Substandard and falsified pharmaceuticals substantially increase levels of morbidity, mortality, and drug resistance around the world. These problems are most urgent in low- and middle-income countries. To assess quality, regulators in these countries often rely on post-market surveillance that collects samples from retail outlets at the end of the pharmaceutical supply chain. Regulators must decide where to spend sampling resources and how to deploy intervention resources—both of which are often in short supply. Additionally, there exists an identifiability problem in the analysis of these post-market samples: how do we discern that quality problems are the fault of the outlet, and not the fault of actors further upstream in the supply chain? The fact that outlets often procure from an array of different distributors, however, provides a valuable opportunity to establish sounder links between poor quality products and their sources.

I am working with Professors Smilowitz and Plumlee at Northwestern University’s Department of Industrial Engineering and Management Sciences to pose and investigate questions involving the propagation of these dangerous products in environments rooted in the supply chains of low-resource countries. We are interested in exploring the contexts in which sampling results from retail outlets, coupled with supply chain information, can provide insights into the sources of low-quality products, as well as feed strategies concerning which outlets to sample next.

To aid our explorations, we have constructed an agent-based, two-echelon simulation model grounded in an ongoing collaboration with the pharmaceutical regulatory arm of Liberia. In this model, outlets procure from a set of different national distributors, with supply chain dynamics changing under different demand levels and individual inventory policies. We have also incorporated diagnostic sensitivity and specificity into the testing mechanism. Using procurement and sampling data from the outlets, we have created different methods of estimating poor-quality prevalence levels at each entity in both echelons, including linear and logistic projections, likelihood maximization, and posterior distribution sampling.

Furthermore, working under this simulation model has yielded ideas on theoretical approaches to understanding these types of pharmaceutical supply chains, particularly under ideal scenarios. One intuitive example is that when outlets each procure from a single distributor, linear projection estimates of the distributors’ poor-quality rates become the average across the observed poor-quality rates of their “downstream” outlets. A more surprising example is that when outlets have only two distributors from which to procure products, it can be shown that the linear projection estimate of a given distributor’s poor-quality rates may be affected by the prevalence rates observed at outlets that do not procure from that distributor.

Despite these fruitful efforts so far, a wide array of theoretical and practical avenues remain to be explored. On the theoretical end: what are the analytical implications of expanding to three-echelon supply chains? How does willingness to shift to different distributors affect the choice of sampling policy? On the implementation side: how can outlet procurement patterns be practically estimated? How can theses models’ results be used to develop operational sampling policies that often face severe resource constraints? How should the implications of diagnostic sensitivity and specificity affect the selection of testing methods?