The Intensive Care Unit (ICU) in a hospital often has the highest cost and the highest congestion level. Patient care in capacity-constrained hospital units sometimes results in scenarios where the demanded quantity and level for care exceeds immediate availability, which may impact patient outcomes as well as economic outcomes. For example, when a new patient arrives to a busy ICU, their admission may be delayed, which has been shown to be associated with worse patient outcomes. Alternatively, hospitals may elect to demand-driven temporary discharge to a current patient in the ICU in order to accommodate the new, more critical patient; such discharges may increase the likelihood of readmission and mortality. Since a large proportion of the patients occupying ICU beds are the patients admitted from the Emergency Department (ED), we can gain operational insights on how to improve capacity allocation of ICU beds and therefore overall patient outcomes by studying the ED physicians’ ICU admission decisions.

Our study focuses on the intertemporal externalities on those ICU admission decisions. In particular, we study how admitting a patient in the current period affects the system status, and, in turn, its ability in admitting another patient with possibly more severe conditions in the next period. We take the structural estimation approach which allows us to estimate the intertemporal externalities from data. We provide a brief description about the model and the estimation strategy below.

We model the ED physician’s ICU admission decision using a dynamic programming model. At the high level, the physician makes the ICU admission decision taking into account its impact on the current patient as well as on future patients through the impact on system status. The state variables are the number of patients of each type in the ED in the current period, and the number of patients in the ICU in the current period. The physician’s decision is the number of patients of each type to admit to the ICU, to reroute to the ward, or to keep in the ED. The decision is
made based on both current period and future period payoffs. Since the focus of our study is the intertemporal externalities on the ICU admission decision, we focus on estimating the discount factor while keeping the other parts of the model parsimonious.

The main difficulty in the estimation is that the discount factor is generally not identified non-parametrically. We make parametric assumptions common in the literature and exploit the richness of the data to achieve identification. The key condition that needs to be satisfied to achieve the identification of the discount factor is that there must exist distinguished state-action pairs in the data where the static payoffs are the same while the future payoffs differ. We show analytically that this condition is satisfied in our model. Moreover, using simulations we illustrate that the discount factor can be recovered in our data.

The estimation procedure is the following. For a given set of parameter values, we first solve for the optimal policy numerically. Second, we compute the predicted choice probabilities for each state given the optimal policy. Finally, we search through the parameter space to find the set of parameter values that maximizes the observed choice probabilities for all states.

We use two years of detailed patient-level ED and ICU data from 21 Kaiser hospitals in the estimation. We find that there is substantial heterogeneity in the estimated discount factor across hospitals. Large hospitals are more forward-looking, while small hospitals seem to be short-sighted. Theoretically, since large hospitals have higher congestion level in the ICU, the gain in being more forward looking is higher. On the other hand, large hospitals also have higher external arrivals to the ICU which leads to lower gain in being more forward looking. Our finding suggests that the impact of the former outweighs the latter.

Our contribution is two fold. First, we contribute to the management of ICU capacity literature by providing empirical evidence about the intertemporal externalities on the ICU admission decision. This improves our understanding of the impact of ICU admission decisions on the overall system performance. Second, our study contributes to the literature in empirical operations management using structural estimation methods. We apply recent theoretical results on the identification of the discount factor in dynamic programming problems in a healthcare OM setting.