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The Disaster Impact on Food Loss and Waste – An Empirical Study of the Food Industry in Japan

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I. Background

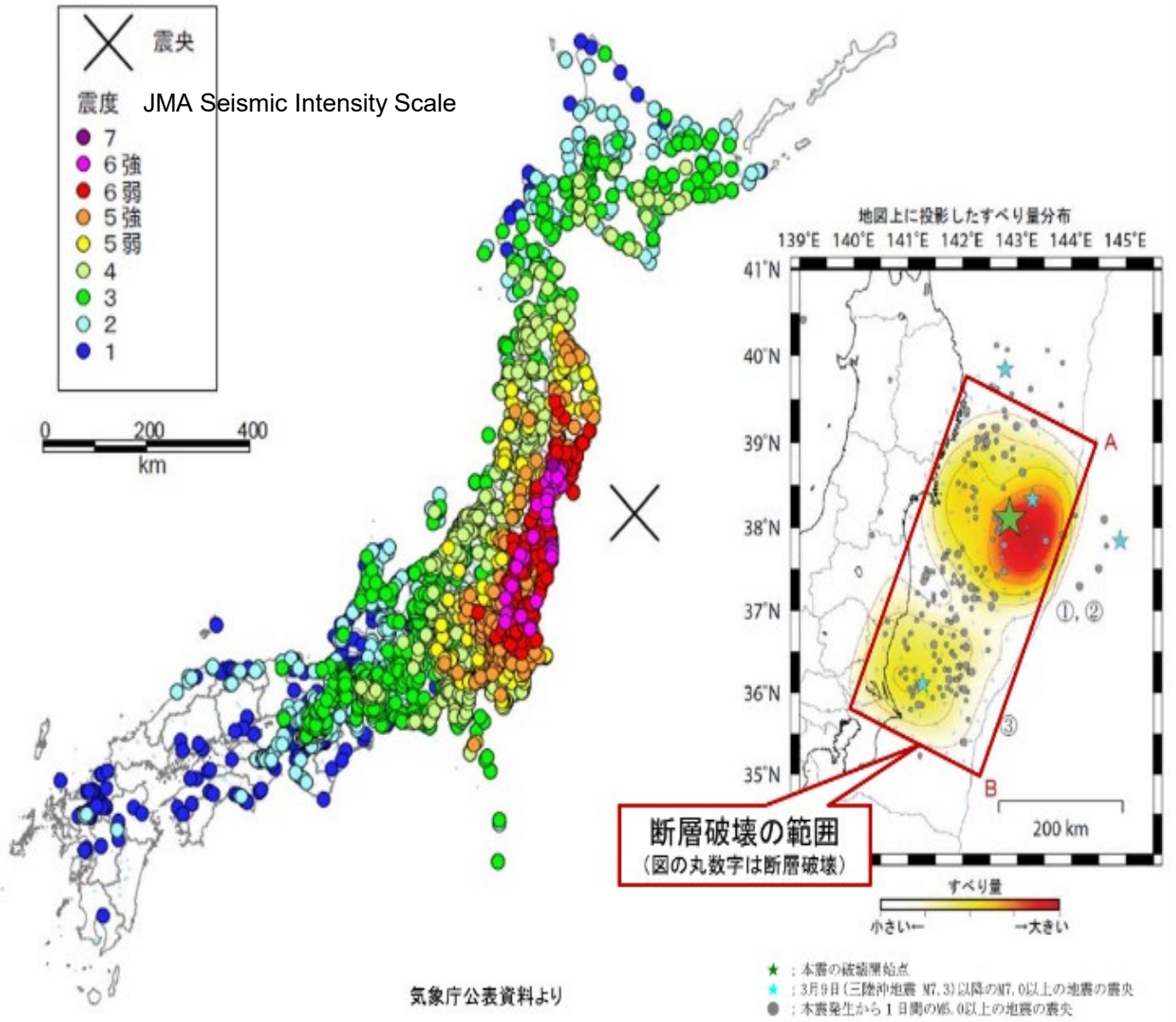
Food loss and waste (FLW)

- **Food loss and waste (Food wastage):** a decrease in mass or nutritional value of food that was initially intended for human consumption and food for human consumption being discarded (FAO, 2013)
- The Causes: inefficiencies in the food supply chains, oversupply due to markets, or individual consumer shopping/eating habits.
- 30% of global food production is lost and wasted, while 811 million people worldwide suffer from hunger (9.9%) (UNICEF, 2021). Reducing FLW serves as a priority for reducing the global hunger and resource waste.
- The food loss and waste generated in Japan in 2020 amounted to around 5.2 million tons. About 53% (275 million tons in 2020) of food loss and waste occur at the commercial stage (Liu *et al.*, 2016), in particular, significantly high food losses and waste are observed in major producing regions in the country (Wakiyama et al., 2019)

I. Background

The Great East Japan (GEJ) Earthquake in March 11, 2011

- A 9.0-magnitude earthquake struck Japan on March 11, 2011.
- The earthquake and tsunami were the strongest and highest ever recorded in Japan. Fukushima nuclear power plant meltdown.
- More than 22,000 people were dead or missing. $360 billion in economic losses has occurred.



