Estimating Lifeline Resilience Factors
Using Post-Disaster Business Recovery Data

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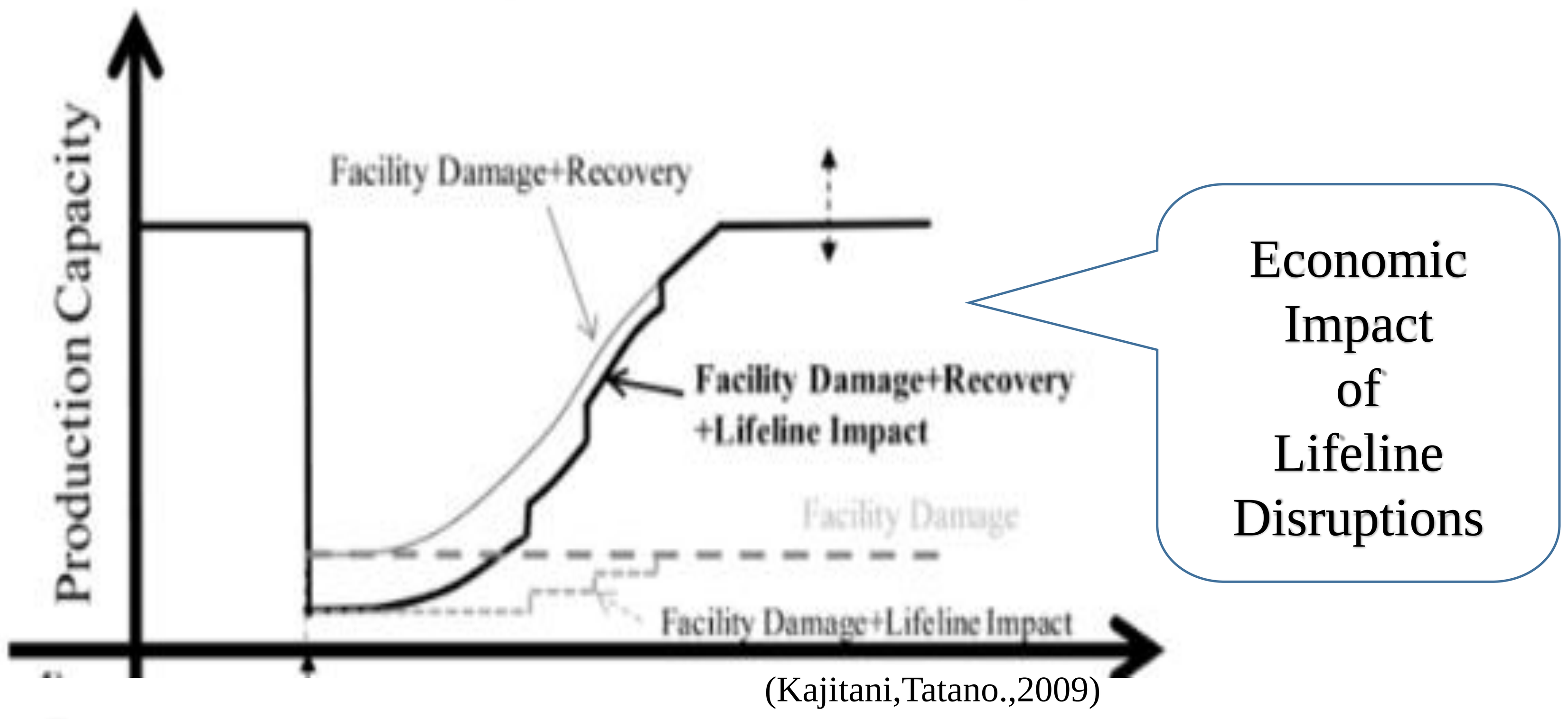
Introduction

