E107

Modelling post-disaster recovery process of industrial sectors: A case study of 2016 Kumamoto Earthquakes

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Highlights

• The business production capacity recovery is modelled via a multi-state semi-Markov model, which is able to decipher uncertainty during the recovery process;

• The proposed model integrates the impact of initial damage rate and lifeline service availability;

• The proposed model is validated by applying it into a real post-disaster case.

Introduction

Understanding the post-disaster recovery process of industrial sectors is critical for ensuring a quicker recovery and estimating economic losses instigated by disasters. However, the recovery process of firms is complex, multidimensional, and the impact of uncertainty and relevant determiners on recovery has not been adequately addressed in past studies. Therefore, this research developed a recovery function for a firm's post-disaster recovery process, which integrated the impact of initial damage rates and lifeline service supply status. To model the stochastic recovery process of industrial sectors, this research establishes a multi-state semi-Markov modelling framework that considers both the sojourn time before production capacity state transitions and the probability of state transition in each production capacity state. Besides, the impact of firm size and sector type on recovery are also acknowledged and compared. After the 2016 Kumamoto earthquakes in Japan, the proposed model was integrated into the firms' recovery process, and the results were consistent with the actual observed dataset and recovery tendency. The proposed model can evaluate the recovery probability at any post-disaster time but is conditional on the initial production capacity rate and lifeline service availability of different industrial sectors. Such a model can contribute by providing empirical evidence to decision-makers and business managers about the systematization of recovery strategies, as well as the prediction of business recovery processes in case of future incidents.

Methodology

This research formulated a recovery function by adapting a semi-Markov model to the conditional recovery probability, which can effectively capture the recovery mechanism and describe the randomness recovery behaviors of firms after disasters.

The semi-Markov process is a class of stochastic processes that integrates both the Markov state jump process and the renewal process. A firm's production capacity recovery process $S(\mathrm{t})$ instantly commences after the disaster, which begins as time t_0 and ends at the time t_n when the production capacity returns to the pre-disaster production capacity level (state n). If a firm's production capacity begins from state i and ends at state n, the recovery time is represented as $t_{i,n}$. Due to an uncertain hazard intensity and diverse thresholds of firms' resistance to disasters, the firm may stay at a random initial production capacity state S-$(t_0) \in \mathbb{N}$. One possible path of a semi-Markov process, for a firm to start from $S(t_0) = 0$, is illustrated in Figure 1.

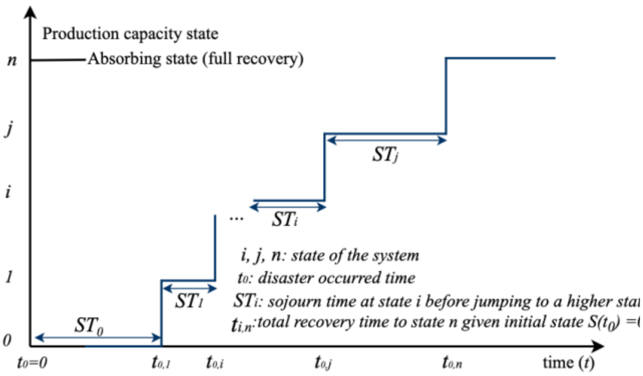

Figure 1. An illustrative path of the semi-Markov process

Results

The calculated conditional recovery probability, which are shown as the recovery curves, are presented in Figure 2.

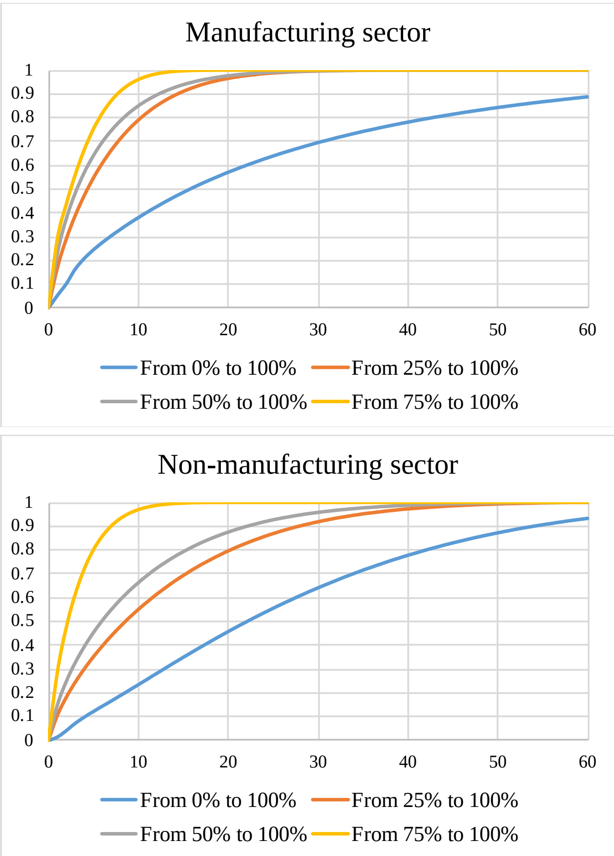

Figure 2. Estimated recovery curves

Validation

It can be observed from the Figure 3 that the estimated results fit well with the observed dataset.

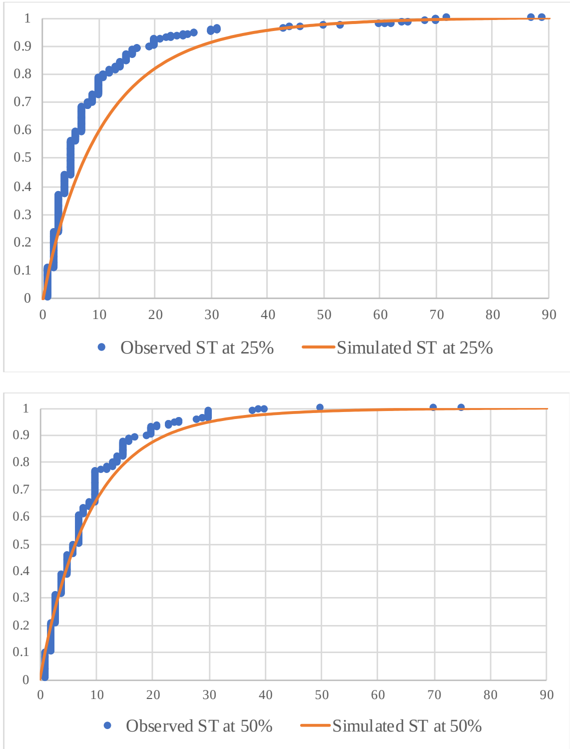

Figure 3. Comparison between observed dataset and estimated recovery curves

Discussion and Conclusion

The main focus of the current study is to formulate a quantitative framework for post-disaster business recovery and prove its viability through an application concerning a recovery process following an earthquake. The recovery function for a post-disaster business recovery is established by considering the initial damage ratios, availability of lifeline services, and the identification of the impact of business size and business sector type. A semi-Markov model with a Weibull sojourn time distribution is proposed to describe and model the stochastic recovery process for the first time and is applied to the post-disaster recovery process following the 2016 Kumamoto earthquakes. The advantages of the proposed model compared with the existing recovery-related model is its ability to decipher uncertainty during the recovery process and to incorporate the impact of determinants related to production capacity.