I. Background

Social norms of Self-restraint (Jishuku)

- Japanese people voluntarily refrained from having fun, luxury goods, and celebration activities to express solidarity with the disaster's victims (Jishuku) (Ida et al. 2015).
- The shelf of supermarkets and convenience stores became empty due to panic shopping, whereas restaurants were empty due to Jishuku.
- The GEJ earthquake caused heterogeneous impacts on food industries.
- How does it affect the food industry and FLW?

panic-buying at supermarket shelves
Photograph: Miyoko Fukushima/Demotix

II. Literature review (FLW)

Author (year)	Purpose	Data	Findings
Takata et al. (2012)	Examined the effect of food waste management practices under the recycling loops policy in Japan on the environmental and economy efficiency	Interviews survey of recycling facilities.	Composting facilities has the least environmental impact and highest economic efficiency, while animal feeds facilities had considerable environmental impact due to their wide distribution and heavy reliance on fuel. Furthermore, the study found that looped animal recycling facilities generated a significant amount of revenues due to the increase in collected waste.
Liu et al. (2016)	Evaluated food waste trends in Japan by estimating the production and intake of calorie/protein during 1990-2012 period.	Official statistics and reports on food production, consumption and food waste.	The overall food waste in Japan total 37.86 million tons in 2011, of which the commercial food stage generated the largest waste, accounting for 53% of the total. However, the recycling rate at this stage was found to be the highest relative to the agricultural production stage, storage and transportation stage, and at the household stage.
Wakiyama et al. (2019)	Quantified regional food loss in Japan using the case of vegetable production and consumption.	Online survey and official statistics	Highest food losses in production sites were observed in major producing regions: Hokkaido, Nagano, Fukushima, and Gunma prefectures. From the perspective of consumption, it was revealed that about 90% of the vegetable destined for industrial use were disposed.
Chauhan et al.(2021)	Identified the key themes in literature in the domain of food loss and waste.	Literature review	Eight key topics were identified in the literature. The review asserts that there is lack of understanding in the driver of food loss and waste management in the domain of factors influencing food loss generation. Another limitation pointed by the author is dearth of policy impact empirical research. Furthermore, a limited number of studies are conducted at micro-level that concern the impact of food loss and waste practices. Additionally, fewer researchers have addressed the problem of circular economy and food loss.
Gillman et al. (2019)	Identified the drivers of on-farm food losses and their environmental impact.	25 semi-structured interviews with growers of leafy greens, tomatoes, and peaches.	Economic risks within the supply drive on-farm food losses. In turn, food losses at farm level is environmental favorable since food losses are often tilled back to the soils rather being dispose in landfills.
Andrea Cattaneo et al. (2021)	Examined the effect of reducing food loss and waste on the environment (water, land and GHG)	FAO database	The reduction in food loss and waste improves resource efficiency; hence reducing environmental impact. In particular, it found that food waste at consumer level at produces favourable local environmental outcome relative to reductions at the farm level.

II. Literature review (Disaster)

Author (year)	Disaster	Data and Method	Findings
Krausmann & Cruz (2013)	Great East Japan earthquake and tsunami	open sources and interviews	both the earthquake and tsunami caused significant damage; however, the tsunami impact resulted in more severe natural hazard triggered technological (Natech) accidents. In terms of business interruption and loss of production capacity, the earthquake was the dominant trigger, with shutdown times between 1 and 6 months on average for the analyzed data set. Lifeline disruption by the earthquake and tsunami contributed significantly to the production capacity loss. Work is in progress to describe in detail the earthquake- and tsunami-induced damage and failures in the Chiba, Kashima and Sendai industrial park
Oh, Deshmukh, & Hastak (2010)	winter flood disaster event in the USA	Case study	The healthcare industry is revealed as the most dependent industry and the electricity and transportation infrastructure are the most significant to the communities and the associated industries.
Krausmann & Cruz (2013)	the Great East Japan Earthquake	Survey of firms in the impacted areas conducted after the earthquake and the other from another survey conducted a few years before the earthquake	having more suppliers and clients outside the impacted areas shortened the recovery time but had only weak effects on sales growth in the medium term. In contrast, having more suppliers and clients in the impacted areas did not affect the recovery time but did improve sales growth. In addition, we identify a negative effect of supply chains on recovery through the disruption of supplies and demands and two positive effects through support and substitution.
(Freeman, Nairn, & Gollop, 2015	Christchurch's earthquakes	94 Christchurch children	Children and young people's resilience and positive commitment to Christchurch are assets that should be capitalized on in the longer-term recovery process
Galbusera & Giannopoulos (2018)	disaster impact analysis and resilience assessment	I-O analysis framework	input-output (I/O) economic models have assumed a prominent role in disaster impact analysis and resilience assessment. Rooted in general equilibrium theory and economic production theory, they catalyse attention on the distinction between direct economic losses and ripple effects that may be generated inside a multi-industry system as a consequence of perturbations
Gibbs et al. (2019)	bushfire in Australia	multilevel models (MLM)	reading and numeracy expected gains from Year 3 to Year 5 scores were reduced in schools with higher levels of bushfire impact. The findings highlight the extended period of academic impact and identify important opportunities for intervention in the education system to enable children to achieve their academic potential.

II. Literature review

Research questions

To the best of our knowledge, no previous study investigated the link between disaster or crisis and FLW management of the food supply chain

1. Does the GEJ earthquake reduce food waste incurred in food companies?
2. How does it affect the food supply chain and the FLW management?
3. To what extent did the disaster affect the food company's business performance?

