining Pareto-optimal policies. Her critique came from her research in the area of

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Discussion paper

environmental finance, where the use of variance to measure risk has been seen as problematic. She proposed that we use 'conditional mean' or what is referred to in the finance world as "conditional value at risk" as a robustness metric. For example, we may consider only resilience metric values lower than a certain threshold percentile and calculate the average of these "bad-tail values." The key objection here is that variance gives the same weight to "good deviations" (resilience greater than the mean) and "bad deviations" (resilience lower than the mean). Accordingly, she argued that, for example, contribution to a high variance arising from a heavy tail in the good direction should not be translated to less robustness. This issue has been a problem in the financial world, and more and more analyses have switched to considering other measures of risk, such as the conditional value at risk, in evaluating their portfolios of investment.

Following that logic, here we propose to use a "below-mean mean" as a new robustness metric, i.e., the mean of all resilience values associated with the "bad deviations." This new definition of the robustness metric has several desirable features. First, it can now be appropriately thought of as a robustness metric in the sense that the higher the value, the more robust the system (unlike the variance for which low variance means high robustness). Second, by using the mean as the threshold value for bad deviations, we remove some arbitrariness associated with prescribing a certain quantile (e.g., 5th or 10th quantile) in calculating the bad-tail mean. Third, it still carries some information about the sensitivity of the resilience metric to outside factors–the information that variance conveys; that is, the higher the "below-mean mean" (i.e., the bad deviations from the mean are small), the less sensitive the resilience metric.

We have implemented the new metric and it did perform better. In particular, using the new robustness metric yields a similar set of Pareto-optimal policies–without the not-so-desirable low-resilience, low-variance policies (which are technically part of the Pareto frontier when using variance as one of the dimensions to determine Pareto optimality) that we had to somewhat arbitrarily ignore in the original submission (Fig. 4).

Indeed, such arbitrary omission exemplifies the problem of using variance to measure robustness and to determine Pareto optimality. I am now of the opinion that the proposed metric is a better metric of robustness, not only for this particular model, but also for robustness of other indicator functions. This change will significantly strengthen our manuscript.

Your time and attention to these changes are appreciated.

Sincerely,

Rachata Muneepeerakul

On behalf of the authors

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