Motivations

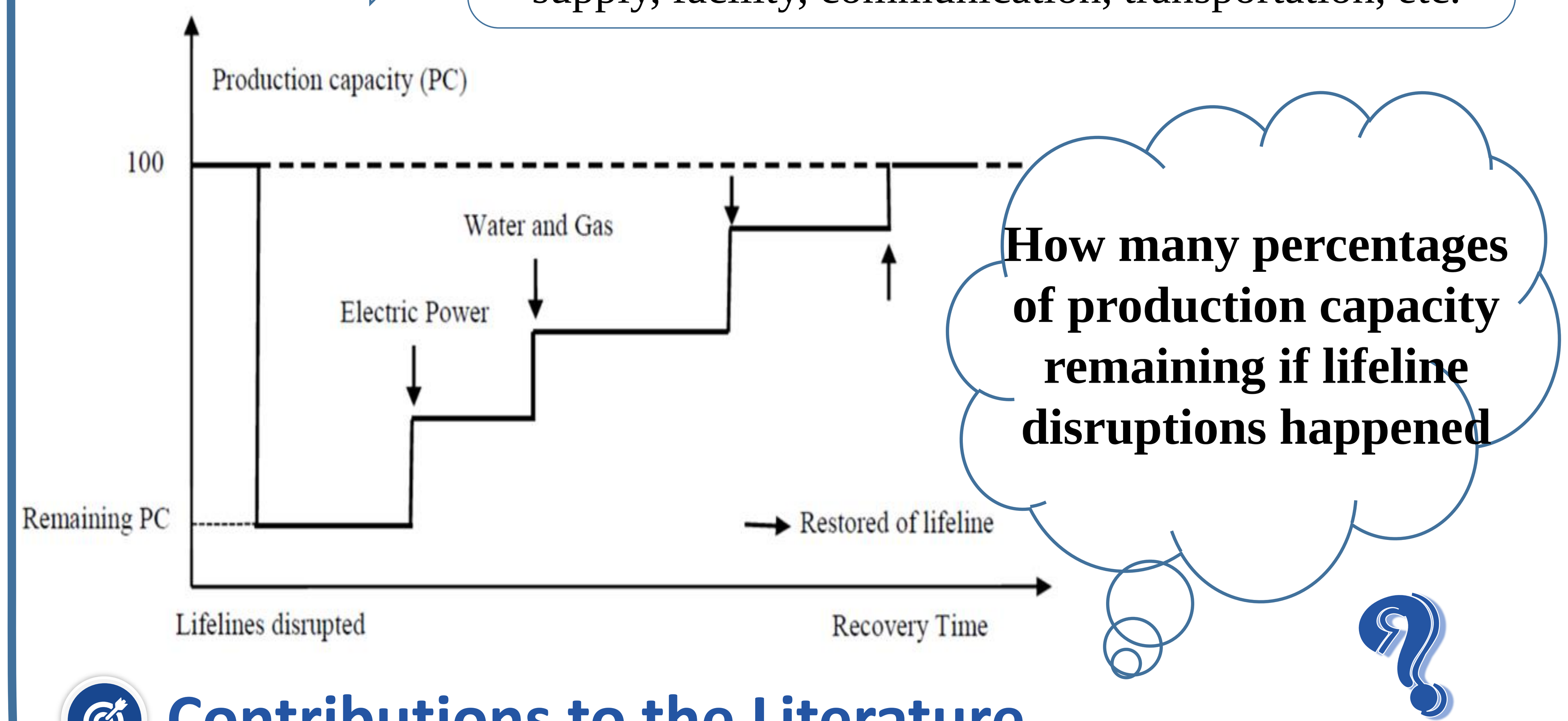
- Recent studies on lifeline resilience factors are derived from business surveys on hypothetical disasters or expert-opinion-based estimations due to a lack of data from firms that experienced the lifeline disruptions after a disaster.



(Kajitani,Tatano.,2009)

Research Questions

- **Lifelines**: Inputs which maintain the output of industries, including electric power supply, water supply, gas supply, facility, communication, transportation, etc.