III. FLW Data

The features of the dataset

- the Utilization of Recyclable Food Waste Survey
- A national survey in Japan
- Conducted by the Ministry of Agriculture, Fisheries, and Forests (MAFF) in Japan
- Based on the Promotion of Utilization of Recyclable Food Waste (Food Recycling Law)
- Annual data since 2003
- Food manufacturing industry, food wholesale industry, food retailer industry, and restaurant industry at the firm level
- Data available: 2009, 2010, 2012, 2013, and 2017
- Repeated cross-sectional data

The questions in the questionnaire

- The total amount of FLW
- Food recycling
- Food final waste disposal
- Sales value
- Industry and business sector
- Location

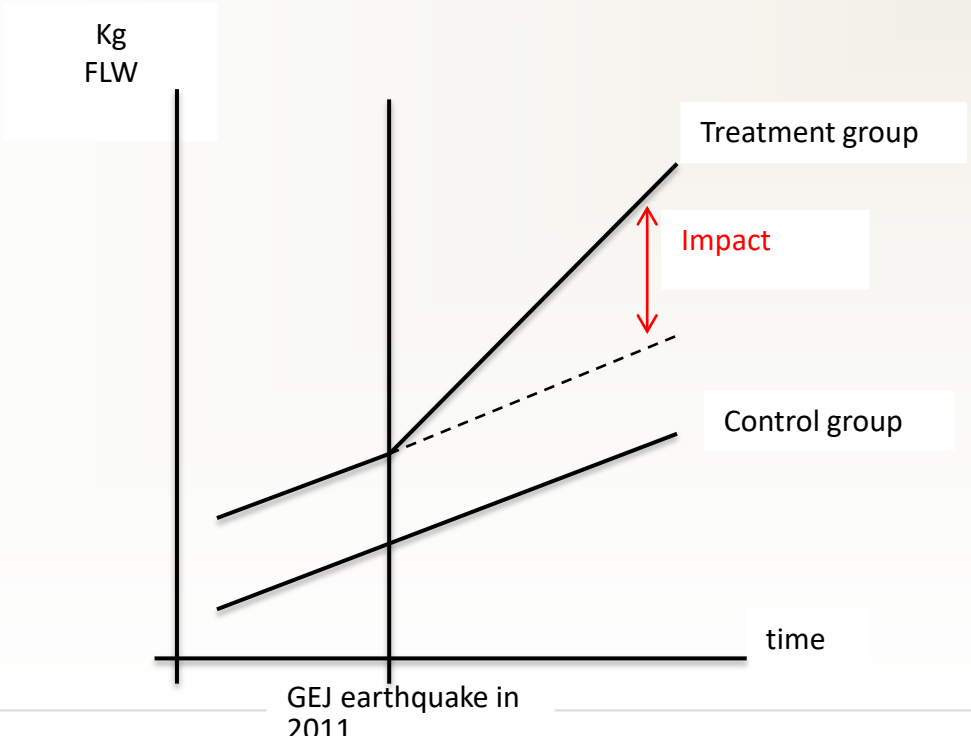
III. Data and Method

Method: Difference in Differences (DiD)

DID: the most popular method to analyze Causal Effects

$$FLW_{it} = \gamma_1 \times Treat_i + \gamma_2 Post_t + \gamma_3 (Treat_i \times Post_t) + \beta' X_{it} + u_{it}$$

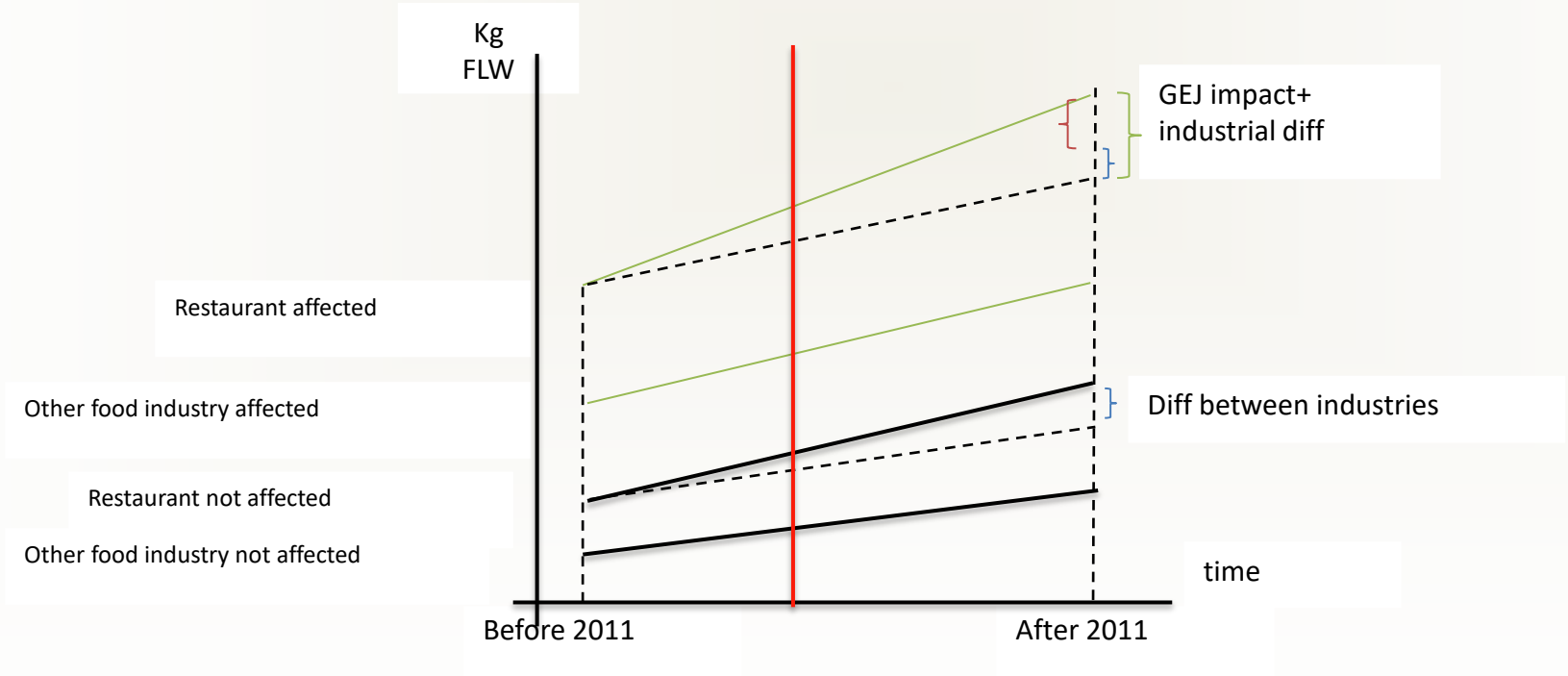
$$r_3 = [T(Treat = 1, Post = 1) - T(Treat = 1, Post = 0)] - [T(Treat = 0, Post = 1) - T(Treat = 0, Post = 0)]$$



III. Data and Method-DDD

DDD: adds a control group to the DID framework to account for the unobservable group- and time-characteristic interactions that might not be captured by DiD.

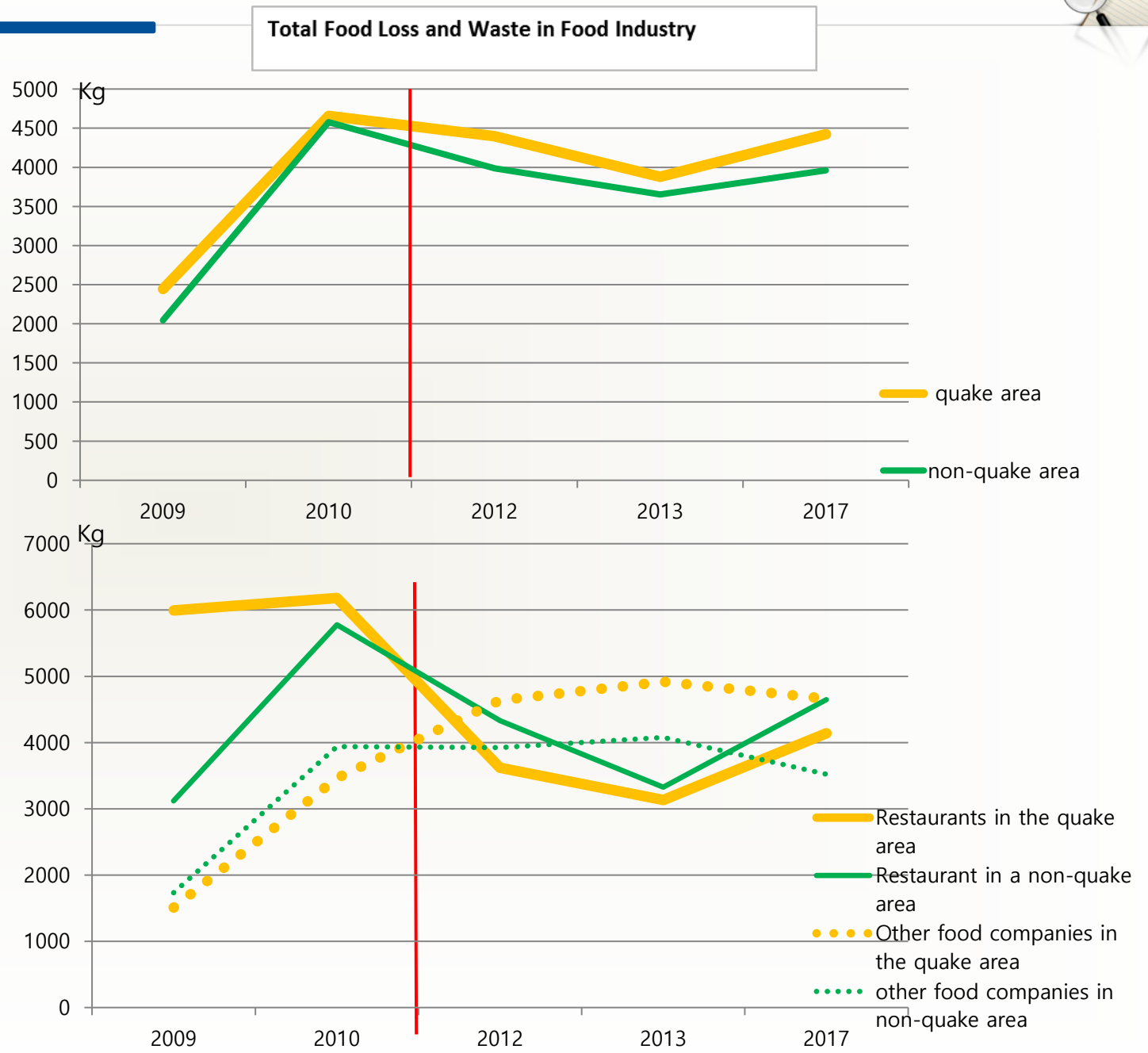
$$FLW_{ijt} = \gamma_1 \times Treat_i + \gamma_2 Post_t + \gamma_3 Industry_j + \gamma_4 (Treat_i \times Post_t \times Industry_j)$$
$$+ \gamma_5 Treat_i \times Post_t + \gamma_6 Treat_i \times Industry_j + \gamma_7 Post_t \times Industry_j + \beta' X_{ijt} + u_{ijt}$$