Contributions to the Literature

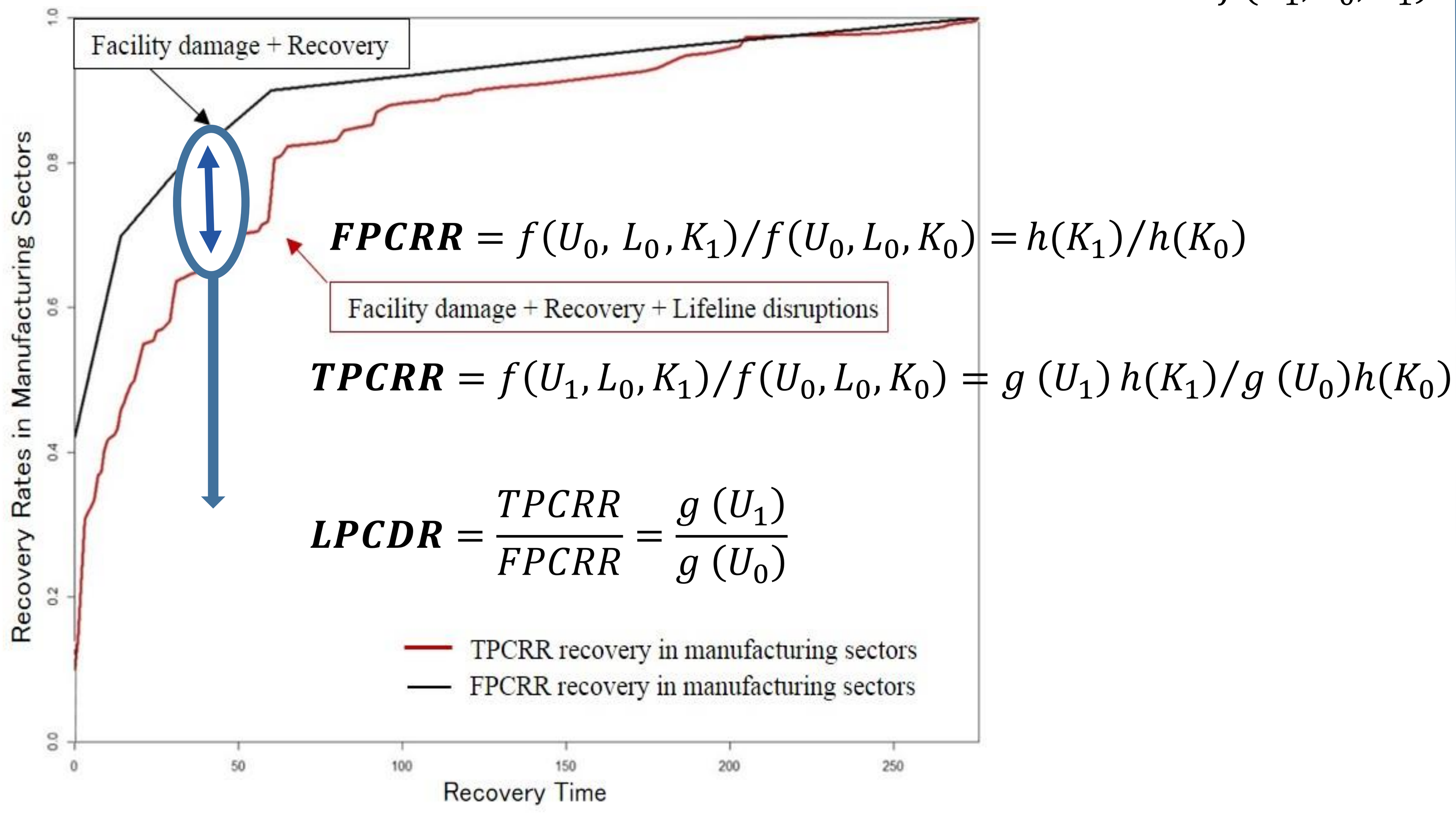
Proposed a method to quantitatively describe the impact of lifeline disruptions on post-disaster recovery in different industrial sectors

Model

- **Production Function:** $f(U, L, K) = g(U)\, l(L, K)$
- **Lifeline Utility :** $g(U_i) = \theta e^{\beta_e E_i}\, e^{\beta_W W_i}\, e^{\beta_G G_i}$

U: lifelines utility
L: labor supply
K: capital service

- **Before disaster:** $f(U_0, L_0, K_0)$ ⇒ **After disaster:** $f(U_1, L_0, K_1)$



$$FPCRR = f(U_0, L_0, K_1)/f(U_0, L_0, K_0) = h(K_1)/h(K_0)$$

$$TPCRR = f(U_1, L_0, K_1)/f(U_0, L_0, K_0) = g(U_1)\, h(K_1)/g(U_0) h(K_0)$$

$$LPCDR = \frac{TPCRR}{FPCRR} = \frac{g(U_1)}{g(U_0)}$$

Figure 2. Recovery processes with and without lifeline disruptions

- **Lifeline resilience factor** $LRF_U = 1 - e^{-\beta_U}$

Results

- Assumed: $TPCRR_{it} = \Delta g(U) \cdot FPCDR_{it}$
- By putting lifeline utility function the equation is derived as:

$$lnTPCRR_{it} - lnFPCRR_{it} = \alpha + \beta_E \Delta E_{it} + \beta_W \Delta W_{it} + \beta_G \Delta G_{it} + \varepsilon_{it}$$

- The parameters β are estimated using observed data

$LRF_U = 1 - e^{-\beta_U}$

Table 2. Lifeline resilience factors estimation results

	Manufacturing sectors		Non-manufacturing sectors	
	Coefficient β_i	LRF_u	Coefficient β_i	LRF_u
(Intercept)	-1.60***		-2.11***	
Electricity	0.023***	0.023	0.012***	0.012
Water	0.782***	0.542	1.053***	0.651
Gas	0.80***	0.552	0.889***	0.589
N	137		297	
F-stat	924.4****		991.7****	

Sector		LRF_u Electricity	Water	Gas
Manufacturing Sector	Materials	0.02	0.51	0.35
	Processing and assembly	0.02	0.42	0.96
	Life-related	0.03	0.82	0.81
Non-manufacturing Sector	Construction	0.02	0.81	0.12
	Transportation	0.02	0.54	0.89
	Wholesale/retail	0.01	0.52	0.54
	Finance, insurance and real estate	0.01	0.63	0.25
	Service	0.05	0.43	0.75

(Coefficients and the significance levels are shown in the parentheses; ****, ***, **, and * denote significance at the 0.1%, 1%, 5%, and 10% levels, respectively)

The lifeline resilience factors vary by sector. The estimated lifeline resilience factors are shown in Table 2.