III. Data and Method

The FLW amount during 2009-2017

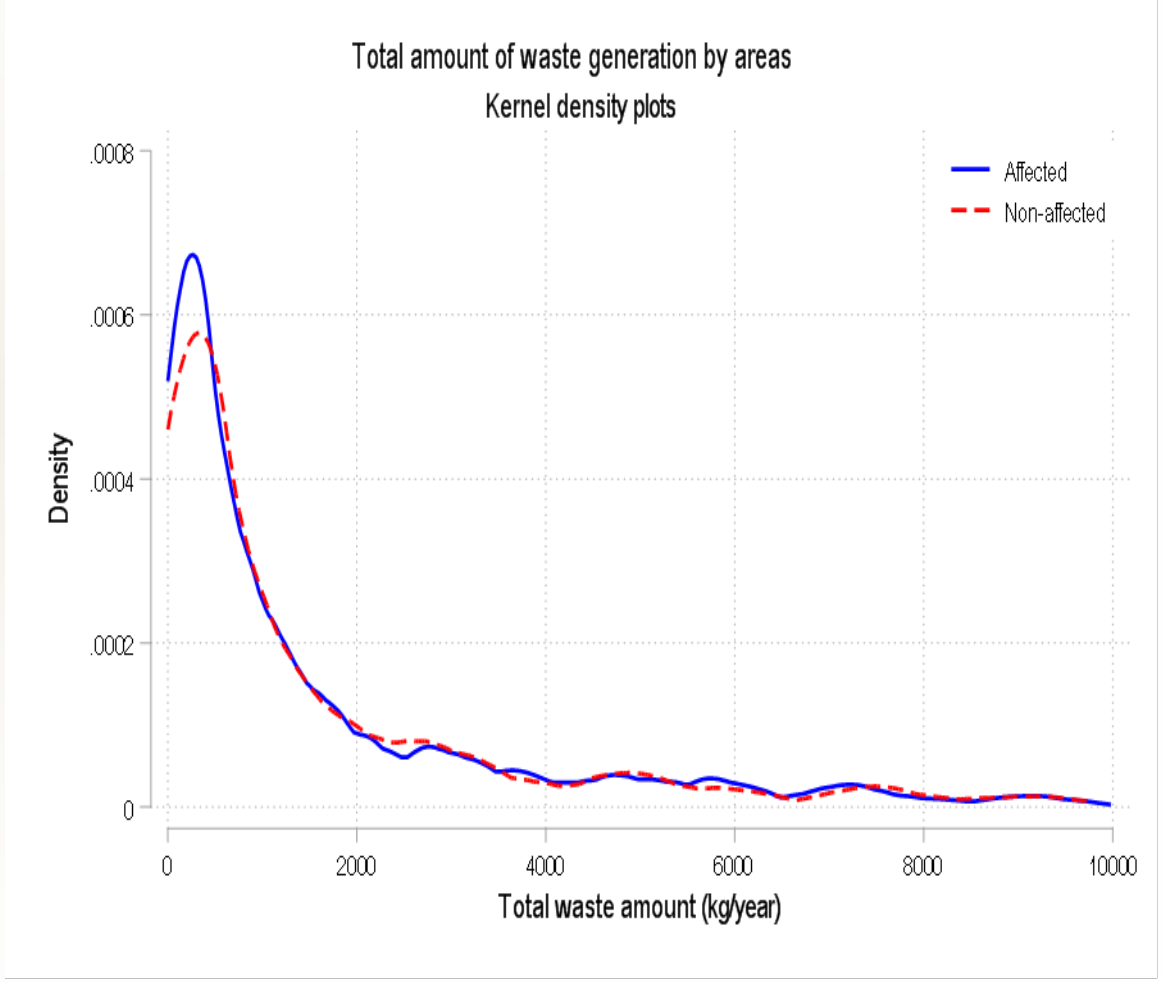
1. The FLW generated by the restaurant industry in quake-hit areas sharply decreased while the FLW of food wholesalers and retailers significantly increased.
2. The FLW generated by restaurants in non-quake hit areas decreased, and the wholesalers' and retailers' FLW increased, but the industrial difference is smaller than that in earthquake-hit areas.



III. Data and Method

The right skewed of FLW

1. Large fraction of food companies generate a small amount of FLW during the period of observation.
2. The distribution of the two areas is right-skewed and long-tailed.
3. The distribution of FLW is smoother for food companies in the non-affected area.
4. OLS method will yield less precise estimates of means and marginal effects
5. Nonlinear response leads to biased estimates for substantial subpopulations.



III. Data and Method

Estimation Model

1. Generalized Linear Model (GLM) is adopted.
2. GLM deals with skewness and related issues through variance-weighting rather than transform methods
3. **GLM with Gamma family and log link is used**.
4. Two-way fixed effect (Year effect and Industry effect) is included.

$$FLW_{ijt} = \gamma_1 \times Treat_i + \gamma_2 Post_t + \gamma_3 Industry_j + \gamma_4 (Treat_i \times Post_t \times Industry_j)$$

$$+ \gamma_5 Treat_i \times Post_t + \gamma_6 Treat_i \times Industry_j + \gamma_7 Post_t \times Industry_j + \beta' X_{ijt} + \eta_j + \lambda_t + u_{ijt}$$

IV. Results-sample statistics

Pre	Full sample		**Restaurant in quake**		Wholesaler and retalier in quake		Restaurant in non-quake		Wholesaler and retalier in non-quake	
	Mean	S.D	**Mean**	**S.D**	Mean	S.D	Mean	S.D	Mean	S.D
Sales value (Thousand Yen)	365980.4	6616653.8	**705967.3**	**15849486.0**	587855.6	9409874.3	55884.8	86043.8	162178.6	674672.2
Total food loss and waste (Kg	3996.0	9684.7	**6133.4**	**12582.2**	2481.6	6792.9	4921.2	9941.8	2905.9	6749.1
Recycled (Kg)	1034.9	5059.7	**656.5**	**4870.7**	710.6	4300.6	458.4	1692.9	914.3	3361.8
Fertilizer	419.6	3029.7	**335.8**	**3477.4**	200.1	1937.5	61.1	375.6	267.8	1449.8
Forage	314.2	2832.1	**131.8**	**1507.8**	253.3	2633.5	148.6	1189.7	451.8	2857.7
Oiled	196.2	2041.3	**62.3**	**332.7**	112.9	1397.4	179.0	1004.3	130.3	887.7
Heat recovery (Kg)	5.1	196.4	**0.0**	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0
Wight reduced (Kg)	65.4	1069.3	**108.0**	**823.6**	32.7	274.5	1.3	9.0	15.6	168.0
Dehydration	36.7	631.9	**78.3**	**697.8**	15.2	174.9	0.2	1.8	10.3	155.9
Dry	13.7	533.2	**14.6**	**357.7**	14.3	161.4	0.0	0.0	4.9	59.4
Waste disposal (Kg)	2890.6	8021.4	**5368.9**	**11680.1**	1738.2	5082.8	4461.5	9655.5	1976.1	6037.8
Local income (Thousand Yen)	3113.4	800.4	**3133.6**	**879.2**	3144.9	644.5	2776.2	335.6	2793.2	345.9
N	7169		**699**		1335		127		305	

Post			**Restaurant in quack**		Wholesaler and retalier in quake		Restaurant in non-quack		Wholesaler and retalier in non-quake	
			Mean	**S.D**	Mean	S.D	Mean	S.D	Mean	S.D
Sales value (Thousand Yen)			**84975.2**	**790383.1**	430162.7	2413735.5	86734.4	533316.7	240200.7	814638.2
Total food loss and waste (Kg)			**3567.4**	**8307.2**	4725.8	11445.3	3926.9	8685.9	3824.8	8834.2
Recycled (Kg)			**404.7**	**1880.0**	1852.1	7114.5	1149.6	4919.2	1223.3	5080.6
Fertilizer			**189.5**	**1329.7**	738.1	4172.3	478.7	3049.6	693.7	3942.5
Forage			**62.3**	**989.1**	593.7	4141.5	381.8	2871.1	310.6	2115.5
Oiled			**112.6**	**618.3**	381.2	3374.6	104.2	469.1	186.9	1521.9
Heat recovery (Kg)			**3.2**	**53.8**	13.2	350.9	0.0	0.0	4.6	67.8
Wight reduced (Kg)			**70.8**	**995.9**	48.3	998.0	64.5	468.2	200.8	2744.6
Dehydration			**69.2**	**995.5**	9.3	210.7	58.4	461.2	55.0	1092.4
Dry			**0.9**	**26.1**	29.1	934.6	0.0	0.0	5.3	81.9
Waste disposal (Kg)			**3088.7**	**7522.3**	2812.3	8837.0	2712.7	6556.6	2396.0	6486.0
Local income (Thousand Yen)			**3270.9**	**1061.2**	3146.6	738.3	2748.0	363.4	2786.4	370.7
Seismic intensity			**4.4**	**1.1**	3.6	1.5	0.0	0.0	0.0	0.0
Aftershocks (above 3) in a month			**12.0**	**16.5**	8.3	16.3	0.0	0.3	0.0	0.0
N			**1760**		2193		293		484	

IV. Results-the estimation of impact of GEJ earthquake on FLW and sales value

1. The GEJ earthquake decreased the FLW and waste disposal of the restaurant industry in Japan.
2. One unit increase in seismic intensity decreased about 528 Kg of FLW, and decreased 313 Kg of final waste disposal.
3. However, the earthquake also decreased sales value; increasing one scale in the intensity decreased 172 million JPY of sales value, about 47%.