In the 2011 East Japan Earthquake case study, the results indicate that the impact of electric power disruption is most severe.

Data

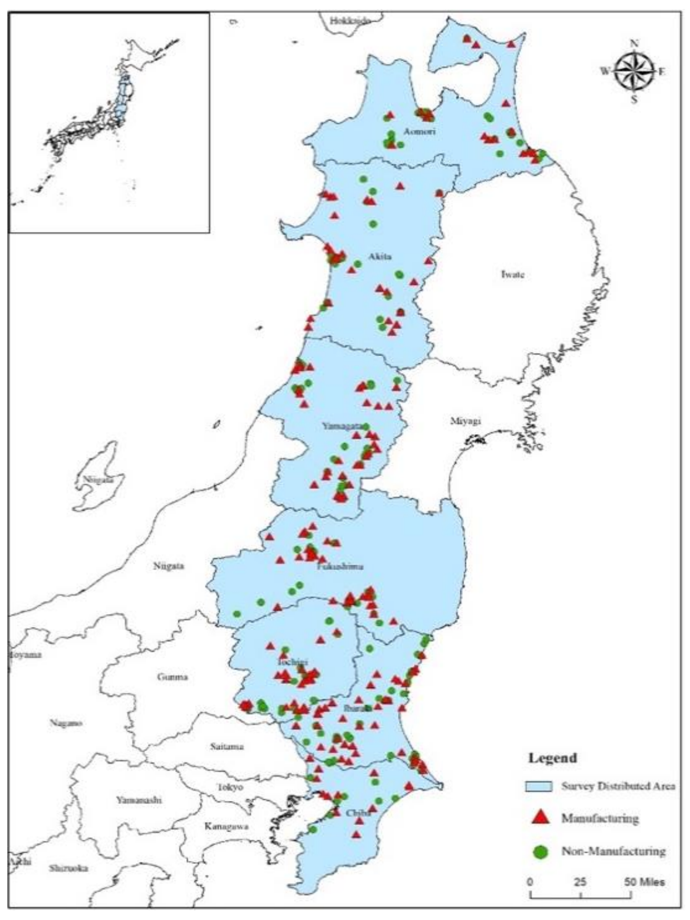


Figure 1. Study Area

- **Database**: Post-disaster survey data after the 2011 Great Japan Earthquake
- **Two Recovery Scenarios**

FPCRR: Production capacity under impact of facility damage, and being defined as the production capacity recovery rate under facility damage.

TPCRR: Production capacity is impacted by both lifeline system disruptions and facility damage, being defined as the total production capacity recovery rate under facility damage and lifeline disruption.

Lifeline disruptions explain the differences between FPCRR and TPCRR

LPCDR: Differences between two scenarios, being defined as lifeline production capacity damage rates

Table 1. Example of questionnaire data

Time	March 11, 2011	March 14	March 22	March 26
FPCRR	$50\|_{F=1}$	$70\|_{F=1}$	$100\|_{F=0}$	$100\|_{F=0}$
TPCRR	$0\|^{E=1,W=1,G=1}_{F=1}$	$40\|^{E=0,W=1,G=1}_{F=1}$	$80\|^{E=0,W=0,G=1}_{F=0}$	$100\|^{E=1,W=1,G=0}_{F=1}$
LPCDR	$50\|^{E=1,W=1,G=1}$	$30\|^{W=1,G=1}$	$20\|^{G=1}$	0

Discussion and Conclusion

- Lifeline resilience factors in different sectors are estimated by using the proposed model.
- The results are consistent with previous studies.

Table 3. Comparison of lifeline resilience factors results with previous research

Case Comparison	Manufacturing			Non-manufacturing		
	LRF_E	LRF_W	LRF_G	LRF_E	LRF_W	LRF_G
The 2011 Great Japan Earthquake (This research)	0.02	0.54	0.55	0.01	0.65	0.59
Tokai area survey data (Kajitani and Tatano., 2009)	0.06	0.54	0.79	0.42	0.56	0.73
ATC-25 (1991) (Expert opinion based estimation)	0.02	0.36	0.58	0.29	0.72	0.86

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Research interests: risk, recovery, resilience, climate change