	Total food loss and waste (Kg)		Waste disposal (Kg)		Sales value (Thous. Yen)	
	Coeff.	S.E	Coeff.	S.E	Coeff.	S.E
_Post × _Restaurant × Intensity	-0.131**	0.06	-0.107*	0.07	-0.472**	0.21
_Post	0.766***	0.15	0.698***	0.17	-0.00165	0.42
_Restaurant	0.224	0.17	0.687***	0.19	-2.017***	0.26
Intensity	-0.0301	0.03	-0.0299	0.03	0.0634	0.06
_Post × _Restaurant	-0.537**	0.21	-0.595**	0.23	-0.216	0.42
_Post × Intensity	0.0563	0.04	0.0586	0.05	-0.0531	0.06
_Restaurant × Intensity	0.0816*	0.05	0.0864*	0.05	0.324*	0.20
Income	9.33e-05***	0.00	8.94e-05**	0.00	0.000273***	0.00
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	7.557***	0.16	6.954***	0.19	13.30***	0.54
Marginal effect	-527.842**	240.28	-312.974*	194.42	-171711**	94.46
Change rate	-13.21%		-10.66%		-46.92%	
N	7,196		7,196		6,501	

Marginal effect measures the impact of the earthquake on the outcome variable

*** p<0.01, ** p<0.05, * p<0.1

IV. Results

The impact of the GEJ earthquake on waste recycling

	Recycled								Weight reduced			
			Fertilizer		Forage		Oiled				Dehydration	
	Coeff.	S.E	Coeff.	S.E	Coeff.	S.E	Coeff.	S.E	Coeff.	S.E	Coeff.	S.E
_Post × _Restaurant × Intensity	-0.212	0.14	-0.0383	0.27	-0.758***	0.22	-0.0577	0.19	0.0116	0.30	-0.0834	0.34
_Post	0.931***	0.27	1.387***	0.41	0.780*	0.43	0.975*	0.53	0.0234	0.76	-1.699**	0.71
_Restaurant	-1.013**	0.41	-0.666	0.79	-1.734**	0.80	-0.482	0.65	0.164	0.91	-0.782	1.00
Intensity	-0.0412	0.06	-0.0554	0.10	-0.0711	0.09	-0.0592	0.11	0.177	0.12	0.173	0.16
_Post × _Restaurant	-0.0809	0.47	-0.874	0.86	1.079	0.94	-0.425	0.69	-1.048	1.08	0.866	1.10
_Post × Intensity	0.0626	0.07	-0.0153	0.12	0.107	0.11	0.220*	0.13	-0.265	0.19	-0.0784	0.23
_Restaurant × Intensity	0.0123	0.12	0.00951	0.26	0.125	0.19	-0.117	0.17	0.138	0.23	0.137	0.27
Income	0.000146**	0.00	0.000112	9.1E-05	.000428***	0.00	7.97e-05	0.00	-1.12e-05	0.00	-0.000103	0.00
Industry fixed effect		Yes		Yes		Yes		Yes		Yes		Yes
Year fixed effect		Yes		Yes		Yes		Yes		Yes		Yes
Constant	6.524***	0.27	5.670***	0.43	4.767***	0.52	4.544***	0.62	4.130***	0.78	4.590***	0.90
Marginal effect	-223.70	144.22	-16.72	118.85	-268.81***	93.39	-11.40	37.26	0.77	19.92	-3.54	14.36
Change rate	-31.62%		-3.98%		-85.56%		-5.81%		1.18%		-9.64%	

N=7,169

Marginal effect measures the impact of the earthquake on the outcome variable

*** p<0.01, ** p<0.05, * p<0.1

IV. Results

The impact of aftershocks

	Total food loss and waste (Kg)		Waste disposal (Kg)		Sales value (Thous. Yen)	
	Coeff.	S.E	Coeff.	S.E	Coeff.	S.E
_Post × _Restaurant × Aftershocks	-0.0170**	0.01	-0.0173**	0.01	-0.00487	0.01
Control variables	Yes		Yes		Yes	
Marginal effect	-68.543**	28.13	-50.483**	23.23	-1764.168	4757.34
Change rate	-1.72%		-1.75%		-0.48%	

	Recycled (Kg)								Weight reduced (Kg)			
			Fertilizer		Forage		Oiled				Dehydration	
	Coeff.	S.E	Coeff.	S.E	Coeff.	S.E	Coeff.	S.E	Coeff.	S.E	Coeff.	S.E
_Post × _Restaurant × Aftershocks	-0.0154	0.0177	0.0279	0.0276	-0.114***	0.0317	-0.0385	0.0323	-0.0338	0.032	-0.0623	0.0429
Control variables	Yes		Yes		Yes		Yes		Yes		Yes	
Marginal effect	-16.25	18.60	12.12	12.18	-37.18	11.33	-7.75	7.02	-2.24	2.20	-2.65	2.08
Change rate	-1.57%		-2.89%		-11.83%		-3.95%		-3.43%		-7.22%	

N=7196

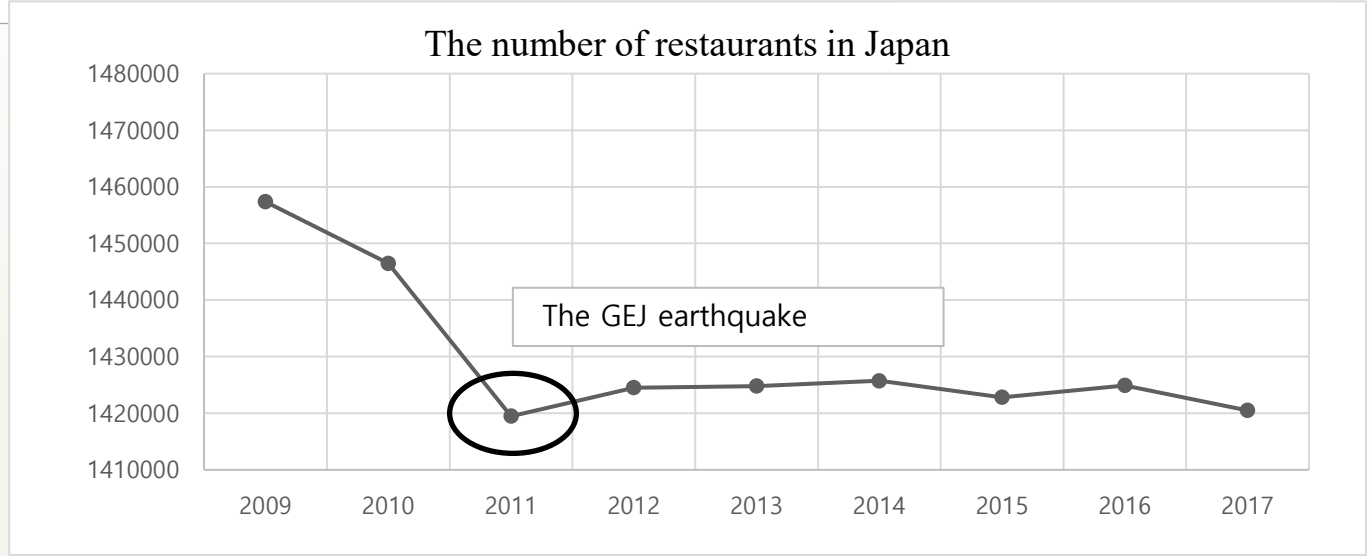
Marginal effect measures the impact of waste prevention policy on the outcome variable

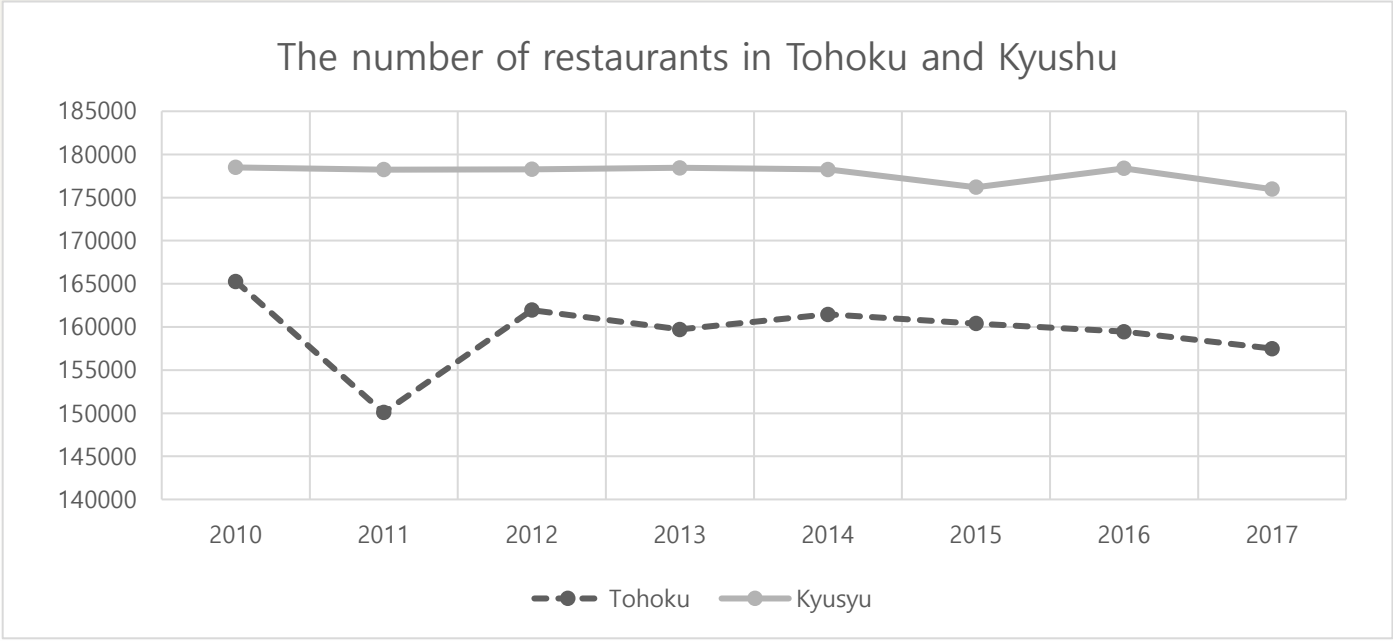
*** p<0.01, ** p<0.05, * p<0.1

IV. Analysis to be continued

Demand driven or Supply driven?

1. Does the decrease in FLW results from the demand side or the supply side?
2. The number of restaurants in Japan decreased by about 27,000 (-1.86%).
3. The number of restaurants in the epicenter (Tohoku) decreased by about 12,000 (-7.91%) compared to no change in the Kyushu area.
4. The decreasing FLW results from both the demand side and supply side, but is higher on the demand side.





V. Conclusion

1. The GEJ earthquake has a positive impact on FLW reduction; it decreased the FLW of the restaurant industry by 13.21 % (528 Kg), whereas the final waste disposal only decreased by 10.66%.
2. The earthquake caused an adverse impact on the food recycling system; the number of food wastes recycled for forage usage declined by 85.56%.
3. The frequency of aftershocks also has a positive impact on FLW reduction, but the impact is smaller than the impact of earthquake magnitude.
4. Decreases in sales value are accompanied by a decrease in FLW, and the decrease rate is more than three times the decrease rate of FLW. Aftershocks did not affect sales value.
5. The positive impact of the disaster on FLW reduction is more likely to be attributed to the demand side, i.e., the social norms of Self-restraint (Jishuku) in Japan.

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Thank you for your attention!